6th EASN International Conference
On Innovation in European Aeronautics Research
Chaired by Spiros Pantelakis & Pedro Moreira

Booklet of Abstracts
## Contents

OPTIMIZATION AND TESTING OF FLUIDIC ACTUATORS FOR ACTIVE FLOW CONTROL AT THE ENGINE/WING JUNCTION .................................................................................................................. 8

EFFECT OF RIM SEAL DIVERSION STRUCTURES ON AERODYNAMIC AND COOLING PERFORMANCE OF TURBINE ROTOR BLADE AND ENDWALL .............................................................................................................. 9

NON-DESTRUCTIVE QUALITATIVE CHARACTERIZATION OF THERMAL DAMAGE INTERACTIONS IN CARBON FIBRE COMPOSITE PANELS ............................................................................................................. 10

EXERGETIC DESIGN OF A JET ENGINE: A PARAMETRIC STUDY .................................................................................................................................................................................................................................................. 11

INVESTIGATIONS ON THE AERODYNAMIC AND COOLING CHARACTERISTICS OF TURBINE STAGE WITH CONSIDERATION OF THE CIRCULAR TYPE DIVERSION STRUCTURE RIM SEAL PURGE FLOW .................................................................................................................................................................................................................................................. 12

VIRTUAL PROTOTYPING OF ENERGY HARVESTING SYSTEMS FOR AERONAUTICS .......................................................................................................................................................................................................................... 13

SOME NECESSARY ADDITIONS TO EASA PART 66 & 147 LICENSES ................................................................................................................................................................................................................................. 14

AERODYNAMIC AND STRUCTURAL DESIGN FOR THE DEVELOPMENT OF A MALE UAV .................................................................................................................................................................................................................................. 15

EXPERIMENTAL DETERMINATION OF FIRE DEGRADATION KINETIC FOR AERONAUTICAL POLYMER COMPOSITE MATERIALS .................................................................................................................................................................................................................................. 16

ACTIVE FLOW CONTROL CONCEPTS AND APPLICATION OPPORTUNITIES FOR COMMERCIAL AIRCRAFT .................................................................................................................................................................................................................................. 17

MICROSTRUCTURAL ASPECTS AND MECHANICAL BEHAVIOR OF COPPER BASE ALLOYS FOR HIGH HEAT FLUX APPLICATIONS .................................................................................................................................................................................................................................. 18

AN OVERVIEW OF FATIGUE IN AIRCRAFT STRUCTURES .................................................................................................................................................................................................................................................. 19

SYSTEM ELECTRONICS FOR ENERGY HARVESTING .................................................................................................................................................................................................................................................. 20

EVOLUTION OF OXYGEN IN AIRCRAFT FUEL TANKS DURING CLIMB ..................................................................................................................................................................................................................................... 21

DYNAMIC RESPONSE OF FUNCTIONALLY GRADED MICRO BEAM BASED ON MODIFIED COUPLES STRESS .................................................................................................................................................................................................................................. 22

SIZING OF FUEL-BASED ENERGY SYSTEMS FOR ELECTRIC AIRCRAFT .................................................................................................................................................................................................................................. 23

FATIGUE BEHAVIOR OF INNOVATIVE MULTIFUNCTIONAL EPOXY RESINS .......................................................................................................................................................................................................................... 24

COMMON COMPUTATIONAL MODEL FOR COUPLING PANEL METHOD WITH FINITE ELEMENT METHOD .................................................................................................................................................................................................................. 25

EFFECT OF LASER SHOCK PEENING PROCESSING PARAMETERS ON FATIGUE CRACK PROPAGATION BEHAVIOUR IN AA2024 .................................................................................................................................................................................................................................. 27

EVALUATION OF FEASIBLE MACHINE LEARNING TECHNIQUES FOR PREDICTING ROT AND TAXI-TIME AT CDG AIRPORT .......................................................................................................................................................................................................................... 28

DESIGN ESTIMATION METHODS FOR LIGHT-WEIGHT AND SUSTAINABLE JOINED WING FOR SMALL PASSENGER AIRCRAFT .................................................................................................................................................................................................................................. 29

MORPHING STRUCTURES AND FATIGUE: THE CASE OF AN UAV WING LEADING EDGE .......................................................................................................................................................................................................................... 30

GENERATION AND EVALUATION OF TIME-RESOLVED 3D-SCAN DATA OF ICE ACCRETION PROCESSES .................................................................................................................................................................................................................................. 31

THERMOPLASTIC BASED CARBON NANOTUBE IN STRUCTURAL COMPOSITE .......................................................................................................................................................................................................................... 32

DESIGN AND TESTING OF AN HELICOPTER AIR INTAKE EQUIPPED WITH BARRIER FILTERS .......................................................................................................................................................................................................................... 33

AEROACOUSTIC OPTIMIZATION OF ROTARY WINGS IN MAV .............................................................................................................................................................................................................................................. 34
EXPERIMENTAL INVESTIGATION OF THE EFFECT OF HYGROTHERMAL AGING ON THE MECHANICAL BEHAVIOR OF CARBON NANOTUBE/PA 6 NANOCOMPOSITE ................................. 35
CONTINUING WITH ENVIRONMENT & PASSENGER FRIENDLY “GREEN” CIVIL AVIATION SOLUTION AIR-TO-AIR REFUELLING (AAR) – WHY NEEDED & HOW TO ACHIEVE, ANOTHER CHALLENGE AHEAD......................................................... 36
REDUCING THERMAL INFLUENCE OF A BLEED PIPE NEAR A COMPOSITE FUEL TANK WALL..... 37
NONLINEAR AEROELASTIC SCALING STUDIES ON HIGH ASPECT RATIO WINGS ....................... 38
MECHANICAL CHARACTERIZATION AND FATIGUE LIFETIME ASSESSMENT OF PLA REINFORCED WITH FUNCTIONALIZED CARBON NANOTUBES .................................................. 39
AIRCRAFT NOISE MODULE DEVELOPMENT FOR INTEGRATION IN MDO FRAMEWORK .......... 40
ACTIVE FLUTTER SUPPRESSION OF A HIGH ASPECT-RATIO WING USING AILERON CONTROL .... 41
ON THE USAGE OF MORPHING CAMBER FOR PERFORMANCE IMPROVEMENT AND LOAD ALLEVIATION OF A SMALL SCALE GLIDER ................................................................. 42
ALUMINIUM FRICTION STIR WELDING AND ADHESIVE BONDED JOINTS ............................... 43
DESIGN AND MANUFACTURING OF NACELLES FOR SMALL TURBOPROP AIRCRAFT .............. 44
ROBUST OPTIMISATION OF AIR DELIVERY DUCT SHAPE .......................................................... 45
CHALLENGES OF SMALL TURBINE ENGINE INSTALLATION ON 1-31T AIRCRAFT .................... 46
EFFECT OF LOW REYNOLDS NUMBER WIND GUST ON AERODYNAMICS OF PLUNGING AIRFOIL 47
FREE VIBRATION RESPONSES OF ADVANCED COMPOSITE BEAMS BASED ON A QUASI-3D HIGHER-ORDER SHEAR DEFORMATION THEORY .................................................. 48
FAILURE ANALYSIS OF T-STIFFENED COMPOSITE PANELS IN COMPRESSION AFTER IMPACT .... 49
DESIGN OF NEAR PURE MODE II SPECIMENS FOR THE ASSESSMENT OF DIS-BOND STOPPING FEATURES IN COMPOSITE JOINTS USING X-FEM ....................................................... 50
A NEW IMA SYSTEM INTEGRATION PROCESS FOR MULTICORE TRANSFER, WITH COMPLIANCE TO INCREMENTAL CERTIFICATION AND ROBUST PARTITIONING ......................................... 51
TIME-DEPENDENT MECHANICAL BEHAVIOUR OF PLA/CNT-COOH NANOCOMPOSITES ......... 52
NANOSTRUCTURED COPPER-CARBON NANOTUBES COMPOSITES FOR AIRCRAFT APPLICATIONS ................................................................. 53
THE EFFECT OF GUSTS ON AIRCRAFT WAKE VORTICES - ONE-WAY AND TWO-WAY COUPLING OF RANS AND LES CODES .................................................................................. 54
AERODYNAMICS OPTIMIZATION OF THE ROCKET PLANE IN SUBSONIC AND SUPERSONIC FLIGHT CONDITIONS ............................................................................................................. 55
GLAMOUR PROJECT: AN OVERVIEW OF DESIGN AND WIND TUNNEL TEST VALIDATION ACTIVITIES OF GUST LOAD ALLEVIATION SYSTEMS .................................................. 56
NDE OF ADHESIVE DISSIMILAR JOINTS USING ULTRASONICS ............................................... 57
ATM4E: A CONCEPT FOR ENVIRONMENTALLY-OPTIMIZED AIRCRAFT TRAJECTORIES .......... 58
AERODYNAMIC ANALYSIS OF THE MAIN ROTOR INFLUENCE ON THE STATIC STABILITY OF THE GYROPLANE ................................................................. 59
APPLICATION OF THE POD METHOD TO OPTIMAL DESIGN OF EXPERIMENT .......................... 60
INVESTIGATION OF THE EFFECTS OF SLOTTED SOLID PROPELLANT’S SECTIONAL GEOMETRY ON STRUCTURAL STRENGTH AND INTERNAL BALLISTIC PERFORMANCE OF A ROCKET MOTOR ..... 61
EFFECT OF DESIGN PARAMETERS ON THE STRUCTURAL MASS OF A TELESCOPIC WING ........... 62
THE LOW POWER SINGLE ENGINE TURBOPROP AEROPLANE CLASS – THE FIRST LINK OF SMALL AIR TRANSPORT ................................................................. 63
STRAIN MONITORING AND DAMAGE DETECTION OF BONDED COMPOSITE STRUCTURES, USING MAGNETOSTRICTIVE SENSORS – LATEST DEVELOPMENTS AND APPLICATIONS .......................................................... 128

DEVELOPMENT OF THE SYMMETRICAL LASER SHOCK TEST FOR THE WEAK BOND INSPECTION ......................................................................................................................... 129

SURFACE QUALITY INSPECTION WITH THE AEROSOL WETTING TEST ................................................................................................................................. 130

INFLUENCE OF REPAIR-RELATED MODIFICATION OF ADHESIVE BONDS ON ELECTROMECHANICAL IMPEDANCE CHARACTERISTICS .......................................................... 131

SOLVING THE TWO EVOLUTIONARY SHAPE OPTIMISATION PROBLEM OF A NATURAL LAMINAR AIRFOIL (NLA) AND SHOCK CONTROL BUMP (SCB) WITH GAME STRATEGIES .......................................................... 132

MODELING OF TILT-WING AIRCRAFT DYNAMICS AS LINEAR PARAMETER-VARYING SYSTEM ............................................................................................................ 133

A COMPARISON BETWEEN CZM AND VCCT METHODS IN PREDICTING MIXED-MODE I+II CRACK GROWTH IN COMPOSITE BONDED JOINTS WITH AND WITHOUT CRACK STOPPERS .................................................................................. 134

BOPACS, BOLTLESS ASSEMBLY OF PRIMARY AEROSPACE COMPOSITE STRUCTURES .................................................................................................................. 135

DESIGN CHALLENGES FOR FUTURE AERO-ENGINES ................................................................................................................................. 136

ENGINE NACELLES DESIGN APPROACH ................................................................................................................................. 137

VEHICLE HEALTH MONITORING SYSTEM WITH SPECIAL EMPHASIS ON POWER UNIT ........................................................................................................ 138

LAB BASED IN-SITU X-RAY MECHANICAL TESTING IN VERY SMALL SCALES ON STATE-OF-THE-ART COMPOSITE MATERIALS, POROUS BARRIER COATINGS, AND NANO-STRUCTURED SYSTEMS .................................................................................. 139

BOPACS BONDED AILERON DEMONSTRATOR TESTING .................................................................................................................. 140

FATIGUE BEHAVIOUR AND DAMAGE TOLERANT DESIGN OF COMPOSITE BONDED JOINTS FOR AEROSPACE APPLICATION ........................................................................................................ 141

THE CIVIL USE OF SMALL UNMANNED AERIAL SYSTEMS (SUAS): LEGAL AND SAFETY CHALLENGES .................................................................................................................. 142

ADVANCED METHODS OF ECONOMY SUPPLIES AND WASTE MANAGEMENT IN ENGINEERING ........................................................................................................ 143

SINTERING SLIDING MATERIALS AND UTENSILS RESEARCH IN PROTECTIVE ATMOSPHERE IN THE UNIVERSAL CHAMBER FURNACE ........................................................................................................ 144

ITAKA – DEMONSTRATION FLIGHTS WITH BIOFUEL ON A LARGE AIRCRAFT .................................................................................................................. 145

A NOVEL DESIGN-FOR-X HOLISTIC APPROACH IN COMPLEX PRODUCT DEVELOPMENT INTEGRATING MODULAR DESIGN AND LEAN THINKING ........................................................................................................ 146

DESIGN-FOR-X INNOVATIVE APPROACH AS A DECISION SUPPORT TOOL FOR THE CREATION OF SCALED MODELS ........................................................................................................ 147

MULTI DISCIPLINARY OPTIMISATION IN AERONAUTICAL ENGINEERING .................................................................................................................. 148

STUDY OF VORTEX ROLL-UP USING DIFFERENT WINGTIP SHAPES .................................................................................................................. 149

NEW DEVELOPMENTS FOR INITIAL BOUNDARY VALUE PROBLEMS INVOLVING MULTI-PHYSICS AT LINKÖPING UNIVERSITY ........................................................................................................ 150

TURBULENCE MODELLING TECHNIQUES FOR AEROELASTIC PROBLEMS: RESULTS AND COMMENTS FROM THE SECOND AIAA AEROELASTIC PREDICTION WORKSHOP .......................................................................... 151

AGILE PROJECT: TOWARDS THE NEXT GENERATION IN COLLABORATIVE MDO .................................................................................................................. 152

AGILE DC-1 MDO PROCESS USING AN EFFICIENT GLOBAL OPTIMIZATION APPROACH .................................................................................................................. 154

AUTOMATED MESHING AND DATA FUSION APPLIED TO CREATE AERODATASET FOR AGILE DC-1 AND BEYOND ........................................................................................................ 156

AIRCRAFT SYSTEM ARCHITECTURES SELECTION FOR AIRCRAFT DESIGN OPTIMIZATION IN AN AUTOMATED PROCESS................................................................................................ 159

THE AGILE METHOD APPLIED TO AIRCRAFT DESIGN AT UNIVERSITY OF NAPLES ........................................................................................................ 161
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGILE MDO METHODOLOGY FOR A 3RD GENERATION MDO FRAMEWORK SUPPORTED</td>
<td>163</td>
</tr>
<tr>
<td>BY A GRAPH-BASED PROBLEM FORMULATION PACKAGE</td>
<td></td>
</tr>
<tr>
<td>STUDIES AND DEMONSTRATION ON ADVANCED AIRCRAFT CONFIGURATIONS*,</td>
<td>164</td>
</tr>
<tr>
<td>CLEANSKY2, LARGE PASSENGER AIRCRAFT, PLATFORM I</td>
<td></td>
</tr>
<tr>
<td>STUDIES TO CONFIGURE A NON-CONVENTIONAL RUDDER ON A COMMERCIAL</td>
<td>165</td>
</tr>
<tr>
<td>TRANSPORT AIRCRAFT: AERODYNAMICS, STRUCTURES AND LATERAL-DIRECTIONAL</td>
<td></td>
</tr>
<tr>
<td>STATIC AND DYNAMIC STABILITY</td>
<td></td>
</tr>
<tr>
<td>LARGE TURBOFAN ENGINE INTEGRATION INTO CIVIL AIRCRAFT VIA ACTIVE</td>
<td>166</td>
</tr>
<tr>
<td>FLOW CONTROL</td>
<td></td>
</tr>
<tr>
<td>BIOFUELS IN AVIATION: TRENDS, FUEL DEMAND AND CO2 EMISSIONS</td>
<td>167</td>
</tr>
<tr>
<td>EVOLUTION IN EUROPE</td>
<td></td>
</tr>
<tr>
<td>I-VISION: IMMERSIVE SEMANTICS-BASED VIRTUAL ENVIRONMENTS FOR THE</td>
<td>168</td>
</tr>
<tr>
<td>DESIGN AND VALIDATION OF HUMAN-CENTRED AIRCRAFT COCKPITS</td>
<td></td>
</tr>
<tr>
<td>I-VISION HUMAN FACTORS ANALYSIS METHOD USING VIRTUAL REALITY</td>
<td>169</td>
</tr>
<tr>
<td>LIFE-CYCLE APPROACH TO ASSESS GREENHOUSE GAS (GHG) EMISSIONS OF</td>
<td>170</td>
</tr>
<tr>
<td>ALTERNATIVE AVIATION FUELS: METHODOLOGICAL CONSIDERATIONS</td>
<td></td>
</tr>
<tr>
<td>VORTEX DYNAMICS IN SUPersonic SHOCK-Boundary Layer Interaction Flows</td>
<td>171</td>
</tr>
<tr>
<td>INVESTIGATING THE DYNAMIC RESPONSE OF HYBRID-ELECTRIC PROPULSION</td>
<td>173</td>
</tr>
<tr>
<td>SYSTEMS</td>
<td></td>
</tr>
<tr>
<td>RENEWABLE JET FUEL FROM ALGAE: A LIFE CYCLE ASSESSMENT</td>
<td>174</td>
</tr>
<tr>
<td>VALIDATION OF A NUMERICAL MODEL BASED ON STACKED-SHELL APPROACH</td>
<td>175</td>
</tr>
<tr>
<td>FOR BIRD-STRIKE USING NON-DESTRUCTIVE TESTS (NDT)</td>
<td></td>
</tr>
<tr>
<td>UNMANNED AIR SYSTEMS: A TOOL IN NOVEL AIRCRAFT DESIGN, VALIDATION</td>
<td>176</td>
</tr>
<tr>
<td>AND EVALUATION</td>
<td></td>
</tr>
<tr>
<td>INVESTIGATION OF BIRD-STRIKE EVENTS ON COMPOSITE WING PANELS</td>
<td>177</td>
</tr>
<tr>
<td>NON-CONVENTIONAL COMPOSITE MATERIALS FOR AEROSPACE STRUCTURES</td>
<td>178</td>
</tr>
<tr>
<td>VIRTUAL TESTING OF COMPOSITE AEROSTRUCTURES</td>
<td>179</td>
</tr>
<tr>
<td>C WING GEOMETRIC DESIGN BASED ON AIRCRAFT FLYING QUALITIES</td>
<td>179</td>
</tr>
<tr>
<td>EFFECT OF COMPOSITION AND TEMPERATURE ON THE DEPOSIT-INDUCED</td>
<td>181</td>
</tr>
<tr>
<td>DEGRADATION REGIMES IN COATINGS AND STRUCTURAL ALLOYS FOR GAS</td>
<td></td>
</tr>
<tr>
<td>TURBINES</td>
<td></td>
</tr>
<tr>
<td>MECHANICAL BEHAVIOR OF A FUSELAGE STIFFENED CARBON-EPOXY PANEL UNDER</td>
<td>182</td>
</tr>
<tr>
<td>COMBINED LOADS</td>
<td></td>
</tr>
<tr>
<td>SYNTHESIS AND STUDY OF NIALX (X = CR, CO) INTERMETALLIC ALLOYS BY</td>
<td>183</td>
</tr>
<tr>
<td>MECHANICAL ALLOYING FOR APPLICATION IN GAS TURBINE ENGINES</td>
<td></td>
</tr>
<tr>
<td>EVALUATION OF DISCONTINUITIES IN AMC FRICITION STIR WELDS PRODUCED</td>
<td>184</td>
</tr>
<tr>
<td>BY DIFFERENT GEOMETRY TOOLS</td>
<td></td>
</tr>
<tr>
<td>TECHNICAL COMPATIBILITY, CERTIFICATION AND DEPLOYMENT OF ALTERNATIVE</td>
<td>185</td>
</tr>
<tr>
<td>JET-FUELS</td>
<td></td>
</tr>
<tr>
<td>NON DESTRUCTIVE TESTING OF CONTAMINATED CFRP SURFACES WITH THE</td>
<td>186</td>
</tr>
<tr>
<td>BONDITNSPECT® SYSTEM</td>
<td></td>
</tr>
<tr>
<td>RENEWABLE JET FUEL FROM ALGAE: A LIFE CYCLE ASSESSMENT</td>
<td>187</td>
</tr>
<tr>
<td>THE FUTURE OF PROPULSION TECHNOLOGY IN THE 21ST CENTURY</td>
<td>188</td>
</tr>
<tr>
<td>SMALL AIR TRANSPORT CHALLENGES</td>
<td>189</td>
</tr>
<tr>
<td>EXERGETIC GREENIZATION FOR BUSINESS AIRCRAFTS: METHODOLOGY AND A CASE</td>
<td>190</td>
</tr>
<tr>
<td>STUDY.</td>
<td></td>
</tr>
</tbody>
</table>
OPTIMIZATION AND TESTING OF FLUIDIC ACTUATORS FOR ACTIVE FLOW CONTROL AT THE ENGINE/WING JUNCTION

Philipp Schloesser, Michael Meyer, Martin Schueller, Perez Weigel, Matthias Bauer

The area behind the engine/wing junction of conventional civil aircraft configurations with underwing mounted turbofans is susceptible to local flow separation at high angles of attack which potentially impacts maximum lift performance of the aircraft. Cause of this flow separation is an interaction of vortices created at nacelle, pylon and at the inboard slat side-edge. The impact is already relevant for the integration of state-of-the art turbofans but is likely to worsen when advancing to future ultra-high bypass ratio (UHBR) turbofan engines characterized by larger nacelle sizes, turbofans closely coupled to the wing and larger slat cut-outs. Active Flow Control applied at the unprotected leading edge inboard of the engine pylon has shown considerable potential in numerical simulations[1] by partners to alleviate or even eliminate local flow separation and consequently regain maximum lift performance. This paper will present two distinctive concepts of fluidic actuation: Pulsed Jet Actuators (PJA) which generate alternating jets when supplied with pressurized air and Synthetic Jet Actuators (SJA) which periodically expel and ingest fluid by means of an oscillating transducer. Testing and optimization of these two actuator concepts developed within the project framework are presented. Both systems are tested and optimized with respect to an upcoming large-scale wind tunnel test to assess the effect of AFC on the flow behavior. The development process includes the actuators themselves as well as their related hardware and required infrastructure.
EFFECT OF RIM SEAL DIVERSION STRUCTURES ON AERODYNAMIC AND COOLING PERFORMANCE OF TURBINE ROTOR BLADE AND ENDWALL

Zhigang LI, Jun LI, Qing GAO, Zhenping FENG

Effect of rim seal diversion structures on the aerodynamic and cooling performance of turbine rotor blade and endwall was numerically investigated using three-dimensional Reynolds-Averaged Navier-Stokes (RANS) and SST turbulence model. The accuracy of the numerical approach was demonstrated by comparison of the experimental data for the aerodynamic performance of Aachen one and half turbine stage. Four diversion structures of rim seal with the straight type, elliptic type, hyperbolic type and circular type were used in this work. The influence of the purge flow from the rim seal with different diversion structures on the aerodynamic performance of turbine blade was analyzed. The pressure distribution near the rotor blade endwall, total pressure distribution at the rotor blade exit as well as the efficiency of turbine stage was discussed. In addition, the cooling effectiveness of different diversion structures purge flow on the turbine rotor endwall was studied. The numerical results show that the turbine stage has the maximum efficiency with the circular type rim seal among four diversion structures. The highest cooling effectiveness of turbine rotor endwall for the circular type rim seal among four diversion structures was obtained. The flow pattern of the rim seal with different diversion structures was also illustrated.
NON-DESTRUCTIVE QUALITATIVE CHARACTERIZATION OF THERMAL DAMAGE INTERACTIONS IN CARBON FIBRE COMPOSITE PANELS

Aswin Haridas, CHAOLONG SONG, Kelvin Hau-Kong Chan, Murukeshan Vadakke Matham

Driven by high strength to weight ratios and advanced design flexibility, the application of composites structures in the aerospace industry is growing exponentially. A very low thermal conductivity and thermal expansion coefficient give it an edge when it comes to applications requiring stringent thermal loads, especially in aircraft engines.

It is thus necessary to characterize the behaviour of such load carrying structures to certify their use in the aerospace industry. Extending the work done in qualitatively characterizing the composite panels under high thermal loads, we found it necessary to consider the thermal damage interactions in composite panels as well. This would enable us to understand such interactions whilst characterising the domain of the measurement technique. The detection of smaller damages is dependent on the sensitivity of the measurement system and if undetected, these damages could interact and increase the spread of the actual damage zone. This paper in this context analyses such thermal damage interactions on 30X30 cm2 carbon fibre composite panels with its structural design and thermal loading conditions as key variables. Shearography and Ultrasound techniques are employed to record the thermal damage interactions with high accuracy and better resolution. The paper also compares the performance of the above mentioned, two non-destructive techniques.
The main purpose of this paper is to perform an exergy analysis of a turbojet engine combustor at different cycle parameters. The main components of the turbojet engine include compressor, combustor, high pressure turbine and an exhaust. Base cycle parameters have been defined for the engine and then differentiation of the combustor exergy efficiencies and destruction rates have been evaluated by changing overall pressure ratio, combustor exit temperature and combustor pressure ratio. For the basic engine cycle combustor unit is found to have lowest exergy efficiency as 62.3 % for the seal level static condition. Compressor, turbine, exhaust and whole engine exergy efficiencies have been calculated as 88.7 %, 96.5 %, 68.2 % and 69.4 respectively. Because of the biggest exergy destruction is seen mainly in combustion system; the combustor inlet pressure (related to the compressor pressure ratio), pressure drop and exit temperature on the exergy efficiencies have been analyzed and the effects on the combustor second law efficiency have been evaluated.
INVESTIGATIONS ON THE AERODYNAMIC AND COOLING CHARACTERISTICS OF TURBINE STAGE WITH CONSIDERATION OF THE CIRCULAR TYPE DIVERSION STRUCTURE RIM SEAL PURGE FLOW

Zhigang Li, Jun Li, Qing GAO, Zhenping FENG

The aerodynamic performance of turbine rotor blade and cooling effectiveness of the rotor blade endwall with consideration of the interaction between the rim seal purge flow and mainstream was numerically investigated using three-dimensional Reynolds-Averaged Navier-Stokes (RANS) and SST turbulence model. Three axial distances between the circular type diversion structure and leading edge of rotor blade was utilized to analyze the inlet flow angle, pressure distribution and total pressure loss of the rotor blade with consideration of the different purge flow from rim seal. The cooling effectiveness on the rotor blade endwall due to the rim seal purge flow was discussed. The obtained results show that the aerodynamic efficiency of the turbine stage increases with the increase of the axial distance between the rim seal and rotor leading edge. In addition, the cooling effective of the rim seal purge on the rotor endwall can be improved with the increase the axial distance. The flow pattern of the purge flow from the rim seal with different axial distances was also illustrated.
VIRTUAL PROTOTYPING OF ENERGY HARVESTING SYSTEMS FOR AERONAUTICS

Zdenek Hadas

This paper deals with a virtual prototyping of energy harvesting systems for aeronautics. Energy harvesting systems could be very interesting alternative for autonomous powering of ultra-low power electronics, sensors and wireless communication. The presented system could convert ambient energy to electricity and it provide autonomous power supply without any batteries or wiring. Mechanical and thermal energy are promising autonomous sources of electrical energy in aeronautics. However, the amount of harvested energy is usually very low and the output electrical power has to be predicted and compared with power requirements of intended ultra-low power application. This paper presents useful tool for prediction of harvested power in aeronautics. This tool provides mathematical and simulation models of such multidisciplinary devices and commonly it could be marked as virtual prototyping of energy harvesting systems. The virtual prototype includes mathematical models of energy conversion, physical laws, multi-physical feedbacks, geometry, electronics, etc. This virtual tool is necessary for development of new energy harvesting systems and new smart materials and structures could be integrated for future development process.
SOME NECESSARY ADDITIONS TO EASA PART 66 & 147 LICENSES

Mukadder Igdi-Sen

EASA (The European Aviation Safety Agency) Part 66 is an aircraft / helicopter maintenance licence. In some Aircraft Fuselage-Engine, Aircraft Avionics and Aircraft Technology Departments (as a Vacational College) in Turkey are educated their students in accordance with this license’s requirements if they want to educate the new high quality aircraft technicians. Our school (is an aircraft technology department in Trakya University, in Turkey) was planned a very good lecture contents according to EASA Part 66 & 147. But some necessary additions to these licenses for the safety of future of aviation were seen and added some additional different lectures to our syllabus of our department. In this paper was explained these necessities and their causes.
In the present work, the preliminary design of a Medium-Altitude-Long-Endurance (MALE) Unmanned-Aerial-Vehicle (UAV) is presented, focusing on the interaction between the aerodynamic and the structural design studies. This work follows the end of the conceptual design phase, where a first concept has been developed and some key parameters have been defined. Hence, the next design phase, which is the preliminary design, is essentially where the aerodynamic and structural optimization procedures are conducted. Considering the aerodynamic aspects of the study, a brief presentation of the fuselage design, wing design, stability and control study, empennage design, and the winglet design optimization technique is made. The aerodynamic calculations and presizing methods are shown, focusing on the CFD methodology which was employed in order to estimate key aerodynamic and stability coefficients. Considering the structural aspects of the design, the internal layout configuration is presented, and the FE Methods, which were employed in order to calculate the safety factors of the structural elements of the UAV, are discussed. Custom parameterized design tools were developed, allowing automatic reshapes of the skin and the internal structural parts, which are mainly made of composite materials. Moreover, emphasis is given on the interaction between the two studies, as well as on the optimization loops, which were carried out in order to fine-tune the performance of the aerial vehicle, maximize the aerodynamic efficiency and reduce the structural weight.
EXPERIMENTAL DETERMINATION OF FIRE DEGRADATION KINETIC FOR AERONAUTICAL POLYMER COMPOSITE MATERIALS

Nathan Grange, Pietro Tadini, Khaled Chetehouna, Nicolas Gascoin, Guillaume Bouchez, Samuel Senave, Isabelle Reynaud

In recent years, the significant growth of composite materials use in the aerospace industry has led to a greater attention on fire safety requirements since, in case of fire event; the behavior of polymer composites is strongly different from that of classical aircraft materials. Aircraft parts dedicated to firewall applications, or located in a designated fire zone, shall meet severe fireproof requirements, such as ISO 2685 and FAA - AC20-135 standards [1, 2]. A large number of studies have been released in international journals to investigate the relationship between fire event and composite degradation kinetics [3-6]. However, because of the non-determinist results of composites fabrication process, the thermal characterization, especially of new advanced materials, represents an essential task. Indeed, as suggested by the European Material and Modelling Council, composite materials are characterized by imperfections and local failures that make their behavior difficult to be predicted.

This work deals with the thermal decomposition analysis of recently developed composite material with carbon fiber reinforcement and thermoplastic resin. The latter is polyether-ketone-ketone (PEKK), belonging to the family of polyaryletherketone (PAEK) known for its high-temperature stability. In addition, a thermosetting phenolic resin, widely used as ablative protection in heat or fire related applications, will be considered for comparison purpose. Thermogravimetric analysis were carried out, considering a temperature range between 25 and 1000 °C for different heating rates under oxidative (air) and inert (argon) atmospheres. With the mass loss results given by the TGA experiments, the kinetic parameters are estimated by means of isoconversional methods.

This work is a key step to carry on CFD calculations at standard fire test conditions. Indeed, such parameters will be included, as well as thermal properties, in the physical modeling in order to numerically investigate the fire behavior of composite materials. This activity works toward the determination of optimum designs for future development of aircraft composite parts.
Aerodynamics drives the aircraft performance, thus influences fuel consumption and environmental compatibility. Further optimization of shapes of all aerodynamic components is an ongoing design activity in industrial offices, this will lead to incremental improvements.

However, active flow control is a key emerging technology, which has the potential to realize a drastic step change in aircraft performance. Airbus collaborates here closely with academia, since fundamental studies are core activities of institutes.

Flow control targets two major goals:
- Low speed performance enhancements mainly for start and landing phase via control of separation at movables and aerodynamically critical regions.
- Drag reduction at high speed conditions via manipulation of viscous flow phenomena

This paper highlights flow control concepts and Airbus involvement in projects for both application options. To mature flow control systematically, local applications of separation control technology are major items for Airbus. In parallel, but at lower maturity level, investigations with academic partner are ongoing to reduce the turbulent skin friction at cruise. Here the complexity of the flow structures close to the wall is very challenging for the layout of efficient flow control actuators, but any reduction of viscous drag has a very large lever on aircraft overall drag.

The paper summarizes findings in European R&T projects, which focus on jet actuation control systems flush mounted to the wall of aerodynamic components. Examples are given for control of separation at aerodynamic sensitive wing regions, and objectives of recently started projects targeting skin friction drag reduction are described.
Today, re-usable rocket engine thrust chambers have been required to sustain even more than one hot operating cycle. A key issue for the application is the mechanical behavior under extreme thermo-mechanical conditions such as thermal gradients and pressure loads during combustion. To withstand the severe thermal environment as well as the cyclic operation, the materials must have high thermal conductivity and increased mechanical properties. In this study the correlation between microstructural aspects and mechanical behavior of copper base alloys for potential application as combustion chamber material were investigated. Therefore, a few alloys containing minor additions of Chromium, Niobium, Silver, Zirconium and even alumina were designed to improve high temperature strength by particle hardening. The potential of the created alloys was studied by electron microscopy to identify the intermetallic phases and ageing behaviour. Mechanical properties were investigated simultaneously by macroscopic hardness, tension testing and compression creep. It was found that the broad field of alloy compositions offers the possibility to adjust an optimum between acceptable electrical conductivity and high strength at elevated temperatures. Nevertheless it is necessary to understand the deformation behavior of the tested materials to predict the lifetime of possible applications.
This presentation is intended as an introduction to the Workshop on Fatigue of the 6th EASN Int. Conference. From safe-life to fail-safe and damage tolerance approaches, the last one emerged as the main design philosophy for aerostructures, allowing weight savings and at the same time increasing reliability and structural integrity in the presence of damages which may have occurred during the manufacturing process or during service. The application of damage tolerance philosophy requires extensive know-how of the fatigue and fracture properties, corrosion strength, potential failure modes and non-destructive inspection techniques, particularly minimum detectable defect and inspection intervals. To face scatter in material properties, conservative approaches considering the worst scenario or statistical methods dealing with the variability of material have been employed in the fatigue assessment of structures. The fatigue life estimation can display substantial variability, illustrating the need for a probabilistic assessment in practical applications. As an example, the variation in the fatigue life for the common scenario of a through crack in an Al alloy plate was evaluated taking into account scatter of properties. The 2010 FAA rule establishing a LOV (limit of validity) puts a bound in the indefinite operational life allowed for by earlier regulations. This requirement, together with the diminishing role of aluminium in airframes, will certainly shape the directions of fatigue, fracture and damage mechanics research in years to come, expanding the knowledge base upon which substantiation of LOV values is made, and ensuring safety under sustainable conditions.
This paper is focused on electronics for energy harvesting, especially for piezo-energy harvesters. We can buy a lot of integrated circuits (IC) produced for this area. How we can find the best one for our solution? Is it better to use IC with integrated diode bridge for conversion of an alternating current (AC) input and direct (DC) output, or rather without? And what about maximum power point tracking (MPPT). We can use IC where MPPT is integrated. Does it really obtain the maximum energy from our energy harvester? We will show you are solutions and answers on these questions in this paper.
The Trans World Airlines Flight 800 (TWA 800) disaster has motivated flight physics studies associated with the oxygen concentration in the fuel tank. Modern airplanes can lower the oxygen percentage in the fuel tank ullage usually by pumping Nitrogen Enriched Air (NEA) in it. However, as the aircraft is climbing, the partial pressure of oxygen in the tank’s ullage decreases. In turn, dissolved oxygen is released from the fuel leading to an increase of oxygen in the ullage. Understanding the oxygen transport in the fuel tank is crucial in optimising protocols for keeping the fuel tank in an inert condition during the flight.

This paper concerns a Computational Fluid Dynamics (CFD) investigation of oxygen and nitrogen concentration in the fuel tank during climb. The problem was studied for two sets of initial conditions: a non-inert ullage (23 wt% oxygen and 79 wt% nitrogen) and an inert ullage (14 wt% oxygen and 86 wt% nitrogen). We emulate the ascend of the airplane by adjusting the pressure of the outlet valve to correspond to the aircraft’s height at each timestep. The results show that the increase of the oxygen concentration in the ullage during the ascent of the aircraft is below 0.3% for both, the inert and non-inert ullage.
In this study, a new unified beam formulation and modified couple stress theory are proposed to study dynamic behaviors of functionally graded micro-beam. This theory accounts for hyperbolic distributions of the transverse shear stresses across the thickness and satisfies both the shear and couple-free conditions on the upper and bottom surfaces of the micro-beam. The material properties of the functionally graded micro-beams are assumed to be graded in the thickness direction according to the Mori-Tanaka scheme. The governing equations and the related boundary conditions are obtained from Hamilton’s principle.

The constructed models include the physical length scale parameter which can introduce the size effect, some results are presented to show the effects of the material length scale parameter, the power law index and shear deformation on the dynamic behaviors of the FG micro beams.
Optimized electric engines are lighter and smaller than conventional piston engines. As a result, new airplane configurations are feasible as engines can be placed in unconventional positions. Through careful aircraft design higher aerodynamic efficiencies of airframe, propeller and propeller integration can be achieved. The energy density of current batteries however still limits strongly the range of purely battery powered aircraft. But if the energy is stored in liquid fuel and converted by a generator into electric energy, then the advantages of electric propelled airplanes and conventional combustion engines can be combined.

But which combustion engine is optimal for such a serial-hybrid electric aircraft? In this new propulsion chain different boundary conditions apply to the engine. These boundary conditions interact with the characteristics of combustion engines. For example: if output power is constant, then piston engines get more efficient the heavier they are. A direct injection diesel engine will be much heavier than a wankel engine which delivers same power, but will have a much higher thermal efficiency. In this presentation it will be shown through considerations on aircraft level, that the optimal combustion engine for an electric hybrid airplane should be heavier and more efficient than the optimal combustion engine for a conventional aircraft. Further, it will be shown, that optimized electric hybrid airplanes can consume significantly less energy than optimized conventional airplanes and could therefore contribute to the Flightpath 2050 goals.
Polymers reinforced with different forms of nanostructured carbon, such as Multi Wall Carbon NanoTubes (MWCNTs), are currently subject of extensive investigation, as they provide the base of composites with improved electrical conductivity, impact resistance, vibration damping, etc [1-3]. Moreover, the need for flame resistance in the exterior polymer composite structures of aircrafts motivated the incorporation of flame retardants into the polymers, such as Glycidyl Polyhedral Oligomeric Silsesquioxanes (GPOSS). Yet, it needs to be thoroughly investigated whether CNTs and flame retardants may serve as defects which are deteriorating the mechanical performance of the material.

In the present work the effect of MWCNTs as well as the combined effect of MWCNTs and GPOSS on the fatigue behavior of the polymer RTM6-2 will be investigated. In order to make a comparison feasible, the same tests have been also conducted to unfilled material, serving as reference. The results of the mechanical tests were discussed supported by Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDS) analyses.

The results have shown that the incorporation of the MWCNTs into the polymer has extended the fatigue life of the material in the range of the moderate as well as the high stress levels. However, the further addition of the flame retardant GPOSS into the enhanced with MWCNTs polymer seems to have a significant deteriorating impact on the fatigue life, as compared to both the reference as well as the enhanced only with MWCNTs material. SEM and EDS investigation revealed MWCNTs and GPOSS agglomerations; they act as defects leading to a degradation of the fatigue resistance.
COMMON COMPUTATIONAL MODEL FOR COUPLING PANEL METHOD WITH FINITE ELEMENT METHOD

Jacek Mieloszyk, Tomasz Goetzedorf-Grabowski

Conceptual and preliminary aircraft concepts are getting mature earlier in the design process, than ever before. To achieve that advanced level of maturity multiple multidisciplinary analysis have to be done, often with usage of numerical optimization algorithms. This calls for right tools that can handle such a demanding task. Often the toughest part of a modern design is handling aircraft’s computational models used for different analysis. Transferring geometry and loads from one program to another, or modifying internal structure, takes time and is not productive. Authors defined unique concept of a Common Computational Model (CCM), which has also few similar points with the concept of Common Parametric Aircraft Configuration Schema (CPACS) [1], and implemented it by efficiently coupling Panel Method [2] for aerodynamic analyses, with Finite Element Method [3] for strength analysis.

The process begins with definition of even advanced geometry, with usage of a Graphical User Interface (GUI). Next natural step is obtaining aerodynamic pressures on the airplane. From the aerodynamic analysis, performance, coefficients for dynamic stability and control, and loads for strength analysis can be obtained. Developed special numerical tool FEMexport is not only able to send geometry with loads for the strength analyses, but also adjust the computational grid by adding internal structure, assigning material properties, and panel thickness to the common computational model. Moreover, after airplane’s structure is defined it is easy to obtain structure mass properties, inevitable for flight dynamics stability and control. Developed package of tools called Multidisciplinary Aircraft Design and Optimization (MADO) [4] is able to utilizes all of this unique capabilities, and can almost automatically generate data for dynamic stability and control analysis.

Practical example of advanced analyses of vertical stabilizer Fig. 1 show the power of the concept. Process includes generation of computational model for aerodynamic analyses, export of the vertical stabilizer structure, which has automatically added ribs, spar walls, materials, panel sets thickness. Fittings and stringers are added manually. Finally static, and frequency strength analysis are done. This is just a single example, from many practical computations done, which shows inevitable advantage of the proposed concept.
Residual stresses introduced by laser shock peening (LSP) can be used to improve the damage tolerance behaviour of lightweight structures. LSP imparts residual stresses much deeper than traditional methods such as sand blasting or shot peening. The aim of the current work is to investigate the effect of LSP processing parameters on the fatigue crack propagation (FCP) behaviour of commonly used aircraft aluminium alloy AA2024 in T351 heat treatment condition. LSP treatment was performed using a pulsed Nd:YAG laser (5 J, 20 ns, 1 mm x 1 mm and 3 mm x 3 mm spot size) on compact tensile C(T)50-specimens with a thickness of 2.0 mm. The microstructural studies using EBSD technique were performed to quantify crystallographic changes in the material trough LSP. FCP tests were performed to investigate the retardation effect of LSP residual stresses. Fractography was undertaken by scanning electron microscopy (SEM) to obtain the relationship between the material structure and the FCP behaviour. The specimens with LSP show significant retardation of fatigue crack propagation. The fatigue crack retardation effect can be correlated with the compressive residual stresses through the specimen thickness. The presence of crack closure in the specimen with LSP was confirmed by the presence of frictional contact surfaces leading to smooth cracked structure. Such effect is not present in the base material, where shear lips and growth bands are easier to visualize.
Currently NASA and American Airlines are jointly developing a decision-support tool called Spot and Runway Departure Advisor (SARDA) that assists airport runway schedulers to make gate pushback decisions and improve the overall efficiency of airport surface traffic. Runway Occupancy Time (ROT) and Taxi Time (TT) prediction provide the estimates to the runway schedulers in real-time airport operations. The prediction is required for enabling efficient runway scheduling that can increase runway throughput and reduce taxi times and fuel consumptions on the airport surface. Systematic analysis of years of radar tracks has allowed to better characterise and predict the ROT and TT profile as a function of meteorological parameters.

This paper presents how Machine Learning (ML) techniques may be used for predicting the ROT and TT profile. Different ML techniques will be assessed on their forecast performance, computational time and amount of data needed for delivering a reliable prediction. The techniques will be applied on 2 different major European airports traffic and will be benchmarked against the fast time simulation outcome of the CAST study using a static approach for deriving the ROT and TT profile. As a result the most efficient ML techniques will be applied on two case studies for predicting the ROT and TT.
DESIGN ESTIMATION METHODS FOR LIGHT-WEIGHT AND SUSTAINABLE JOINED WING FOR SMALL PASSENGER AIRCRAFT

Andrea Cini, Alessandro Anobile, Konstantinos Bacharoudis

One of the main challenges facing aeronautical engineers nowadays is the design of lightweight highly efficient structures to meet severe emission and noise regulations. The rising concern of aircraft manufacturers with life-cycle cost reduction further increases design limitations and complexity throughout the entire design process. Such constraints promote the introduction of non-conventional structural architectures, wider use of composite materials and manufacturing technologies, requiring preliminary, but accurate, specific estimation methods since the design conceptual phase. For the work presented, a fully composite joined-wing configuration was chosen to improve the performance of a new generation small passenger aircraft. The wing internal structure and materials were optimised with the aim of reducing weight and manufacturing, assembly and maintainability costs. Global structural properties of the upper and lower wings were selected by using beam theory to obtain the best compromise between specific strength/stiffness and cost. Different conceptual structural solutions were generated using the function analysis technique and evaluated in term of weight and manufacturing cost. Integrated structures were preferred to riveted joints in order to reduce weight and simplify assembly, trying to maintain multiple load paths to ensure fail-safe wing structure capability. A preliminary weight estimation method was developed on the basis of first-approximation beam and shell theories, sizing each wing component according to its design load conditions. Local buckling, preliminary fatigue and foreign object damage evaluations were taken into account during preliminary sizing as well. Component shapes, contrary to the black metal approach, were optimised to enhance composite lay-up properties, resulting in a nearly-uniform stress distribution across the sections. Costs related to tooling, man-hours, assembly and manufacturing process were predicted using semi empirical formulae based on industrial experience and novel process experimental demonstrators. The developed methods are useful tool to quantitatively assess the structural efficiency of innovative joined-wing structures made on composite material.
MORPHING STRUCTURES AND FATIGUE: THE CASE OF AN UAV WING LEADING EDGE

Sérgio J. Moreira, Sérgio M. O. Tavares, Paulo M.S.T. de Castro

Damage tolerance is a design philosophy that allowed weight reduction and improvement of the reliability of aeronautical structures. With the emergence of novel aircraft structural concepts, which make use of large scale shape deflections to achieve improved flight performance across significantly different flight regimes and missions, unusual crack paths and fracture modes may take place. Consequently, morphing concepts require a full understanding of the materials’ behaviour in primary or secondary structures in order to reliably withstand unusual and demanding operating conditions. A case study of a morphing leading edge developed for the wings of an UAV is presented in this communication. Leading edges are subjected to damage originated by bird strike or other events, and those damages can compromise the structural integrity and stability of the flight. In addition, due to the deflections during the morphing structure actuation, cracks will propagate, eventually until reaching critical sizes. A preliminary analysis of possible crack propagation scenarios is presented considering the stress and strain during the operation of the morphing leading edge.
Aircraft icing is an important research field in aviation engineering and in particular with regards to flight safety, the understanding of icing phenomena is essential to make flying safer. Critical surfaces like wings, the empennage, control surfaces or engine intakes have to be kept free of ice during all flight phases. Hence, appropriate de-icing and anti-icing systems have to be developed which have to be investigated experimentally under critical icing conditions. The most realistic and reliable way to test systems under icing conditions are flight tests with a special equipped aircraft. A cheaper, faster and hence more often used alternative to flight tests is using a certified and properly equipped icing wind tunnel.

When studying ice accretion processes experimentally it is desirable to document the generated ice shapes as accurately as possible. The obtained set of data can be used afterwards for aerodynamic studies, the improvement of icing test facilities, the development of design criteria, the validation of ice accretion simulation tools as well as for many other applications. In the past, various ice shape documentation methods have been established including photography, cross-sectional tracing, molding and casting as well as 3D-scanning. FH JOANNEUM has developed a new ice shape documentation technique, which allows the time resolved 3D-scanning (4D-scanning) of arbitrary ice surfaces during an ice accretion process. Based on that information, detailed evaluations of the experiments can be performed and hence a better understanding of the ice accretion process itself can be achieved. Especially glaze ice formations show relatively high roughness levels and hence a strongly varying 2D-contour in spanwise direction of the wing. Therefore, statistical evaluations including the averaged 2D-contour, standard deviations, correlation coefficients and volume, respectively ice accretion rate calculations are performed using an appropriate evaluation tool.

This work introduces on the one hand the application of the 4D-scanning technique to glaze ice shapes produced in FH JOANNEUM’s small-scale icing wind tunnel and on the other hand a suitable semi-automatic evaluation tool. As an outline to future work, the scanning technique was applied to larger rime and glaze ice shapes produced in Rail Tec Arsenal’s icing wind tunnel.
THERMOPLASTIC BASED CARBON NANOTUBE IN STRUCTURAL COMPOSITE

Nadir Kchit, Michael Claes

The goal is the improvement in mechanical and electrical properties of carbon fiber reinforced polymer (CFRP) through addition of thermoplastic polymer modified with carbon nanotubes (CNTs). Two approaches were proposed to introduce thermoplastic/CNTs in multiscale structural composite. The first approach is deposition of CNTs thermoplastic veils between the layers of a composite laminate stack and the second approach is powder coating of conventional prepreg by CNTs thermoplastic powder. It is expected that thermoplastic modified CNTs will improve the resin toughness and reduce crack propagation increasing CAI strengths. Thanks to the combination of good electrical and mechanical characteristic of CNTs and toughness of thermoplastic it was shown that the damage tolerance as well as electrical conductivity of multifunctional carbon fiber reinforced polymer was improved compared to conventional composite.
DESIGN AND TESTING OF AN HELICOPTER AIR INTAKE EQUIPPED WITH BARRIER FILTERS

Patrick Hendrick

The design of an air intake equipped with IBFs (inlet barrier filters) for a light helicopter using a small turboshaft will be described and explained from the specifications to the final manufacturing, going through the integration considerations in the small available volume of such a light helicopter, the CFD computations and the computations of the engine performance in normal operating mode and in emergency conditions with the by-pass door open (when the filters are clogged). After that, the testing of the intake on a test bench and on the helicopter itself will be explained and the analysis of the experimental results shown, with in particular the total pressure losses and the distortion indexes (in steady state) at the inlet of the compressor.
Small scale Unmanned Air Vehicles or MAV are of increasing importance thanks to the diversity of their possible applications. As a result, noise reduction becomes of primary interest for obvious strategic reasons or for environmental issues if the traffic continues to grow. Aside of other propulsion solutions such as conventional propellers or flapping flight, rotary wings provide better stability, control and resistance to gust. In the past decades, much have been done in understanding the noise from rotating blades at regular size, since the emergence of aeroacoustics with Lighthill’s early work and its application in rotating frameworks by Farassat and Brentner. However, noise reduction of small scale rotors have rarely been addressed. The best compromise between aerodynamic and aeroacoustic phenomena of MAV rotor blades is still to be found. The present work introduces a fast optimization of MAV rotor blades based on endurance preservation and noise reduction. Parameters involved are the number of the blades, their chord length and their twist angle. The aerodynamic performances are predicted through BEMT while the sound is propagated with a wave extrapolation method based on the FW-H analogy. Broadband noise prediction is addressed and a numerical tool is developed and validated. The results of the optimization process are discussed and compared to experiments, RANS and LBM numerical simulations.
EXPERIMENTAL INVESTIGATION OF THE EFFECT OF HYGROTHERMAL AGING ON THE MECHANICAL BEHAVIOR OF CARBON NANOTUBE/PA 6 NANOCOMPOSITE

Elli Moutsompegka, Konstantinos Tserpes, O. Murariu, Leila Bonnaud

Polymer nanocomposites find an increased use in structural applications due to their improved mechanical properties over pristine polymers. As polymers are highly sensitive to environmental conditions, the understanding of environmental effects on the mechanical behavior of polymer nanocomposites could extend their use in applications in which hygrothermal environments are present.

The objective of the present work is to investigate experimentally the effect of hygrothermal aging on the mechanical behavior of polyamide 6 (PA 6) filled with 10 wt.% carbon nanotubes (CNTs). The specific polymeric matrix material was selected because it is used in a wide range of applications and is highly susceptible to moisture.

Neat and CNT-filled PA 6 samples were prepared by melt mixing using an internal mixer. The samples were subjected to two different hygrothermal conditions, namely 25°C/85%RH and 40°C/85%RH into an environmental chamber until saturation point. The reference conditions are 25°C/55%RH. Unaged and aged, neat and CNT-filled samples were subjected to tension and 3-point bending tests.

The results from mechanical tests show a considerable degradation of the mechanical behavior of both neat PA 6 and CNT-filled PA 6 specimens due to moisture absorption. The Young’s modulus and flexural modulus of the materials are decreased by more than 30% while the flexural strength by 6-17%. The decrease is larger for the conditions of 40°C/85%RH which reveals that the effect of combined elevated temperature and moisture is more critical. On the other hand, the decrease in the properties is smaller for the CNT-filled PA 6 specimens than for the neat PA 6 specimens, which shows that the presence of CNTs mitigates the effect of hygrothermal aging. Finally, it is observed that the increase in the properties of the neat PA 6 material offered by CNTs is so large that it compensates the negative effect of hygrothermal aging.
CONTINUING WITH ENVIRONMENT & PASSENGER FRIENDLY “GREEN” CIVIL AVIATION SOLUTION AIR- TO-AIR REFUELLING (AAR) – WHY NEEDED & HOW TO ACHIEVE, ANOTHER CHALLENGE AHEAD

Raj K Nangia

In view of the maturing technologies in aerodynamics and propulsion, researchers recognise that direct efficiency advances require increasing developmental effort. However, operational solutions exist. Over last 15 years, the author has been continually involved in such (eg EU-FP7 “Recreate”) and particularly in AAR and energy harvesting Formation Flying.

Efficiency metrics emphasize “Why and What”, giving an understanding of the range sensitivities, operational concepts and performance goals via the importance “X-factor”. For given range, current aircraft are greener than previous generations. Medium range aircraft are always greener than Long ranges types. However, major trend is for the latter: twin-aisle A350, A380, B787, B777X (10+% payload, 40+% fuel to MTOW). Shorter range single-aisle aircraft are “feeders” types/newer derivatives; A320, B737 class (20+% payload, 20+% fuel to MTOW).

AAR is taken for granted/on demand in Military expertise developed over 80 years. Tankers are sky “gas-stations”. The missions aim for success rather than be concerned with fuel usage. Tankers accompany and refuel short-range aircraft over longer missions. AAR can be strong enabler for civils. Small tankers (A320 size) can operate over short radii, refuelling longer range cruisers en-route.

AAR will always be in top hierarchy over any technological advances, offering step change towards highly efficient aviation. The pros and cons of Operational issues, routing and constraints: Turbulence, Air Navigation, environmental impact are discussed.

Replacing today’s Inter-Continental system with AAR gives fuel savings and CO2 emission reductions, 15-30% depending on range. Additionally, 30-40% weight savings lead manufacturers/operators focus on smaller aircraft. Major COC and DOC reductions (similar order) occur. Noise, emissions, wake effects are favourable, meeting ACARE goals. A bye-product is that Laminar-flow aircraft introduction can be eased.

AAR provides higher benefits as system develops towards point A- B rather than “hub-spoke” solution. The smaller AAR-cruisers imply ground-based opportunities: smaller airports making new connections, easing the transit pax handling, reducing total travel time.

For sustainable aviation growth and future urbanisation, short flights are replaced by other transport modes. The relief in capacity (less short flights) becomes available for long flights (where aviation: only solution). To maintain transport capacity, it is not necessary that more AAR cruises are needed, These operate at 20+% payload to MTOW. More likely is that the total mass (metal) in air will be lower.

Certification, Operational rules will need revision. New tankers or others modified from civil aircraft, already respect most CS25 regulations. We aim for automatic refuelling (demonstrated US-UCAV). Work is needed to bring such technologies into Civils. We allude to newer versatile twin-aisle cruisers with differing pax capacities that cruise World-wide ranges with AAR, blending with Formation Flying. All this should “spur/vitalise” Aviation. In “Clean Sky”, we should aim for practical demonstration: EU before NASA?
REDUCING THERMAL INFLUENCE OF A BLEED PIPE NEAR A COMPOSITE FUEL TANK WALL

S. Maryam Moghadasi, Albert Jan de Wit, Fabio Chiacchio

Over the years, several fuel tank explosion accidents have highlighted the risks of aircraft fuel tanks. Studies have been carried out by airworthiness authorities that have resulted into additional certification requirements for transport category airplanes with respect to flammability of the fuel tank. These newly introduced certification requirements necessitate detailed and accurate predictive models for flammability analysis assessment of unconventional fuel tanks (Summer, 2008)[1]. The requirements consider composite materials as unconventional.

A fuel tank model performs internal analysis of the fuel and fuel vapor and external analysis covering effects of the environment on the tank walls, such as hot spots. A typical hot spot near the wing fuel tank wall is the bleed pipe inside the leading edge. In order to prevent fuel vapors accumulation in case of fuel tank leakage and the tank wall of becoming too hot, the area in front of the tank is ventilated. To determine the necessary ventilation, at present, thermal studies are performed using SAE AIR 1168-3 standard (International, 1990). A step towards improving prediction of hot spot thermal effects on the tank wall is via 3D simulation.

In this study the wing leading edge is investigated. Different ventilation configurations are outlined and the thermal behaviour of the front spar (tank wall) is investigated. Initial results of the 3D analysis show that thermal improvements can be achieved via changes to the baseline design. Hence, benefits of using 3D analysis are promising. Furthermore, the models can be used to support a flammability analysis assessment.
Today, in order to improve aircraft performance through the reduction of fuel consumptions and enhanced lift-to-drag ratio, the wings aspect-ratio (AR) has been increased. The combination of high aspect-ratio and low structural weight results in very flexible wings that can suffer large deformations, causing aeroelastic problems that can lead to catastrophic structural failure. To prevent this, previous computational analysis and experimental tests must be conducted to verify that the wing will not suffer any aeroelastic problem within the flight envelope of the aircraft. Experimental tests, such as wind-tunnel tests, on high AR wings must guarantee that the scaled model will replicate the desired scaled aeroelastic response of the full-size wing. To accomplish that, aeroelastic scaling methodologies must be developed. We propose to analyse, by using a finite element (FE) analysis and a simplified model, the effects of the primary quantities choice on the results, the difference between two modal matching approaches (direct modal matching and the Coordinate Modal Assurance Criterion, COMAC), the difference between two scaling methodologies (mass and stiffness distribution matched simultaneously and sequentially), and the option of using a laminated composite beam for the reduced model. Both scaling methodologies will be used in the scaling procedure of a rectangular wing with an AR of 20, and the influence of the high nonlinearities will be analysed. Posteriorly, the scaling procedure will be applied to a more complex wing model based on the EU FP7 Project NOVEMOR reference wing.
MECHANICAL CHARACTERIZATION AND FATIGUE LIFETIME ASSESSMENT OF PLA REINFORCED WITH FUNCTIONALIZED CARBON NANOTUBES

V. C. Pinto, R. M. Guedes

European regulation increasing environmental demands, especially on dealing with products end of life phase, lead the research for green composites able to replace the oil-sourced composites. Advanced, sustainable, lighter, eco-friendly and innovative polymer composites have been increasingly raising interest among aerospace sector.

In order to balance sustainability and cost in the aviation industry, composites of renewable materials have been developed for interior body parts, underlining the evolution towards a greener industry. Deriving from renewable resources, bio-sourced and biodegradable polymers, such as polylactic acid (PLA), and its composites possess enough potential to provide benefits to companies, natural environment and end-customers by reducing petroleum resources dependency.

Bio-sourced polymers, like PLA, exhibit a complex mechanical behaviour, non-linear time-dependent, viscoelastic/viscoplastic. Fatigue and excessive laxity due to the viscoelastic/viscoplastic behaviour are considered the main reasons for material failure.

Aiming to optimize polymers’ performance, different types of reinforcement may be used. The approach to resort to inorganic nanoparticles to reinforce the matrix was developed in this study. Using carbon nanostructures as nano-reinforcements, bio-sourced polymer, PLA was reinforced with different weight percentages of functionalized carbon nanotubes (CNT-COOH).

An experimental mechanical evaluation of these nanocomposites was performed focusing on tensile properties, strain field measurements with non-contact measuring techniques and fatigue lifetime assessment. Comparing to neat PLA, PLA/CNT-COOH nanocomposites exhibit improved toughness and elastic modulus and longer fatigue lifetime, while proving quality of nanofillers dispersion may meaningly influence mechanical behaviour.
Market competitiveness has instigated the aircraft industry to innovate in its designs to produce increasingly cost-effective aircraft. Considering this trend the EU FP7 project NOVEMOR had the aim to research innovative air vehicle configurations. In the scope of this project a MDO software tool is being developed to allow analysis and preliminary aircraft design of novel aircraft configurations and morphing solutions. One aspect that must be considered in the design stage of new aircraft is noise generation. Noise emissions are a human health hazard and one of the top sources of annoyance to populations affected by aircraft noise. Its negative affects on well-being have lead to increasingly strict noise standards and projects whose goals encompass significant perceived noise reductions such as Clean Sky. This thesis focuses on the development of the acoustic module to be integrated in this MDO framework, which will allow to predict noise emissions in the design phase. This module will use Farassat’s 1A formulation to solve the acoustic equations allowing for the determination of loading and thickness noise from the airframe. Landing gear and propulsion noise will be integrated by empirical relations and tabulated data. Lastly, the Module will make post-processing analysis to confront the results with international standards (such as defined by ICAO, FAA, and EASA), facilitating evaluation of noise legislation accordance to the preliminary developer. With this module both a reference regional jet and a joined-wing already subject to previous optimization aircraft will be analysed.
ACTIVE FLUTTER SUPPRESSION OF A HIGH ASPECT-RATIO WING USING AILERON CONTROL

Frederico Afonso, José Vale, Éder Luiz Oliveira, Fernando Lau, Afzal Suleman

The design of wings with higher aspect-ratios is an observable trend in recent commercial aircraft. This is mainly supported by the well-known aerodynamic benefits, such as higher lift-to-drag ratio and lower induced drag. However, to ensure a low structural weight these designs present very flexible structures that are prone to suffer high deflections under normal operating conditions, which can render in aeroelastic instabilities such as flutter. To prevent these catastrophic events active control is a possible solution.

An in-house nonlinear aeroelastic framework able to analyze flutter in the time domain on high aspect-ratio wings was enhanced with the capability of including aileron control laws to suppress flutter. A commercial regional jet reference wing of the EU FP7 project NOVEMOR will be extended to exhibit an aspect-ratio of 16. Given the limitations of the present framework, a reduced scale model will be used in order to present flutter at subsonic speed. The possibility of using the ailerons as active controls to suppress flutter will be accessed and time history plots of the amplitude response with and without active flutter control will be shown.
ON THE USAGE OF MORPHING CAMBER FOR PERFORMANCE IMPROVEMENT AND LOAD ALLEVIATION OF A SMALL SCALE GLIDER

José Lobo Vale, Frederico Afonso, Fernando Lau, Éder Oliveira, Afzal Suleman

Morphing aircraft technologies have been studied for several years now with the purpose of improving flight efficiency. Nevertheless, the efforts so far did not produce conclusive results showing beneficial effects of morphing in aircraft where missions are dominated by a nearly constant cruise flight condition. This study explores the application of morphing for load alleviation as means to reduce the required wing structural weight without compromising the overall aircraft performance. A comparative study between the lift over drag ratio (L/D) performance of a 1m span fixed wing glider (FWG) and a 1m span camber morphing wing glider (CMWG) is presented. Both aircraft are aero-structurally optimized for the best L/D ratio for specific pairs of speed and payload mass values. A combination of lifting-line theory and 2D viscous calculations is used for the aerodynamics and an equivalent beam model is employed for the structural analysis. Pull up and down maneuvers at 25m/s and near stall angle of attack are assumed as the critical load cases. Results of the FWG optimization will be shown, in terms of Pareto Fronts (PF) and L/D vs Design Variables plots and its performance, in several trimmed flight conditions with varying mass and velocity. These results will be compared to the ones from the CMWG optimization and conclusions will be drawn about improvements in the L/D ratio that can be achieved throughout the flight envelope with morphing and about potential reductions in the wing structural mass due to the load alleviation strategy.
Environmental regulations and emission targets set upon the transportation industry have led to the pursuit of more efficient structural designs involving the use of new materials and innovative designs. These innovations require advancements in manufacturing and assembly technologies. One technology that has been proposed for joining aluminium components and even replacing riveting is friction stir welding (FSW). FSW is a solid state joining method and is capable of producing sound welds in previous hard to weld aluminium alloys when used in a butt-joint configuration. Even though in butt joint configuration FSW leads to high performing joints in quasi-static loading conditions, fatigue loading and high strain loading, when used in overlap configuration the mechanical performance of the joints is substantially lower. Overlap joint configuration is desirable in various designs for easier tolerance management or for resemblance to current employed joining technologies, such as riveting, among other reasons. Another technology that has received increased interest and which is commonly used in overlap configuration is adhesive bonding. Adhesive bonded joints introduce a high degree of flexibility in structural design as they allow joining of dissimilar materials and the mechanical properties of the adhesive itself and the joint may be tailored to a certain degree. In this work both of these techniques were combined to produce a hybrid joining technology. Advancements in manufacturing technology development, mechanical characterization under quasi static, fatigue and high strain loading conditions and in numerical modelling will be presented.
The aim of this paper is to present the results of prepreg nacelles design and manufacturing for I-31T aircraft. The work was part of the European Union project "Efficient Systems and Propulsion for Small Aircraft"- ESPOSA.

The new engine cowling design was preceded by Computational Fluid Dynamics numeric analyses stage, which purpose was to optimize the external geometry. Use of TP100 engine was assumed, which was installed on the I-31T aircraft in the framework of the ESPOSA project. Engine size and the necessary accessories dictated engine space volume and the new cowlings size. This article presents the process of external geometry adjustment, chosen results of numerical analyses, 3D model design, manufacturing process and tests results. The new cowlings underwent ground and in-flight tests. Monitoring during the test included external and internal cowling temperatures. The collected test data were further analysed.

In majority of modern aircraft propulsion system cowlings are made of composite. Currently, there is a trend to manufacture initially solution treated materials – i.e. glass and carbon fiber prepregs. Such approach allows to accelerate the fabric layup process and achieve highly repeatable structure. Materials that are currently available on the market allow to manufacture the cowlings and simultaneous weight minimization. Owing to the applied 3D software for both design and manufacture of machining tools, it is possible to substatntially shorten the time of manufacturing a complete element.

The cowlings were designed in cooperation with the NLR – Netherlands Aerospace Centre, who is a partner in the ESPOSA project and has experience in prepreg elements design.
ROBUST OPTIMISATION OF AIR DELIVERY DUCT SHAPE

Krzysztof Marchlewski, Łukasz Łaniewski-Wołłk

We discuss a shape optimization method and its results for the air delivery duct of a turboprop engine. Our objective function is the total pressure loss in the channel. The input parameters of the simulation describe the geometry of the duct as well as the flow conditions. All these parameters are known with a prescribed tolerance uncertainty. In consequence we take into account those uncertainties while performing optimization process. The optimization method is based on a surrogate model Kriging approximation. It allows us to incorporate uncertainties of the variables into the model. This is achieved with the use of the Gaussian Process properties. At the same time, utilization of the Response Surface Method reduces the needed number of evaluations of the objective function, allowing for the use of high fidelity Computational Fluid Dynamics simulations to obtain it. We start with choosing the initial points for which the objective function (pressure loss) should be evaluated. The initial number of points should be limited, but large enough to roughly catch the main features of the objective function. This is why the Design of Experiment technique is used. Subsequently we set up the surrogate model and prepare the mean response surface. Our knowledge about the optimum is improved by using the sample criterion. It allows us to add new points where the objective function should be evaluated and do it in minimal number of steps. The optimization is finished when satisfactory improvement is achieved.
The aim of this paper is to present the challenges of small turbine engine installation on I-31T. The work was part of the European Union project "Efficient Systems and Propulsion for Small Aircraft" - ESPOSA. The main object of the project is to develop ideas and technologies for new turbine engine designs for small aircraft. In the project, Institute of Aviation was responsible for installation of TP100 (PBS) engine on the I-31T aircraft.

This paper brings out the challenges of the design stage and describes the ground and flight test objectives. In-flight test phase is one of the most important aspects of any aircraft development programme. Therefore, all newly designed components have been thoroughly tested during the flight test campaign. The different components installed in the aircraft were tested in order to validate their integration and proper operation of the system.

A few of the most interesting issues chosen to be presented are as follows:
- Engine bay cooling
- Rear air inlet design
- Exhaust system design
- Integration of 28V and 14 V electrical system
- Nacelle’s weight and parts reduction
- Glass cockpit installation
- Flight Test Installation (FTI)
- Airworthiness certification criteria for special category turboprop aircraft
- In-flight tests and performance

All the design activities and tests, described in the paper were aimed at building a new class of aircraft – Single Engine Turboprop SET(L). It has provided an opportunity to test the reliability, necessity and functionality of the new class of aircraft for small air transport.
Growing application of micro aerial vehicles (MAV) sets in demand for accurate computations of low Reynolds number flows past their wings. The applications usually involve complex unsteady phenomena that depend on the kinematics of the vehicle such as pitching, plunging, and flapping motions of wings. The objective of present study is to investigate the effect of unsteady freestream velocity or wind gust on a harmonically plunging symmetric NACA0012 airfoil at Re = 1000. The influence of unsteady parameters, such as reduced frequency of plunging motion (0.25<k<0.5), non-dimensional plunging amplitude (hos≤0.2) and non-dimensional amplitude of wind gust (0.1≤λ≤0.4) has been studied. Computations have been carried out using commercial software ANSYS Fluent 16.0. Results have been presented in the form of streamlines, vorticity contours, lift and drag signals and their spectra. It is observed that the ratio of plunging frequency to gust frequency (f/fg) has strong influence on periodic characteristics of unsteady wake. The wake of plunging airfoil illustrates vortex lock-in phenomenon analogous to the wake of an oscillating cylinder. It has also been observed that for a fixed plunging amplitude, an increase in value of k results into a change from positive drag to thrust.
FREE VIBRATION RESPONSES OF ADVANCED COMPOSITE BEAMS BASED ON A QUASI-3D HIGHER-ORDER SHEAR DEFORMATION THEORY

Zaoui Fatima Zohra, Hanifi Hachemi Amar Lemya, Meradjah Mustapha, Tounsi Abdelouahed, Ouinas Djamel

This paper presents an analytical solution to the free vibration analysis of functionally graded beams by using a refined hyperbolic shear deformation theory in which the stretching effect is included. The modulus of elasticity of beams is assumed to vary according to a power law distribution in terms of the volume fractions of the constituents. Equations of motion are derived from Hamilton’s principle and Navier-type analytical solutions for simply supported beams are compared with the existing solutions to verify the validity of the developed theory. Numerical results are obtained to investigate the effects of the power-law index and side-to-thickness ratio on the natural frequencies.
Aeronautical mobile box-type structures such as flaps, composed of thin T-stiffened composite panels, can be submitted during manufacturing or in service to different kind of low energy impacts such as dropped tools for example (Foreign Object Damage). As a result, Barely Visible Damage must be carefully taken into account during the sizing phase as stiffener or skin damages could highly influence the behavior of the panels in terms of static strength, stiffness and buckling/post-buckling phenomena. In the frame of a commercial regional aircraft project, SONACA has developed and conducted an experimental and virtual testing campaign on representative T-stiffened composite flap panels to determine the level of impact energy leading to a BVID and assess the behavior of the damaged structure under compression in comparison to the undamaged one. Secondly the objective was to determine a compression strain allowable of the damaged stringers to size the structure. Test plan and experimental results as well as numerical modeling for BVID, strain gages and buckling predictions on impacted and non-impacted stiffened panels will be described in this paper. Based upon correlations between experimental and numerical results, accuracy of the developed model will be discussed.
This study attempts to identify and design a suitable experimental test specimen to assess the effectiveness of dis-bond stopping features in a composite bonded joint for aeronautical applications. The initial part of the study is concerned with the validation of the assumption that bonded fuselage panels with reinforcing frames and stiffeners undergo close to pure mode II failure in the adhesive. This validation was performed by simulating the crack propagation in a typical fuselage under cabin pressure differential loading using Cohesive Zone Modelling techniques in Abaqus. The second part of the study focussed on the design and optimisation of a laboratory-scale testing specimen under close to pure mode II conditions. The objective of this study was to identify a feasible specimen geometry which would have a controlled crack front propagation under pure mode II behaviour at the adhesive interface and analyse the effect of a washer shaped dis-bond stopping feature which restricts shearing in the adhesive layer. This analysis was performed using the combined capabilities of Abaqus and Morfeo in X-FEM to propagate the crack inside the adhesive using a pseudo Paris law. The study was performed in the framework of the BOItless assembling of Primary Aerospace Composite Structures (BOPACS) FP7 project.
Interference in multicores are undesirable for hard real-time systems in the aerospace industry, for which predictability of a system behavior and deadlines enforcement at runtime are mandatory.

We propose a safe integration process for the allocation and scheduling of IMA applications on multicore COTS, which takes inter-core interference into account. To do so, we developed a static timing analysis to bound maximum inter-core interference due to memory sharing, and then produce safe bounds on tasks worst-case execution times. We then propose to use constraint programming to automate the software-to-hardware allocation and schedule generation activities. The corresponding search procedure embraces our static timing analysis to ensure that the finally selected solution – i.e. software-to-hardware allocation and static schedule – corresponds to an architecture guaranteed to always respect its deadlines.

In [1] we proposed a similar IMA integration process, but it is not compliant with the current avionic incremental certification acceptance process, and fails to implement robust partitioning. To the best of our knowledge, it was the first work of the literature to propose a consolidated approach for IMA integration on multicore taking into account interference without needing for software or hardware modification. In this paper, the integration process relies on a different allocation strategy that enables to enforce a robust time and space partitioning, and remains compatible with incremental certification acceptance. Eventually, our work still does not rely on hardware nor software modification.

TIME-DEPENDENT MECHANICAL BEHAVIOUR OF PLA/CNT-COOH NANO COMPOSITES

V. C. Pinto, R. M. Guedes

In order to achieve greener, lighter and innovative solutions for specific aeronautic components, bio-sourced polymers and composites production and validation have been recently highlighted.

Polymers exhibit complex viscoelastic/viscoplastic mechanical behaviour with a non-linear time-dependency of stress and strain and with temperature dependency. Experimentally, this phenomenon is typically observed during creep tests. After an elastic response until reaching the creep load level, under a moderate loading rate, a slow and continuous increase of strain at a decreasing loading rate follows.

Bio-sourced polymers like polylactic acid (PLA) and others are submitted to cyclic loading above the elastic limit, exhibiting hysteresis, accumulating plastic strain at each load cycle. This will result in long-term ruptures caused by fatigue and excessive laxity due to material creep and consequent failure of the components. When compared to other polymers, neat PLA presents higher tensile strength, however, despite having a considerable short-term strength at higher loading rates, lifetime under static loading conditions is unsatisfactory, being prone to creep failure. This can be explained by the plastic flow created by molecular mobility induced by stress.

Aiming to optimize PLA’s performance, inorganic nanoparticles might be used for reinforce the matrix. Functionalized carbon nanotubes (CNT-COOH) in several weight percentages were considered for long term mechanical behaviour improvement of PLA.

Time-dependent behaviour of PLA and PLA/CNT-COOH nanocomposites analysed through creep tests for several stress levels. The incorporation of CNT-COOH proved to decrease the creep strain and unrecoverable strain with remarkable decrease for all stress applied conditions on permanent and recoverable strain. Creep resistance increased for some stress levels with the incorporation of CNT-COOH, through the creep compliance analysis. Hence, PLA/CNT-COOH nanocomposites presented a less viscous and more elastic mechanical behaviour than PLA.

The time-dependent behaviour of viscoelastic materials can be defined in the field of continuum mechanics through constitutive laws, including time as a variable in addition to the stress and strain variables. Proving PLA and PLA-CNT-COOH nanocomposites non-linear viscoelastic behaviour, power law and Burger’s model may be employed to describe experimental time-dependent behaviour.
NANOSTRUCTURED COPPER-CARBON NANOTUBES COMPOSITES FOR AIRCRAFT APPLICATIONS

Isabel Graça, Alberto C. Ferro, Mafalda Guedes

Several assemblies in aircraft, such as diaphragms, precision bearings and bushings, door components, brake systems and pitot systems, are used under extreme conditions. They are submitted to repetitive sliding contact, thermo-electric transport, high compressive and wear forces, and a range of temperatures, pressures and atmospheres. Their reliable performance under these conditions is paramount to the safe landing of aircraft, and the choice of material is critical. The unique combination of high thermal and electric conductivity allied with good strength and ductility, good creep, fatigue and corrosion resistance found in copper make it an obvious choice for such applications. However low strength and hardness issues require development of new copper alloys and composites to improve service life, reliability and suitability under extreme conditions.

In this context the development of novel copper-based composites refined to the nanoscale was envisaged, through mechanical alloying of mixtures containing copper and carbon nanotubes. Tailored batches containing copper and 2 wt% carbon nanotubes were milled in a planetary ball mill for times varying between 1 h and 16 h, at 400 rpm. A ball-to-powder ratio of 20:1, alumina vial and copper spheres were used, under dry conditions or with addition of isopropanol. SEM/EDS, TEM/EDS, Raman spectroscopy, X-ray diffraction, microhardness test and eddy currents signal evaluation were used to study the produced composites. The powders were characterised regarding their size distribution, microhardness and electrical conductivity. The microstructure of the copper matrix was studied regarding copper crystallite size and carbon nanotubes distribution in the metal; the reinforcement carbon nanotubes were characterised regarding their size and crystallinity after milling.

Attained results show that mechanical alloying of the studied Cu system produces nanostructured powders containing reinforcement carbon nanotubes homogeneously distributed in the metallic matrix, together with copper grain refinement. The produced nanocomposites exhibit apparent bonding at the Cu/nanotubes interface, suggesting potentially efficient mechanical load transfer Remarkable microhardness increase was achieved. Also, the achieved conductivity values suggest sufficiently low interface electrical resistance.

Further experiments are on course regarding wear performance, but these preliminary results envision copper nanostructured composite materials for high strength electromechanical applications.
Aircraft wake vortices present a potential risk to following aircraft, particularly during final approach and landing, as wake vortices may remain in the air corridor for a long time. Wind, turbulence, thermal stratification, and ground proximity are the key factors influencing the wake vortex evolution, but also the wake vortex generation behind the aircraft. Flying through a gust influences the wake vortex roll-up process and its evolution. Note that gusts may affect a single or both counter-rotating wake vortices depending on the shape of the gust. Both vortices influence each other by inducing a downward velocity. Disturbances may therefore lead to local vortex tilting and later to complex three-dimensional deformation. This work employs two different hybrid RANS-LES approaches to investigate the effect of gusts on wake-vortex evolution. In a one-way coupling, a pre-calculated RANS velocity field of the aircraft’s near-field is “flown” through an LES domain. The effect of a sine gust on the turbulent wake is modelled by manipulating the RANS-field accordingly. As a more sophisticated approach a two-way coupling is being developed. Here an LES and a URANS solver are coupled bi-directionally, exchanging values at every physical time step. Both approaches are compared.
Suborbital vehicles can have a few possible applications. The most popular is commercial tourist flights, but it also can use in astronauts training. What is more such vehicle can be used as a lunch system for micro satellites. Due to the marked demand on suborbital vehicle the concept of a Modular Airplane System (MAS) has been developed at Warsaw University of Technology.

The concept of MAS assumes two tailless vehicles which joined together create a conventional aircraft. The first vehicle is a mother airplane; the second one is a rocket plane which is used as a tail during the whole system flight. The carrier lifts the rocket plane above Earth’s thick atmosphere layer (troposphere). Next the vehicles are separated, then the carrier turns back to the airport. The rocket plane performs suborbital flight and crosses the boundary of outer space. During the re-entry flight the vehicle flying with wide range of Mach numbers. One of the project assumptions is that the rocket plane does not have heavy thermal shield. The vehicle is designed with Leading Edge eXtension (LEX); a vortex lift generating by the LEX allows to efficiently reduce sink rate during the re-entry flight. To ensure proper vehicle aerodynamic characteristic optimization process of the vehicle geometry is necessary. The preliminary results of such research for the low Mach number only were promising and were presented during ICAS 2014 conference and CEAS 2015 conference. The paper presents the result of numerical study on an aerodynamic shape of the rocket plane LEX but this time for the wider range of Mach number. Especially, the main goal of the research was to obtained the best LEX shape by the optimization process. The computation was made for flight conditions which may occurred during the re-entry phase – for transonic and supersonic speeds and at high angles of attack.

Figure 1 Layout of Modular Airplane System, mother plane (light gray) and rocket plane (dark gray).
GLAMOUR PROJECT: AN OVERVIEW OF DESIGN AND WIND TUNNEL TEST VALIDATION ACTIVITIES OF GUST LOAD ALLEVIATION SYSTEMS

Sergio Ricci

The combination of Natural Laminar Flow (NLF) with an aggressive use of maneuver (MLA) and gust load alleviation (GLA) technologies could offer the potential to greatly improve both the weight and aerodynamic terms in the classical Breguet range equation. For all these reasons the interest in the development, implementation and experimental verification of MLA and GLA technologies is becoming a key topic in the development of the next generation transport aircraft.

Aiming at this global target, the GLAMOUR project was submitted in response to the SP1-JTI-CS-2013-01-GRA-02-022 call under the JTI-Cleansky 1 initiative. It tackles the main target in two different ways. At first, having the Green Regional Aircraft as reference, starting from the active control laws proposed by manufacturer LEONARDO COMPANY-Aircraft Division, formerly Finmeccanica, and ITD member of Cleansky program, it tries to deeply explore their validity over the entire flight envelope, and to extend them with new control strategies based on alternative approaches, such as the Neural Networks, as well as based on Robust Model Predictive Control techniques. Finally, an extended experimental validation campaign will be conducted at Wind Tunnel available at Politecnico di Milano. A large wind tunnel half aircraft model properly scaled is manufactured and tested in a free-free configuration allowing to validate MLA and GLA techniques. Aiming at this goal, a dedicated gust generator has been designed, installed and tested into the wind tunnel.

In summary, the main project objectives are:
• Validate the Load Alleviation techniques based on control architectures provided by ITD member
• Develop of alternative control schemes
• Design and manufacturing of a wind tunnel model representing half GRA aircraft
• Design and manufacturing a gust generator
• Perform wind tunnel test under gust excitation
NDE OF ADHESIVE DISSIMILAR JOINTS USING ULTRASONICS

Elena Jasiuniene, Liudas Mazeika, Vyktas Samaitis, Vaidotas Cicenas

There is a high demand for lightweight structures for aerospace. To achieve this hybrid structures where introduced where dissimilar materials like metals and composites are joined together using adhesive bonding technology resulting in high performance lightweight structures. However, nondestructive evaluation of quality of adhesive dissimilar joints using ultrasonic waves is problematic due to essentially different acoustic properties of joined materials and novel approaches are needed.

The objective of this work was to develop novel ultrasonic nondestructive evaluation techniques for inspection of adhesive dissimilar joints, made from different material combinations, having different geometries, and joined using different adhesives.

Adhesive metal/composite joints made from steel/composite, aluminum/composite and prefabricated titanium/composite were investigated. Dissimilar joints produced from different metals to fiber reinforced composites presented the challenge to the nondestructive evaluation technique to be implemented, as different acoustic impedances, propagation velocities and attenuation in the dissimilar materials in combination with complex geometries and rough surfaces complicate the inspection. Several samples with adhesive dissimilar metal/composite joints with and without defects were investigated using focused ultrasonic transducers. A special post processing method for extraction of information about the adhesion area was proposed and tested on experimental data. It was demonstrated, that the proposed method removes the influence caused by surface/interface unevenness and positions of the defects in the joints can be determined.
Beyond the desire to minimise fuel use and hence CO2 emissions, currently the consideration of environmental aspects in en-route flight planning has not been operational practice. The reason for this is a low TRL (technology readiness level) of a flight planning method that considers a multi-dimensional environmental impact assessment and a lack of scientific support to motivate environmental flight planning. The exploratory research project ATM4E (Air Traffic Management for Environment, SESAR2020) addresses this gap and has as main objective to explore the feasibility of a concept for environmental assessment of ATM operations working towards environmental optimisation of air traffic operations in the European airspace.

The study will present how a multi-dimensional environmental cost function (ECF) concept is established for trajectory planning, which includes air quality impact (for key pollutants) and noise in addition to climate impact. This concept integrates existing methodologies for assessment of the environmental impact of aviation, in particular a concept for climate-optimisation which has been developed in a feasibility study of the North Atlantic in the EU funded aeronautics project REACT4C. These ECFs are derived from dedicated model output of atmospheric global circulation models, e.g. EMAC, local air quality tools, e.g. Open ALAQS and noise models, e.g. STAPES. Further objective is to evaluate the implications of environmentally-optimized flight operations to the European ATM network, by using a multi-dimensional environmental criteria assessment, which considers simultaneously with operating costs different environmental impacts: climate, air quality and noise.
AERODYNAMIC ANALYSIS OF THE MAIN ROTOR INFLUENCE ON THE STATIC STABILITY OF THE GYROPLANE

Marcin Figat

This paper presents the results of aerodynamic analysis and the static stability of the gyroplane ZEN-1. This kind of vehicle is a type of rotorcraft which uses a non-powered rotor in autorotation to develop lift and engine-powered propeller to provide the trust. Both of them disturbing the flow around the vertical and horizontal stabilizers of the gyroplane. The main goal of presented research was to find the influence of both rotated components on the static stability of considered vehicle. The change of the stability derivatives was the measure of this effect.

Analysis starts from the aerodynamic computation of complete model of gyroplane (Figure 1). The aerodynamic influence of the main rotor and propeller rotation were modeled as an actuator disc. First, analysis was made for different flight conditions like angle of attack and sideslip angle. Moreover, different rotation rate and configuration of the main rotor was considered. The Figure 1 presents the Cp distribution on gyroplane ZEN-1. The presented research was made within program “Innotech” of the National Centre for Research and Development.
APPLICATION OF THE POD METHOD TO OPTIMAL DESIGN OF EXPERIMENT

Wojciech Gryglas, Łukasz Łaniewski-Wołlk, Michał Dzikowski

Ability to automate and optimize instrumentation strategy is crucial to improve the cost, accuracy and robustness of complex flow experiment setup. The proposed optimization methodology is based on covariance minimization by utilizing the A-criterion. To be able to construct A-criterion the Fisher Information Matrix is required, which can be obtained from a model built by the Proper Orthogonal Decomposition (POD) method as surrogate model. POD based approach ensures stability of the optimization process and allows to formulate generic methodology which is problem independent. Furthermore, thanks to the availability of the surrogate model, it allows to reconstruct solution in the whole measurement domain basing only on the data gathered from the optimized sensor locations. The POD model construction requires to perform a set of numerical simulations of a phenomenon that is being measured for the range of all permissible parameters. The number of CFD calculations can be large nevertheless they can be performed in parallel with minimal human interaction. The amount of gained information from simulations allows to predict locations where the measurement uncertainty will be minimized. The proposed optimization methodology was verified by using virtual experiment data, which was created by adding random error to the results of simulation performed using the fine grid. Verification was performed for the flow around NACA 0012 profile and for the turbine cascade. The results confirmed the efficiency of the proposed methodology.
INVESTIGATION OF THE EFFECTS OF SLOTTED SOLID PROPELLANT’S SECTIONAL GEOMETRY ON STRUCTURAL STRENGTH AND INTERNAL BALLISTIC PERFORMANCE OF A ROCKET MOTOR

Ceyhun Tola, Melike Nikbay

Within the content of this study, relationship between the sectional geometric parameters of HTPB (Hydroxyl-terminated polybutadiene) based slotted solid rocket propellant on structural integrity and internal ballistic performance of a motor will be examined benefiting from response surface method. Structural strength of the system will be examined performing linear viscoelastic finite element analysis on Abaqus FEA (Finite Element Analysis) software environment under the assumption of plane strain. Finite element analysis results will be evaluated using deterministic approach. On the other hand, zero dimensional ballistic solver will be developed and used to determine the variation of chamber pressure, thrust with respect to time and to evaluate specific impulse of the rocket motor. As a result, two different response surfaces will be constructed to present graphical representations about the effects of sectional geometric parameters on solid propellant’s structural strength and internal ballistic performance.
EFFECT OF DESIGN PARAMETERS ON THE STRUCTURAL MASS OF A TELESCOPIC WING

Pedro D.R. Santos, Diogo Bento Sousa, Pedro Vieira Gamboa

Morphing has initially been applied to aircraft for control purposes and later to perform shape changes since it has been recognised that geometry and size changes can benefit aircraft’s aerodynamic performance and extend its flight envelope. However, morphing concepts typically present an undesired mass increase due to their inherent complexity both in the load carrying structure and in the systems that perform morphing. Simple yet sufficiently accurate mass prediction methods for designing morphing wings at the conceptual or preliminary design phases are seldom available or non-existent at all. The benefits that one morphing concept can offer over another or even over a fixed wing are thus quite difficult to assess without resorting to complicated and time consuming finite element structural models.

This paper addresses the effect of various wing design parameters on the structural mass of a telescopic wing concept previously developed. The parameters considered in this study are maximum wingspan, wing chord, span variation ratio, aircraft take-off weight and design load factor. The main goal of this work is to derive a multivariable function of the mass of such morphing wing concept. First, a minimum weight optimization problem with stiffness and strength constraints is implemented and solved for a large number of combinations of the above wing design parameters where the design variables are structural thicknesses. A parametric structural finite element model of the wing is built in APDL and solved in ANSYS. Second, a mass function is created by fitting a multivariable polynomial to the obtained data.
THE LOW POWER SINGLE ENGINE TURBOPROP AEROPLANE CLASS – THE FIRST LINK OF SMALL AIR TRANSPORT

Jerzy Bakunowicz

The flight training process of an civil airplane pilot candidate has been attached to the propeller piston engine driven aeroplanes. The smallest turboprop aircrafts available are still far above the piston, concerning engine power and performance, and operational costs as well. The transnational collaborative project ESPOSA (Efficient Systems and Propulsion for Small Aircraft) co-funded by European Commission focuses on the innovative application and integration of low-powered turbine engines with airframes of low performance SEP(L), MEP(L) class and helicopters. One of the vessels mentioned is I-31T single engine, low wing monoplane fourseater, derived from the airframe of I-23 Manager airplane. The work in a project covered the conversion of aircraft from piston propulsion to the turbine TP-100 engine, designed by PBS, Czech Republic.

The paper presents the analysis of introduction of single engine turbo-prop aeroplane class. Following the results of flight testing and additional performance and sizing calculations the new class was compared to the existing ones in terms of performance, flight loads, mass penalty, fuel economy and several other factors. Concerning small air transport initiative and commuter class, especially, the new class was tried to be placed as a starting point in commercial pilot career. The paper is summarised with remarks about required change of regulations and requirements for design process as well as for crew licensing.
SKIN-SIDE STATIONARY SHOULDER FRICTION STIR WELDING (SSFSW) OF DISSIMILAR T-JOINTS: CHALLENGES AND RESULTS

Alessandro Barbini, Pedro Emilio Gazola, Jan Carstensen, Jorge dos Santos

In this study welds of AA2024-T351 skin with AA7050-T7651 stringer from the outer shell side with SSFSW have been analyzed. This process would allow a reduction of aircrafts weight through the elimination of the rivets and the lower flange of the stringer.

SSFSW allows a superior surface finishing, without further machining or post-welding treatments. Thanks to this, not only a weld in the fillet zone, where the available space is limited, is possible but also on the outer side of the skin.

Difficulties have been faced in order to develop a robust system that warranties a high repeatability and quality of the joints. Initially it has been decided to focus on the problems related with the probe. High stresses were leading to short probe life and frequent maintenance. Through the reduction of assembly parts and the increase of the tool stiffness, a solution was found, making possible to achieve long welding distances, without tool failure or exchange. The coating of the shoulder has made possible to achieve higher surface finish quality and reduce the material adhesion on it. The clamping system development permitted fast and easy fastening process and perfect geometrical output of the joint.

Attention has been paid to possible industrial application, keeping the welding speed over a limit of 300mm/min. A parameter study has been made in order to maximize the strength of the joints in hoop-stress direction and for the pull-out of the stringer. In the end the results obtained has been compared with the one of riveted joints for similar testing condition.
The subject of proposed paper is a multidisciplinary optimization of joined-wing aircraft. In a result of the research an optimization algorithm of whole configuration of joined-wing with electric propulsion is proposed. The optimization process is a global search optimization suitable for preliminary design of joined-wing. Modular algorithm based on automatic geometry generator, FEM solver and aerodynamic panel method is developed. Whole process is optimized to decrease huge computation cost to the minimum.

The general optimization objective is to maximize the range of aircraft for assumed mission, as it is the major disadvantage of electric aircrafts. The payload and battery capacity are fixed. Global, local geometry and structural parameters are selected as a design variables.

Optimization is performed in serial manner – structure optimization is conducted inside aerodynamic optimization step. During structure optimization, strength is checked for few sizing load cases obtained from loads envelope. Only structural parameters are variable at this stage. In the aerodynamic loop objective function is optimized by changing only geometrical parameters.

For optimization purpose a meta-model of response surface is created and then used in next steps. Final optimization is conducted in two stage process. The first stage is the global one and it uses genetic algorithms. The second stage which is gradient based optimization is the local stage that improves first estimation of optimum.

Based on proposed algorithm a program was coded and some tests were done. Next, two optimization test cases for UAV and VLA inverted joined-wing aircrafts were performed. Based on results of prepared optimizations it was proven that proposed algorithm can be successfully used to improve the range of inverted joined wing aircraft.
Nowadays, the UAV field is experimenting a great expansion. Several efforts are being done by scientists and engineers to implement, in miniaturized hardware, low computational load and high performance navigation, guidance and control systems. In this context, images constitute a valuable information source, but the extraction of useful information from them is generally a very computationally expensive process. A deep study of the state-of-the-art techniques for pitch and roll angles estimation shows that the following three-step method is commonly used: (a) edge detection, (b) skyline detection using the Hough transform, (c) pitch and roll angles estimation. This paper presents an algorithm aimed to improve the speed and precision of the attitude estimation process. The method seeks the closer edge to the previous skyline. Once this first horizon point has been found, the algorithm searches for the closest vertical match in the next column. Based on such a roughly estimated horizon, the algorithm defines a search area around it and then applies a linear regression least squares method on the reduced set of points. The algorithm can be easily implemented with very a low computational load. The methods was tested by using images provided by a generic camera mounted on most UAVs, hence considering a real scenario, with noise and maneuvers. It has given promising results, being of interest not only for the aerospace industry but also for academia.
Technology is currently immersed in an era of continuous progress and expansion of navigation systems. These are evolving towards high performance systems, offering a precise, efficient and safe air navigation. In addition, the growing demand for Unmanned Aerial Vehicles (UAVs) increases even more the level of exigency on this activity. Therefore, in the context of the development of unmanned navigation technologies, the aim is to implement positioning systems that will allow high precision even in though environments.

Until now, air navigation systems have mainly relied on Global Navigation Satellite Systems (GNSS), in particular, on the worldwide spread Global Positioning System (GPS). However, the so called GNSS-denied environments open a new research line which pursues the development of alternative technologies which will cover this gap in positioning systems’ service. Among all of the different technologies aimed at giving a navigation solution in the absence of any kind of GNSS, this paper presents one based on the Signals of OPortunity (SoOP), particularly, it presents positioning systems based on Global System for Mobile Communications (GSM) signals. Hence, referencing the SIMLess concept, the system described in this paper, SIM-free and supported by open data bases, permits the positioning based on the information sniffed from the signals broadcast by a set of several nearby base station of the GSM network. It provides same and in some cases even better accuracies than the already developed techniques, not being necessary to synchronize the link between the mobile terminal and the Base Station Transceiver (BTS).
EXERGETIC GREENIZATION FOR BUSINESS AIRCRAFTS: METHODOLOGY AND A CASE STUDY

Ozlem Sahin, Onder Turan

To safeguard against today’s rapidly changing environment and improve profitability, successful airlines must choose an aircraft that minimizes risk and is adaptable to an ever-changing market environment. In addition, passengers demand comfort and service similar to that offered by major carriers. Minimization of the environmental effects of aircraft fuel emissions, conservation of the air transport fuel energy reserves, improvement of energy consumption reduction strategies for airliners, development of economical flight procedures in air traffic management, and achievements in more efficient air transportation in today’s aviation industry substantially depend on an accurate energy modelling for commercial aircrafts. In the present energy and exergy model (ENEX) of a Saab 340 aircraft at maximum power is broadly analyzed based on energetic and exergetic perspectives. Lack of energy and exergy analysis of business aircraft ENEX analysis makes the paper original and becomes main motivation for aircraft during typical flight.
COMBINED, MULTI-BODY AND FEM APPROACH, TO ASSESSING THE IMPACT OF LAUNCH OF RESCUE PARACHUTE IN CASE OF EMERGENCY LANDING GYROPLANE

Adam Dacko, Lukasz Lindstedt, Miroslaw Rodzewicz, Cezary Rzymkowski

The goal of the study was assessment of impact of launch of special rescue parachute system on mitigation of a gyroplane structural damage as well as pilot/passenger injury risk in emergency situations in numerous flight configurations. Both multi-body and FEM models were used.

The gyroplane Finite Element analysis (MSC.NASTRAN) covered both statics and buckling behavior, as well as the eigenvalue extraction. Special attention was given to transient dynamic response. Nonlinear transient analysis of “hard landing” allowed for estimation of dynamic characteristics of the landing gear components, resulting in strength analysis and stiffness estimation (input for Multibody analysis). Analysis of transient dynamic effects of sudden braking of the rotor before the main parachute deployment gave information on extent of possible blade damage. Dynamic effects of structural response of the fuselage to deployment of the main parachute were also analyzed.

Multibody analysis (MADYMO) covered both kinematic and dynamic global behavior of the structure (input to the FEM model). Special area of interest was pilot/passenger injury risk assessment for different flight and emergency landing scenarios. The MADYMO providing an advanced numerical model of FAA Hybrid III dummy, allows to calculate the loads affecting the human body (e.g. forces, accelerations and deformations in different body regions) as well as a number of injury criteria (for assessment of injury risk).
OPTIMISATION OF SMALL AIRCRAFT PARAMETERS IN THE INITIAL PHASE OF THE PROJECT

Andrzej Iwaniuk, Witold Wiśniowski

An elaboration of a future aircraft design concept has become increasingly complex due to changes of the basic criteria for evaluating emerging solutions. In the past, the basic performance characteristics of an airplane were the only selection criteria. Today, more and more emphasis is placed on factors such as impact on the environment, cost-effectiveness, or comfort of travel.

The paper presents a method to optimise parameters of a small aircraft for use in the initial phase of a project taking into account the requirements of aviation safety imposed by the European Union certification specifications CS-23 and a requirement of aircraft competitiveness within the total transport system.

Requirements and design assumptions were formulated based on the concept of the Small Air Transport system (SATs).

The method is based on the multidisciplinary design optimisation and covers the basic areas related to the design of aircraft: aerodynamics, aircraft structure, performance and expected operating costs. The objective function is defined as the value of the direct operating costs per 1 passenger-kilometre. Evolutionary algorithm was applied to solve the optimization problem.

As an example of the use of this method, optimisation of design parameters of the two classes of aircraft: Commuter 9-seater and 19-seater commuter was carried out. Optimisation results are compared with the parameters of aircraft in service.

Analysis of the sensitivity of the objective function with respect to selected parameters of the aircraft was also made which allow selecting the most important variables responsible for the operational costs.
High altitude cruise represents a crucial issue for small size low pressure turbines (LPT), commonly used in the propulsion of unmanned air vehicles (UAVs). The Reynolds number can drop below 25000, which in turn can lead to laminar boundary layer separation on the suction surface of the blades. This makes the turbine working in off-design conditions with very poor performances. Modifying the blade shape to counteract the boundary layer separation is not a feasible solution since the performance of the turbine will be adversely affected at the engine design conditions (take-off and landing). Therefore, the implementation of a boundary layer control system on the suction side of the turbine able to operate only at low Reynolds number is the most practical solution.

The present study investigates experimentally and numerically the potential of an alternate current (AC) driven Single Dielectric Barrier Discharge Plasma Actuator (AC-SDBDPA) to reattach the separated flow at a Reynolds number around 2·10⁴. The SDBDPA was designed and manufactured by means of lithographic technique, which ensured a thin metal deposition with high manufacturing reliability control.

The experimental approach comprised the actuator testing over a curved plate with a shape designed to reproduce the suction surface of a LPT. A closed loop wind tunnel was employed. The curved plate was mounted directly over the bottom wall of the test section. The AC-SDBDPA was placed in a grove made at the middle of the curved plate and located at the front side of the adverse pressure gradient region. Sinusoidal voltage excitation was tested. The flow measurements –with and without actuation– were carried out by laser Doppler velocimetry (LDV) and particle image velocimetry (PIV). Planar measurements were performed over the curved plate at the midspan plane. Simultaneously to the velocity measurements the applied voltage and the discharge current were acquired in order to determine the device dissipated power.

The experimental data was complemented with CFD simulations based on the finite volume method. The actuator effect was modelled as a time-constant body force calculated prior to the fluid flow simulation by using a dual potential algebraic model. Reynolds Averaged Navier Stokes (RANS) method was used to consider the turbulence effect. The validity of the numerical model allows to expand the study of the actuation effect including different locations and multiple devices, saving considerably experimental efforts.
BIOFUEL SUSTAINABILITY AND CERTIFICATION

Melanie Guittet

With the rapid growth and increased consumption of biofuels worldwide, and the multitude of policy decisions supporting this expansion, growing concerns about the biofuels sustainability have arisen. Therefore, the European project "ITAKA", aiming at supporting the development of aviation biofuels in an economically, socially, and environmentally sustainable manner has devoted considerable effort to take sustainability into account, in a quantitative and qualitative manner.

More precisely, in addition to wide ranging research aiming at optimizing and consolidating the biofuel sustainability along the whole value chain, a robust assessment of a lifecycle greenhouse gas (GHG) calculation for the produced bio jet fuel have been set up, using both the EU RED and RSB criteria and methodologies. This pathway includes feedstock production, feedstock processing, biofuel production, biofuel distillation, and all transport steps involved. These two certifications allow certifying the full value chain of the biofuel according to the RSB-EU RED Standard, taking into account other parameters than GHG emissions. At the same time, it highlights gaps and improvement areas in the RSB-EU RED Standard with the goal to strengthen it as an international standard for certification of bio jet sustainability for all pathways and feedstock.

This assessment has been made possible thanks to an online tool called RSB tool, which allows a very precise stepwise evaluation of the GHG emissions, thus allowing to perform a sensitivity analysis aimed at finding out about the range of possible optimization and the most sensitive steps.

In addition to these LCA measurements, both land use and indirect impacts of camelina oil production have been assessed in Spain and Romania. This analysis is not numerical in nature, but rather it is a qualitative assessment that focuses on the impacts of production practices and choices. In Spain, camelina is being introduced in cereal rotation schemes in arid and semi-arid regions. In arid regions and regions of low productivity, camelina is proving to be a hardy crop with potential to reduce the level of fallowing and increase overall productivity. In addition, camelina meal could result in a net reduction of animal feed imports, and overall have a net ILUC reducing effect. Additionally, the micro-level processes that lead to global-level ILUC through displacement dynamics depend on the specific context and should be assessed case-specifically. At a more macro-level, it is also possible to assess displacement and shifts in production, in retrospect (a posteriori). Such an assessment would need to determine whether the prior production of a feed or food crop in a region has been displaced by a growing production of camelina, and to what extent the displacement has been substituted by camelina by-products. In evaluating displacement, the historical (5 or 10 year) trend in previously existent production of food, feed and fiber should be assessed. In heavily contaminated land, camelina production can be said to have no ILUC risk if it does not displace prior production and if production of food, feed or fiber is not possible due to contamination concerns.
This paper discusses the problems of designing a fuel installation for the I-31 Turbo aircraft. The project was carried out under the European Union project entitled ESPOSA – "Efficient Systems and Propulsion for Small Aircraft".

I-31 Turbo has been created on the base frame of the I-23 "Manager" aircraft, through replacement of its original piston engine, the Lycoming O-360 A1A, with a TP-100 turboshaft engine. Moreover, the front of the plane, from the bulkhead 1, was altered, while the old navigation and piloting equipment was substituted with a modern "glass cockpit". These modifications required designing of a new fuel system within the engine chamber. The existing fuel system in the fuselage and wings was adapted for the new JET-A fuel.

In order to confirm whether the installation in the wings and the fuselage would provide the consumption rate required by the TP-100 engine (a tripling of the fuel flow and a ten-fold increase in kinematic viscosity of fuel), calculations and simulations had been carried out. The calculations were verified using the second I-23 aircraft, designated for ground tests. The ground tests studied the flow of the fuel from the auxiliary tank and were carried out under two different fuel temperatures (-20 and 20°C) and two different plane attitudes (0 and -10.70).

The project was documented in 3D in CATIA V5 program and in project documentation. To sum up, the main innovative element of the fuel system in the engine chamber is the module containing the pumps, filters, one-way valves, flowmeter, among others. This concentration of parts allows a significant reduction in plane servicing time in between flights.
ANALYSIS OF POTENTIAL WAKE VORTEX ENCOUNTERS AT A MAJOR EUROPEAN AIRPORT

Frank Holzäpfel

The long-lived counter-rotating vortex pair generated by any flying vehicle poses a potential risk to following or crossing aircraft. The highest risk to encounter these so-called aircraft wake vortices prevails in ground proximity, where the vortices cannot descend below the glide path but tend to rebound due to the interaction with the ground surface.

In this talk potential wake encounters in immediate ground proximity are analysed. The verified encounters were reported at runways 16 and 34 of Vienna International Airport during the years 2013 to 2015. The wake vortex prediction model P2P is used to investigate whether a wake vortex encounter is plausible or not. Meteorological conditions are documented by data measured by ultrasonic anemometers, a Sodar, and a wind profiler as well as by numerical weather prediction data. For the two potential encounters in the year 2015 also flight data recorder data were available such that a very detailed analysis of the incidents could be achieved. In both cases encounters appear very likely and the flight track through the wake vortices can be reconstructed in detail in good agreement with the wake vortex predictions. In three other incidents of the year 2014 at least the types of the leading and the following aircraft as well as the flight altitudes are known. For seven further incidents the aircraft types are known but the flight altitude has to be estimated. In the latter cases any conclusions appear highly speculative. In summary, wake vortex encounters appear probable or at least possible for eight of the twelve investigated incidents whereas in only four cases encounters can be excluded.

In six of the eight cases with probable encounters the meteorological situation is characterised by weak crosswinds combined with tailwinds. Weak crosswinds may compensate the self-induced lateral propagation of the upwind vortex, such that it may hover over the runway directly in the flight path of the following aircraft. During touchdown so-called end effects trigger instabilities propagating against flight direction. Further, in close ground proximity the interaction with the ground is very fast. However, tailwinds transport vortex segments generated at higher altitude towards the runway. So both effects usually contributing effectively to rapid vortex decay are attenuated by tailwinds. It is concluded that the combination of crosswinds below 1.5 m/s with tailwinds can be considered favourable for wake vortex encounters directly prior to touchdown.
CONTROL OF CONDUCTED EMISSIONS OF AN AERONAUTICAL CONVERTER FOR HVDC POWER DISTRIBUTION SYSTEM

Víctor Saborido Rodríguez, Carlos Guillermo Domínguez-Palacios Durán, Pablo González Vizuete, Joaquín Bernal Méndez, María Ángeles Martín Prats

Modern aircraft design is currently oriented toward the More Electrical Aircraft (MEA) concept. Under this trend, an electrical power distribution system based upon a high voltage direct current (HVDC) and high switching frequency scheme (with 270V or 540V power buses) has been proposed to increase power density and thus save weight. The implementation of a new HVDC power distribution systems makes it necessary to design a new generation of 270VDC/28VDC power converters to supply power to the avionic systems. These converters will have to meet stringent specifications in terms of weight and volume. Also they will have to comply with strict electromagnetic compatibility (EMC) requirements that are applicable to on-board equipment (RTCA/DO-160 norm). In this work we will present some EMC-oriented design strategies that affect the noise propagation inside the converter and that allow for lowering conducted noise emissions. We will focus in a particular architecture of a DC/DC power converter suitable for aeronautical application. We will present a theoretical justifications and simulation results to show that reduction of conducted noise emissions can be achieved by means of a proper selection and placement of components.
The paper focuses on the evaluation of a light aircraft spin. The main purpose was to achieve a highly reliable mathematical description of aircraft motion beyond stall conditions. The analysis was carried out for two light propeller-driven aircraft certified in compliance with Federal Aviation Regulations Part-23. Its first part is devoted to the verification of the simplified methods, which were used to identify the aircraft ability to recover from a spin and estimate the primary flight parameters. Then, the simulations of the fully developed spins were executed. The computational results were subsequently compared to in-flight data recordings. Additionally, the significant objective of the investigation was to verify if the aerodynamic characteristics determined numerically are coherent with the wind tunnel measurements. Further study confirms the coincidence between the calculated aircraft behaviour in a spin and the observed response of the aircraft within the course of flight tests. Furthermore, all the outcomes are in accordance with the requirements of the airworthiness standards. The findings include the summary of the conducted analysis. The mathematical models of aircraft motion have been found credible for the predictions of the spin properties. The numerically defined primary aerodynamic characteristics, focusing particularly on the range of high angles of attack, are very close to the data from the experiments performed on the scaled aircraft models. The simplified methods are reliable to determine the basic dynamic properties of light aircraft at the preliminary design stage, whereas the spin simulations allow for a comprehensive recognition of spin performance.
DEVELOPMENT OF THE HUMAN PERFORMANCE ENVELOPE CONCEPT FOR COCKPIT OPERATIONS

Ilenia Graziani, Bruno Berberian, Barry Kirwan, Patrick Le Blaye, Linda Napoletano, Laurence Rognin, Sara Silvagni

In this paper, we introduce a new approach based on the delimitation of the Human Performance Envelope (HPE) concept for cockpit operations. The metaphor underpinning the HPE concept suggests that, when studying performance degradation and recovery, we need to consider a range of interdependent factors (e.g., workload, fatigue, etc.) as a whole, instead of considering one/two single factors in isolation. If these factors, working alone or in combination, are studied borrowing the envelope metaphor, it can be possible to determine the starting point in which significant performance degradation could affect safety. Two steps are introduced: 1) a literature review about the HPE components affecting performance and their measures; 2) the identification of potential interactions between the HPE components through experimentations performed in May 2016, where we collected behavioural, psycho-physiological, performance-based and subjective data through real-time simulations. The triangulation of the measurements would allow us to determine:

• Points where human performance deteriorates.
• Behavioural and/or physiological markers, which are critical in signalling performance degradation.
• How to increase the envelope improving performance and safety.
• How to develop effective recovery measures through innovative HPE based solutions.

This paper will outline the new paradigm, and then propose how the HPE can be measured in pilot-in-the-loop simulations in high fidelity cockpit simulators with Air Traffic Control support. The most promising psycho-physiological, performance-based, and subjective measures that can be triangulated to characterize the HPE and the associated degradation and recovery points will be outlined, as well as an experimental paradigm for HPE measurement.
NEW APPROACHES IN CPACS-BASED PRELIMINARY DESIGN OF AIRCRAFT FUSELAGE STRUCTURES USING PYTHON

Jan-Niclas Walther, Michael Petsch, Dieter Kohlgrüber

Combining the expertise of many institutes, an increasingly sophisticated interdisciplinary aircraft design process is being developed at DLR, using the CPACS data format [1, 2] as a means of exchanging results. Within this process, TRAFUMO [3] (Transport Aircraft Fuselage Model), developed at the Institute of Structures and Design, is currently the established tool for automatic generation and subsequent sizing of global finite element fuselage models using ANSYS and the Python programming language.

Recent efforts to increase tool performance and to open up the modelling chain for a wider range of finite element solvers have led to a lot of functionality being shifted from specific routines in ANSYS to Python. This includes the automatic creation of global finite element models based on geometric and structural data from CPACS and the conversion of models between different codes. Taking advantage of the modular and object-oriented nature of Python, each new module has been implemented independently with a well-defined central data format in place for storing and exchanging information, thus laying the groundwork for a new all-Python model generation chain, which provides more flexibility at significantly improved runtimes.

In the presented paper, the overall structure of the newly developed model generation chain will be introduced. Additionally, the development status of several key modules, such as geometry processor, finite element generator and converter will be discussed in detail, with special attention paid to the interfaces between modules.
THE IMPACT OF HEFA FUEL BLEND RATIO ON GASEOUS EMISSIONS AND SMOKE NUMBER IN A SMALL GAS TURBINE

Simon Christie, Prem Lobo, David Raper

Sustainable HEFA biofuel have a different chemical composition to Jet A-1. Understanding how this shift in fuel composition might perturb engine emissions and the downstream consequences for air quality and climate change are therefore important. To date there has been no comprehensive mapping of the relation between fuel composition and the emissions from a gas turbine engine although some basic principles of understanding are beginning to emerge.

In this contribution, we report experimental emissions data from a fully instrumented small gas turbine (a Garratt auxiliary power unit) when powered by a sustainable HEFA biofuel derived from used cooking oil at a number of different blend ratios and referenced to a standard Jet A-1 fossil fuel. Fuel blend ratios in the range from 0% to 100% are considered at three standardised engine-operating conditions, and gaseous species NOx, CO, UHC, together with soot aerosol characterised in terms of smoke number and nvPM are reported. The concentration of gaseous exhaust species each show a small to nominal decrease with increasing blend ratio, whereas smoke number and nvPM show significant reductions of up to 90%. The large number of fuel blends studied (n=15) enable relatively modest trends in the data to be visualised and presented as statistically significant. The data are also discussed in relation to fuel flow that scales linearly with energy content in the blend.

In assessing the impact of fuel chemistry on emitted species, small-scale gas turbine tests are advantageous over full-scale rig tests in that comparatively modest quantity of fuel is required and tests are relatively low cost.
This work presents a knowledge-based definition of aircraft fuel systems, oriented to its use in the conceptual design and integrated into the RAPID design tool. Fuel systems appear early in the design process as they are involved in several first estimations. For instance, fuel weight is a significant part of take-off weight and decisive in aircraft sizing and range estimations. Therefore, including fuel systems earlier in the design process creates an opportunity to optimize it and obtain better solutions.
Landing gear weight calculations can be carried out using statistical or analytical methods. Statistical methods were used in the past and offered quick group weights, however, they are not capable of computing with accuracy the weight of unconventional landing gears which have special geometries and performances. In this work, landing gear weight is computed using analytical methods.

The procedure established by Kraus and Wille is acquired as a baseline so as to create a program able to deal with landing gear weight calculations. This program has been designed to be as much flexible as possible, giving the user the freedom to modify many options and parameters.
HIGHLY NON-LINEAR SENSING DEVICES IN STRUCTURAL HEALTH MONITORING OF AIRCRAFT

Helge Pfeiffer, Jurgen Perremans, Hans Sekler, Marc Schoonacker, Martine Wevers

Sensors in traditional non-destructive testing (NDT) are usually working in a quasi-linear mode. However, this raises a number of difficulties when these sensing principles are applied to structural health monitoring (SHM). Base-line variations and complex sensor data due to diverse interferences with complex aircraft structures are one of the main obstacles for a broad-scale implementation of SHM in aircraft. There were diverse solutions proposed to tackle these problems, such as advanced data processing and dedicated high-end hardware components. However, those excessive hardware requirements will in turn involve extra power supply and technologies for robust and extended data storage and processing. All these elements establish serious obstacles for a fast implementation of SHM in routine maintenance operations; not to forget the limited coverage inherent to some systems.

Besides the idea of focusing and limiting monitoring to selected hot-spots for avoiding large scale monitoring, an interesting alternative is offered by highly non-linear sensing devices. They are characterized by a sharp sensor response depending on an outer parameter that is related to a certain damage threshold. The highly non-linear behavior is in this way an ideal tool to filter out baseline variations and thus, the probability of detection is superior with respect to many other technologies. On the other hand, those sensor systems are known to measure very local. But this disadvantage can be tackled by for instance the use of “wire sensors” allowing defect localization over bigger distances.

In the literature, but also in operational practice, there are a number of highly non-linear sensing devices reported, such as the alarm wires in bleed air systems reporting overheat or crack gauges in fatigue testing.

The paper is intended as a review on the different sensing principles applied for structural fuses, and the underlying physical principles are in most cases electrical conductivity or optical transmission. Finally, we present a number of examples already implemented, such as the detection of corrosive liquids in aircraft (Boeing 737-500, Boeing 747-400) or the detection of leakage of hydraulic liquids or fuel.

Part of the research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n°212912.
In aeronautics, nowadays many innovations are pushed by the high demanding requirements of fuel savings and lower emissions. Major aircraft industries as Boeing, Lockheed Martin and Airbus are developing new solutions to reach these objectives. These solutions regard new fuel-efficient engines, new aerodynamics and new materials. A fiber-carbon structure weighs less than a traditional one, hence comporting a reduction of the aircraft weight and therefore of the fuel consumed.

New trends aim to lower the required mission fuel concern the aircraft on-board systems, too. Both in civil and in military field new technologies and system architectures have been introduced to reduce the fuel required to supply power to the users (i.e. secondary power) and/or to lower the entire mass of the airplanes. In particular, new trends are moving towards an “electrification” at various levels of the secondary power. Innovative solutions are characterized by the following features: suppression of the hydraulic system, removal of the pneumatic system, growth of electric voltages, “electrification” of actuators, anti-ice system and Environmental Control System. Various aircraft concepts could be designed adopting one or more combinations of the expressed features. Some of these solutions could bring benefits – as lower Maximum Take-Off Mass (MTOM) and reduced fuel consumption – others may be disadvantageous. The Boeing Company claims a fuel reduction of about 3% due to the innovative electric air-conditioning system installed aboard the brand new Boeing 787 (Sinnet, 2007). The compression of external air done by dedicated electrically-driven compressors, instead of the tapping of pressurized air from the engines entails a more efficient – and therefore a more fuel-effective – generation of secondary power. In the military sector, example of more electric aircraft are well represented by both the Lockheed Martin F-22 Raptor and F-35 Lightning II, due to the adoption of the primary electric voltage up to 270 V DC, comporting a weight reduction of electrical conductors and machines (Moir and Seabridge, 2008).

In the preliminary design of a new aircraft, great attention should be placed on the architecture selection and sizing of the on-board systems, due to their impacts – fuel consumption, weights, volumes, space constraints – on the overall airplane. Thus, it is mandatory to size the aircraft systems since the first phases of the airplane design. The European research project H2020 AGILE (AGILE “Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts”) is focusing on the set up of an innovative framework for the Multidisciplinary Design and Optimization (MDO) of conventional and future air-vehicles. The current paper exploits some of the results obtained by AGILE project with the aim of proposing an innovative workflow for the on-board systems design integrated within the overall aircraft design process.

The aim of this workflow is the automated selection of the best systems architecture designing an aircraft with the objective of minimizing the MTOM. A system architecture is characterized by one or more of the following features:

1. The actuators of the Flight Control System and the landing gear could be conventional hydraulic or electric (i.e. Electro-Mechanical Actuators EMAs and Electro-Hydrostatic Actuators EHAs).
(2) The anti-ice system could be aerothermal, i.e. protecting the wing leading edge and the engine cowl with hot pressurized air tapped from the turbofans, or electric, hence preventing the ice accretion by means of electric resistances.

(3) The Environmental Control System ECS could be conventional – hence cooling and expanding pressurized air bled from the engines – or innovative. In this case, the external air employed for cabin conditioning is pressurized by dedicated electric-driven compressors.

(4) The pneumatic system could be removed if both the anti-ice system and the ECS are electric. Thus, the engines should be electrically started, entailing more powerful electric starter-generators connected to the High Pressure shaft of the turbofans.

(5) The hydraulic system – if present – is typically characterized by oil pressurized at 3000 psi (~20.7 MPa). Innovative trends are moving towards an oil pressure increment up to 5000 psi (~34.5 MPa) causing a reduction in volumes and weights of the hydraulic generation and distribution systems.

(6) The electric system could be characterized by traditional 28 V DC and 115 V AC 400 Hz voltages or by the innovative higher voltages: 270 V DC and 235 V AC variable frequency. This increase may entails a global reduction in weight of the system.

The introduced workflow is arranged in NOESIS OPTIMUS, a process integration and design optimization environment that provides design engineers with a complete solution for system and product improvement. Optimus is based on a simulation workflow management system that captures and federates different design tools and automates their execution in a seamless and efficient way at different levels, depending on the multi-disciplinary assessment and optimization architectures selected for the product design process at hand. Once the workflow is created, design exploration and optimization algorithms can be applied out of the box to address the design challenges of reducing mass, and respecting the various aircraft configuration constraints. This multidisciplinary design optimization environment based on Optimus will be used in this context to perform MTOM minimization using machine learning based algorithms for adaptive space exploration, modeling and optimization.

The tool ASTRID (Chiesa et al.) has been integrated within the workflow. ASTRID is composed by two modules; the first one is aimed at the preliminary overall aircraft synthesis and design (i.e. weight estimation, aerodynamics, propulsion and flight mechanics). The second module is focused on the sizing of all the aircraft on-board systems, as avionics, Flight Control System, landing gear, air-conditioning, anti-ice system, fuel system and the power supply systems, i.e. pneumatic, hydraulic and electric systems.

The workflow implemented within Optimus is depicted in Fig. 1. The tool ASTRID is integrated through the Matlab Interface (see the block with the red borderline). The software receives the inputs from both an xml file (“cpacsInput.xml” block) and a Matlab script (Matlab Interface block with the blue borderline). In detail, the inputs downloaded from the xml file are generic of the entire aircraft – e.g. Top Level Aircraft Requirements, weights, dimensions, performances – while the data saved in the Matlab external file are specific for the systems design. Finally, the results obtained by ASTRID are stored in the file named “cpacsOutput.xml".
ADVANCED CONCURRENT DESIGN OF A COMPOSITE WING BOX
CONSIDERING MATERIAL SELECTION, MANUFACTURING PROCESS
PLANNING AND MODELING OPTIMIZATION OF THE COMPOSITE PANELS

Konstantinos Bacharoudis, Thomas Turner

Key challenges facing aircraft manufacturers are the need to reduce fuel consumption whilst continuing to meet increasing emissions regulations. These requirements are directly related to weight reduction of the aircraft structure. On the other hand, minimizing life cycle cost of the structure plays a very important role in the product development and is a driver for materials and process selection.

Introducing new materials such as novel composite materials and related manufacturing processes, while retaining a conventional design approach, i.e. the so-called ‘black metal’ approach, normally results in minimal or no benefit from the use of the new technologies. At the same time, it has been shown that incorrect decisions in the early stage of the design, introduces significant costs for redesign in later stages. A systematic approach to deal with these issues and optimize the structure in terms of weight and cost is to implement principles of concurrent engineering.

In the present work, a concurrent simulation approach was developed for the design of a composite wing box. The methodology aims to address design / process selection decisions at a very early stage in the wing box design (preliminary phase). It takes into account several candidate materials starting from the selection of carbon fibres and epoxy resins and critically, unites this with the fabrication planning of the laminated parts. Material selection strategies and manufacturing process trade off studies were performed and assessed in terms of cost enhancing commercial simulation process software e.g. WITNESS. This procedure was tied with the optimization procedure of the structural design of the composite laminate panels of the wing box section. One major advantage is that the proposed methodology permits to increase the resolution of the analysis as more and more information becomes available in latter stage of the design.
STREAMLINING CROSS-ORGANISATION PRODUCT DESIGN IN AERONAUTICS

Erik Baalbergen, Johan Kos, Clément Louriou, Cedric Campguilhem, James Barron

Aerospace development programmes generally involve collaboration in engineering between different organisations, in order to develop innovative products efficiently, to involve necessary skills from the supply chain and to spread risks and costs among the partners. The size and complexity of the programmes, the market demands and the contexts of competition all require the collaboration to be effective and efficient. Advances in IT provide many new capabilities to support collaborative design but a step change is needed to harness and coordinate this support to be effective and efficient.

Collaborative engineering activities and workflows span the partner organisations. Engineers wishing to cooperate smoothly are however facing security constraints. For example, fire walls and proxy servers hamper a seamless execution of collaborative workflows. The restrictions assist organisations in protecting their assets and in being compliant with legislation and regulations. From a programme technical point of view, effective and efficient collaboration in this world full of security and connectivity constraints is a major challenge.

In the paper, we outline the context of collaborative exchange in aerospace engineering between multi-disciplinary specialists, highlight the issues, explain the elements needed for an effective approach, and propose a solution that has been demonstrated in the EU FP7 project TOICA. The paper describes the technology that supports aircraft manufacturers and their supply chains in jointly performing analyses of innovative aircraft designs. The illustration of the technology is a multi-partner analysis and optimisation study of a pylon design subject to thermal constraints.
In laminated composite materials, the fatigue process involves several damage mechanisms that result in the stiffness degradation of the structure. One of the most important fatigue damage mechanism is interlaminar damage (delamination). In order to account for delaminations in the safety assessment of an aircraft, reliable computational tools are required to simulate the occurrence of static and fatigue driven delaminations, and to analyse their effect on the structural integrity. The development of such computational methods represents a scientific challenge. While several proposals to account for delamination under static loads have shown their efficiency in the analysis of different load cases, simulation tools for fatigue delamination are limited, and their predictive capabilities are still questionable. In this work, a load envelope cohesive zone model (CZM) based on previous work of the authors is presented. The quasi-static CZM used as a basis of the fatigue model has been modified, as well as the definition of the internal variables of the damage model and their evolution under fatigue loading. The model is implemented in ABAQUS as a user-interface (UINTER) subroutine. The fatigue model is validated comparing its predictions with experimental data obtained in test specimens cyclically loaded under pure mode I, mode II. In addition, the predicted fatigue response of a skin-stiffener composite structure loaded in tension is presented.
AN EXPERIMENTAL STUDY OF A PITCHING AND PLUNGING WING WITH A NACA64418 AIRFOIL

Dimitrios Yiasemides, Dimitrios Gkiolas, Demetri Mathioulakis

The aerodynamics performance of a 1m long rectangular wing with a NACA 64418 airfoil is examined in a subsonic wind tunnel, executing a plunging and pitching motion at a Reynolds number of 1 million (based on its 0.5m chord), Strouhal numbers (St) up to 0.03, where St=fc/U and angle of attack amplitudes up to 6o. The wing was made of aluminum blocks (see Fig.1) via a CNC machine, and at its midspan forty (40) pressure taps were opened in order to measure the pressure distribution along the chord using fast responding absolute pressure transducers (KULITE XCS-062 and MEGGITT 8515C-15). In order to increase their output signal, each transducer was connected to a custom made amplifier which was installed inside the wing (Fig.2). In order to perform a plunging motion, the wing was attached at its two ends to carriages which were oscillating perpendicular to the wind tunnel longitudinal axis with an amplitude of 50mm (10% of the wing chord length) via connecting rods and a motor of adjustable rotational speed. Concerning the wing pitching motion (about the spanwise axis of the wing) this was implemented by using a computer controlled motor (stepper motor) attached to one of the previous two carriages. The whole supporting system from which the wing was suspended was not mounted on the wind tunnel to avoid any vibrations transferred from the tunnel to the wing (see Fig.3). Besides pressure measurements, a commercial 2D PIV system (TSI, Inc.) was used to obtain details of the velocity field around the wing and its wake. In phase averaging was done by using a sensor attached to the moving carriage on which the stepper motor was mounted, and another sensor was attached to the metallic frame from which the wing was suspended. Thus, it was possible using the first sensor to take in phase measurements regarding the pitching motion of the wing when its trailing edge passed from a preselected point, while the second sensor was used when plunging motion was examined again when the oscillating carriage passed from a preselected location.

In Fig.4 there are shown some representative pressure coefficient versus x curves, where x is measured along the wing chord for a pitching case of f=1Hz, zero mean angle of attack and angle amplitude 4 degrees. Red line represents the phase averaged data, while the blue line the corresponding steady measurements.

Fig.1 The wing at the wind tunnel
Fig.2 Amplifiers installed inside the wing
Fig.3 A schematic of the wing moving mechanism
Fig.4 Experimental Cp distributions along x. Red line is the phase averaged and blue line is the steady case. Pitching frequency=1Hz, angle amplitude=4deg, mean angle =0 deg. At the top of each figure, the number shown is the geometric angle of attack.
OPTIMIZATION OF UNCONVENTIONAL AIRCRAFT CONFIGURATIONS UNDER UNCERTAINTY

Plamen Roglev

To meet the ever increasing demands confronting future aircraft new and unconventional configurations should be investigated. During the conceptual design phase of new aircraft designers have to evaluate a large number of different concepts, searching for the one that meets the requirements in the best way. The conceptual design tools need to provide rapid exploration of the whole design space and visualization of the dependencies. The application of mathematical modelling and optimization is a fundamental method in engineering of designs for which no or little historical data is available. At this stage the degree of uncertainty is high. It is present in the models, the interdisciplinary interfaces, the requirements, and the operating conditions. The classical conceptual aircraft design which incorporates statistically derived formulae implicitly accounts for the presence of uncertainty, but this approach is impossible for novel configurations. Often novel configurations prove to be superior to the classical ones only in very limited operating conditions or modes of utilization. So uncertainty has to be confronted by applying mathematical techniques to explicitly quantify it and optimize the systems in its presence. A number of probabilistic approaches are developed for the representation of parameter uncertainty. However this approach substantially increases the computational cost of the optimization process which prevents its wide application.

A methodology for robust multidisciplinary optimization aiming at the alleviation of this problem including screening of design parameters and novel mathematical approaches will be presented. As a demonstration it is applied to a conceptual design of box-wing UAV.
ASSESSMENT OF QUASI-STATIC AND FATIGUE PERFORMANCE OF UNI-
DIRECTIONALLY FIBRE REINFORCED POLYMERS ON THE BASIS OF
MATRIX EFFORT

Alexander Krimmer, Rico Leifheit, Andreas Bardenhagen

Today the assessment of the load carrying capacity of uni-directionally (UD) fibre reinforced polymers (FRP) is carried out on ply level. Extensive material testing is required to determine the strength properties of each fibre-polymer-combination. In addition these strength properties depend on the state variables of the ply such as temperature, humidity and fibre volume content (FVC) as well as the interaction with neighbouring layers. The latter is a function of the stress ratio during fatigue testing, which increases the testing effort even further. Commonly this behaviour is taken into account by utilising complex piecewise linear Goodman diagrams.

In this paper a new approach is presented to describe the damage onset of the matrix as a first step for an enhanced strength and fatigue assessment and prediction. Stresses on lamina level are translated into stresses on the constituent level meaning fibre and matrix. Hence, the focus lies on the matrix behaviour mainly driving damage and fatigue behaviour of UD FRP. With the ability to express stresses and strains on matrix level a simplified description of strength as well as fatigue behaviour can be achieved. Because the matrix usually is an isotropic material an equivalent stress approach is legitimate and a simple symmetric Goodman diagram can be applied. This allows the definition of a matrix effort as the ratio between ambient and allowable stress. Furthermore, the state variables mentioned above are inherently taken into account. Hence the load carrying capacity becomes a function of temperature, moisture, FVC and other influences. Finally a general description of the succeeding phases of the damage and fatigue process of the lamina is given.
One of the most important constraints within the design process of flexible aircraft is to avoid aeroelastic instability for all combination of speed and altitude encompassed by the flight envelope. This constraint affects the structural design as well as the aerodynamic design both impacting the calculated aircraft performance. It is therefore of significant importance to understand the aeroelastic behavior of the concept during all design phases and avoid major changes in the detailed design phase which bring along inherent costs. This holds both for the design of next generation aircraft concepts, for example strut-braced wings with increased wing’s slenderness, as well as new designed conventional aircraft components. The latter is often a major challenge for tier one and two suppliers that do not have the overview of the total aircraft system which is needed to understand the aeroelastic behavior. Their component optimization process affects the aeroelastic behavior of the entire aircraft system and is therefore critical when included in the overall design. This paper provides an overview of the work done at the Netherlands Aerospace Centre in various design phases of the aircraft going from conceptual design using methodologies for fast aeroelastic modelling to detailed design incorporating correction factors used from higher fidelity tools.
NUMERICAL EVALUATION OF SHEAR AND FLEXURAL PROPERTIES OF POROUS CFRP LAMINATES UTILIZING X-RAY CT DATA

Antonis Stamopoulos, Konstantinos Tserpes, Spiros Pantelakis

Pores are the most common defect in carbon fiber reinforced plastics (CFRPs). Experimental studies have shown that pores may significantly reduce the matrix-dominated properties of CFRP laminates such as the shear and flexural properties. In the present paper, the shear and flexural properties of porous CFRP unidirectional (UD) laminates containing pores of three different contents were evaluated using a multi-level numerical simulation methodology developed previously by the authors. The methodology exploits data extracted from X-ray computed tomography scans. The analysis of detected pores was performed using the VG Studio MAX software. The software parameters were validated by optical microscopy measurements. The progressive damage modeling method was applied in three simulation levels. In the first level, the behavior of the epoxy resin, in the presence of small pores, was simulated by means of a representative unit cell (RUC). In the second level, the behavior of the epoxy resin, in the presence of small and large pores, was simulated by means of a RUC comprising the epoxy resin, in which the behavior simulated from the first simulation level is assigned, and a single pore (MObject) in which all large pores are clustered. In the third simulation level, the short-beam shear and the 3-point bending specimens were modeled and loaded according to DIN EN ISO 14125 and ASTM D2344 standards, respectively. The elastic properties and strengths of the porous UD ply, were computed using analytical micromechanics relations. The numerical results, which correlate well with results from mechanical tests, show a considerable reduction of the short-beam strength, the flexural modulus and the flexural strength.
ANALYSIS METHOD FOR GUIDED WAVE PROPAGATION DIRECTION IN ANISOTROPIC STRUCTURES

Artur Szewieczek, Michael Sinapius

Guided waves such as Lamb waves enable a Structural Health Monitoring (SHM) of modern composite structures. However, due to complex wave propagation different scanning and imaging methods were developed in the past. They enable a better understanding of wave interaction with complex structures. Beyond video animations of wave propagation advanced analysis methods are possible.

A promising tool is the virtual design and optimization of sensors and sensor networks based on acquired measurements. In this technique, a piezoelectric transducer is used for guided wave excitation in a specimen. An air coupled ultrasonic sensor is moved over the specimen surface. For every scanning point the received signal is recorded. After this, a compensation of wave radiation through the air gap combined with a model of the investigated specimen is used to reconstruct its surface deformations. The deformations are applied on a numerical model of a virtual sensor which delivers the response signal. In this way an optimal dimensioning of sensors in number, position, form and material properties can be developed for SHM sensor networks.

Applications like this require knowledge of the propagation direction of every guided mode within a wave field. The actuator position cannot be used exclusively because mode conversions may occur on any position. This paper presents a method for propagation direction evaluation out of acquired measurement data. In combination with a mechanical model of the structure anisotropic propagation is utilized for accuracy improvement. Results are calculated in the time domain and contain a specific time window for any identified wave mode. The presented method can be used for advanced applications of guided wave analysis.
DESIGNING PRO-COMPOSITE TRUSS LAYOUT FOR LOAD-BEARING AIRCRAFT STRUCTURES

Alexander Shanygin, Evgeny Dubovikov, Victor Fomin, Ivan Mareskin

One of perspective directions of development of load-bearing aircraft structures is searching for pro-composite layouts, which allow using advantages of composite materials to a greater extent, and to save structure weight.

During the international cooperation of TsAGI with the European and Russian partners the pro-composite truss layout for airframes have been developed. The hybrid metal-composite rod elements are the basic load-bearing elements in such layout. Reinforcing fibers in these elements are directed close to their longitudinal axis as much as possible, i.e. along the main force flows. It allows using most effectively the characteristics of high strength fibers in composite structures.

The problems connected with joining of composite elements, were solved by use of metal tips in the rod elements structure. Modern winding and braiding technologies allow creating such structure elements with any design, sizes, parameters of stacking etc. Deep automation of existing technologies allows reducing essentially labor input and cost of manufacturing such structures in comparison with the technologies applied for manufacturing the aircraft structures with conventional layout.

In the given work the algorithm of sizing of the structure with proposed layout has been developed. The algorithm allows carrying out the strength analysis of the load-bearing elements in the automated mode. It is shown that the structure of hybrid rod elements, allows to create system of protection for the structure against impact and climatic influences. Results of weight analysis have shown advantage of proposed layout in comparison with conventional layout in application to the composite structure of caisson.
EXERGY-BASED SUSTAINABILITY ANALYSIS OF A TURBOJET ENGINE FOR SUBSONIC FLIGHT

Onder Turan, Hakan Aydin

In order to reduce the negative impacts created by the pollutant emissions, the energy sources for an aircraft should be efficiently utilized. If one wants to approach environmental considerations for air vehicles incorporated with sustainability and thermodynamics, there are two methods: energy analysis through the first-law of thermodynamics and exergy analysis through the second-law of thermodynamics. In this study, exergy-based sustainability indicators of a J57 turbojet engine for subsonic flight regime (i.e. military thrust power) are defined and calculated. For this aim, the exergy analysis for this running condition is firstly executed in order to derive the sustainability parameters. At this running condition, the engine produces 45.3 kN thrust. Moreover, the calculated exergetic sustainability parameters for the turbojet engine are exergy efficiency, waste exergy ratio, exergy destruction factor, recoverable exergy ratio, and environmental effect factor and exergetic sustainability index. It is expected that the use of these indicators based on exergy may be possible to assess the sustainability and environmental effect for gas turbines for air transportation and mechanical drive applications.
MECHANICAL BEHAVIOUR OF AZ31B MAGNESIUM ALLOY IN A DROOP NOSE MECHANISM

Luis Reis, Eduardo Aguiar, Jesus Pereira

Since the beginning of aviation, changing the shape of the structures inflight is seen as the ideal situation for increasing performance in an aircraft. Due to technological limitations, the use of these structures became difficult to implement. Recently, with the development of smart materials, new ways of actuations and the necessity of increasing the efficiency, morphing concepts have been researched, studied and manufactured, and like all new technologies, the future of morphing is not defined. Among several morphing structures, the smart leading edge (droop nose) is one of the most investigated devices.

Magnesium alloys belong to the category of the lightest structural material, and present great potential for aeronautical purpose: high specific strength, low density, good machining and recycling capabilities. It was widely used in the past, but due to corrosion problems its application was restricted. Nowadays, technologies provide magnesium with a similar level of protection of aluminum. This research focus on the mechanical behavior of the magnesium alloy AZ31B.

This article presents the design of a droop nose mechanism incorporating magnesium alloy AZ31B, the advantages and limitations that magnesium alloys brings to leading edge devices and the concepts of damage tolerance in aeronautics incorporating cutting edge results on biaxial fatigue issues.
DESIGN OF A TELESCOPIC WING MECHANISM USING A AZ31B MAGNESIUM ALLOY

Luis Reis, Jesus Pereira, Eduardo Aguiar

Morphing in the aeronautical field, is adopted to define ‘a set of technologies that increase a vehicle’s performance by manipulating certain characteristics to better match the vehicle state to the environment and task at hand. Morphing structures are desired for improvement of the aircraft performance, expand its flight envelope, ability to fly multiple types of missions, perform radically new maneuvers and reduction of drag and vibration. “The key to morphing aircraft; a truly smart structure”.

There are several challenges in the design of morphing aeronautical structures, the integrity of compliant structures must be ensured under all circumstances. The structure should be rigid enough to withstand the loads but flexible enough to morph and the skins must possess a high degree of deformability whilst maintaining the shape and structure integrity under all circumstances to withstand loads including compression, tension, and the shear and bending characteristics of aerodynamic loads.

The aim of this research is to analyze a previously selected telescopic mechanism and to explore and advance the concepts of damage tolerance in aeronautics incorporating cutting edge results on mix-mode loading issues. The material used in the mechanism is a magnesium alloy and the results will be compared against a standard aluminum used in aeronautical structures. The reduced weight, higher efficiency, decreasing of CO2 emissions and the possibility of recycling are the main reasons for the demand and consequently increase in magnesium production and investigation.
The ITAKA project is aimed to demonstrate the development of aviation biofuels in an economically, socially, and environmentally sustainable manner, improving the readiness of European technology and infrastructures.

ITAKA has performed research and demonstration activities along the biojet value chain from production to its final use by the airlines in commercial operations, using conventional airport infrastructures and also dedicated supply for testing flights.

At the feedstock side, progress has been made for camelina and UCO, which have improved their potential in Europe. At the refining phase, results show that we should still work in the ASTM procedures to adjust the parameters of the fuel to the real needs of the aircraft. At aircraft-fuel systems level, tests on engine, APU and flights have provided information about performance and emissions, delivering interesting potential benefits as the reduction of frequency of maintenance or the mitigation of local pollutants.

Particularly relevant, ITAKA has provided the first worldwide demonstration of comingled use of biojet fuel at an airport, providing key elements for the discussions about trading emissions and market based measures, other than demonstrating the drop-in characteristics of the biojet and generating public awareness about the use of biojet fuel at airports.

Interesting results have been gathered from the project about the technical, operational and performance challenges and opportunities of using alternative fuels. Also, some gaps have been identified, especially related with the market situation that should be discussed to continue promoting the use of alternative fuels.

As a result, ITAKA outputs can be used by the scientific community as a basis for further research and for strategic decision making about alternative fuels for aviation agendas.
ITAKA – DEMONSTRATION FLIGHTS WITH BIOFUEL ON A REGIONAL AIRCRAFT

Thiago Cestari

The ITAKA aims to demonstrate scale up production viability of the renewable bio jetfuel, evaluating economic, social, environmental and regulatory implications in a large-scale use in regular airline aviation. The renewable bio jetfuel produced by ITAKA used camelina as biomass. It was refined using HEFA (Hydroprocessed Esters and Fatty Acids) process and certified as per ASTM D7566. Embraer joined ITAKA to confirm that the use of renewable bio jetfuel is technically viable and foster the use of biofuels in regular airline aviation. An engineering performance assessment for aircraft engines and fuel system was performed, comparing the use of conventional jet fuel x renewable bio jetfuel. KLM Cityhopper airline was chosen as ITAKA’s associated partner to perform the renewable bio jetfuel Flight Campaign. The whole fleet of E190 was available for the campaign avoiding operational restrictions for the airline. A 200 MT of renewable biojetfuel, was made available at Oslo (Norway) airport solely dedicate to the E190 Flight Campaign. It was performed a total of 80 flights using the renewable bio jet fuel by KLM Cityhopper int he fixed flight route from OSL (Oslo, Norway) to AMS (Schiphol, Netherlands). The flight duration (OSL - AMS) was around 1h30min with the aircraft flying using a final renewable bio jetfuel blending between 20-30%. E190 aircraft and refueling data were collected during the entire Flight Campaign to substantiate the Engineering Performance Assessment done.
AN EVALUATION OF AIRCRAFT SEQUENCING WITH DIFFERENT CONSTRAINTS

Ozlem Sahin

Point Merge System (PMS) is an arrival route enables controller to collect, manage and sequence air traffic in safe, regular and fast. PMS referred to as performance based navigation due to based on area navigation (RNAV) route structure. In this study, PMS is constructed for converging runways at the busiest airport in Turkey. As it is known, PMS consists of a single merge point and sequencing legs. Mostly, inner leg level is preferred being higher than outer leg level. In this paper, while designing the procedure, the level constraints of inner and outer legs are changed inversely. Traffic scenario is created by using real radar traffic data and worked in the fast time environment. The aircraft approach sequences are analyzed. Finally, the results show a strong correlation between approach sequences applying same procedure with two different constraints.
The paper aims at analyzing the viability of a hybrid powertrain for a conventional single main rotor helicopter configuration. Hybrid powertrains have the advantage of allowing the thermal engine (usually a turboshaft gas turbine in rotorcraft applications) at their best efficiency, saving the excess power in a battery pack during flight phases that require less power, while relying on battery energy during (usually short) phases, when more power is required. As a further advantage, particularly relevant for single-engine rotorcraft, the battery pack should allow for a few minutes of endurance in case of engine failure. Instead of completing an autorotation descent with a critical engine-out landing, the residual energy in the batteries can be used for landing the rotorcraft by means of a more conventional (and inherently safer) powered landing sequence. These advantages need to be weighted against the increased weight and complexity of the resulting powertrain. The viability of the concept, which has been the objective of some patents, thus needs to be assessed by means of a careful analysis of both instantaneous power balance and overall energy balance over the entire mission. Such an analysis allows one to evaluate if weight penalties associated to the hybrid powertrain (the presence of a battery pack coupled with large electric generator and engine) are worth the advantages in terms of better overall efficiency and increased safety. The analysis is performed by means of a Matlab model of the proposed powertrain and a multi-objective optimization environment. Two different mission profiles are considered: a simple transport mission and a search-and-rescue mission profile. In the first simpler scenario, the helicopter is required to cover a given distance at cruise speed between the takeoff and the landing sites. In the second case, the helicopter is required to reach the operation area at high speed, perform operations assimilated to hovering at low altitude, and return to the base. The investigation is aimed at maximizing the electric endurance and minimizing overall fuel consumption, while keeping the volume of the powertrain as small as possible. An elementary model is adopted for estimating power absorbed by main and tail rotor and on-board systems during the mission. Then, a rule-based energy management strategy selects, at any time, the power to be delivered by the engine and the motor. Both machines are simulated with scalable models that calculate their efficiency as a function of working point and altitude (for the thermal engine). The electric power to/from the electric machine is used to calculate current supplied by or delivered to the battery and update its state of charge. The instantaneous specific fuel consumption of the engine is used to evaluate the residual fuel mass available on board and, consequently, the weight of the helicopter. The investigation is performed with state of the art technologies for batteries, engines and motors. However, technological trends for high-performance batteries will also be investigated, provided that energy density of lithium batteries is expected to increase from 200 Wh/kg to 1700 Wh/kg within next 10-20 years.
Aviation is solely responsible for the 3% of all the emissions of today’s industrial life. Electric propulsion options seem to be a key player in achieving better environment and sustainability. New powering concepts for more electric aircrafts are being developed, subjecting to developing better battery technologies, fuel cells and other types of engines and systems. Batteries are becoming more critical systems for electric propulsion in aviation. Batteries itself have energy consumption for their management requirements. It is shown that, in case a higher energy demand than the nominal capacity of the batteries are subjected, batteries tend to generate heat more likely. Therefore higher the energy capacity of the battery, the lower the thermal management as required against higher weight and cost of the batteries.

Battery capacity determination, depending on the aircraft electric loads, is very important under various parameters such as weight and cost of the batteries. On the other hand, capacity and thermal issues present a multi parameter optimization problem. This work discusses a parametric approach for battery energy capacity determination for aviation in order to determine an optimum capacity which does not need or requires minimum thermal management. An optimized capacity of the batteries with less energy required for management proposes more efficient and reliable energy storage with less cost and weight which at the end results in lower operating costs.
THE BEHAVIOURAL DIGITAL AIRCRAFT ENVIRONMENT

Jean-Claude Dunyach

The European project TOICA, launched in September 2013 and led by Airbus, intended to radically improve the way thermal studies are performed within aircraft design processes by simultaneously modelling and simulating in a collaborative environment the thermal behaviour of aircraft airframe systems, equipment and components. It created and managed an overall thermal aircraft architecture that provides an optimised thermal behaviour of the overall aircraft.

This thermal aircraft architecture was developed and exploited in a Behavioural Digital Aircraft (BDA) environment that is tailored to support the activities of the thermal architects and experts. It is shared in the extended enterprise with design partners and supports new advanced capabilities developed by the project, in particular:

• An Architect cockpit, to allow the architects and experts to monitor the thermal assessment of an aircraft and to perform trade-off studies
• Super integration to support a holistic view of the aircraft and to organise the design views and the related simulation cascade

This presentation will concentrate on the BDA general organisation and structure, with emphasis on the benefits.
The efficient management of thermal energy on board modern commercial aircraft has emerged as a priority for aircraft manufacturers and their supply chains in order to propose competitive solutions to new market demands whilst continuing to reduce development costs. This new priority, which requires the “thermal behaviour” to be managed from both a top overall aircraft level viewpoint and in detail down to a sub-component level, has become more complex due to the following inter-related challenges:

Modern aircraft use significantly more electrical systems in preference to hydraulic and pneumatic systems.

Increased use of composite materials in aircraft structures leading to new complex constraints for the design.

New requirements to improve passenger thermal comfort and to provide in-flight entertainment and power supply for passengers’ mobile devices.

Environmental European targets (reduction of fuel consumption, of CO2 and NOx emissions, of noise, etc.) becoming more challenging.

The key to addressing these thermal challenges lies in the ability to model and simulate the thermal behaviour of the whole aircraft including systems, equipment and components to the required level of detail and quality.

The TOICA project launched in September 2013 (32 partners, 26,5 M€ budget) is delivering an optimised thermal behaviour of the entire aircraft’s systems, equipment and components – managed through a Behavioural Digital Aircraft environment tailored to support the activities of the thermal architects and experts.

Six use cases illustrating the thermal strategies, jointly defined between architects and experts, demonstrate the benefits of the TOICA approach on two realistic aircraft configurations. Throughout the project, physical and virtual plateaus are organised with architects and experts for the definition, selection and evaluation of thermally optimised aircraft configurations.

The overall presentation of the project will be followed by technical presentations of the main TOICA results.
Composite materials are already being used in the mass production of structural components in automotive industry in particular at BMW Group. Adhesive bonding is basically the best technique for joining CFRP (carbon fiber reinforced plastics) light-weight structures. The conventional NDT (non destructive testing) methods being used today focus on the detection of material defects, e.g. debonding. In this case there is no information about the surface properties or bond quality. A new ENDT (extended non destructive testing) method is the BoNDTinspect system which is based on a patent held by the Fraunhofer IFAM. A ultrasonic atomizer nozzle create an water-aerosol, these small water droplets are sprayed onto the surface. Depending on the surface properties (surface energy or contamination state) the aerosol will form wide or narrow drops. We determined to test certain contaminations (for example release agent, oil, fingerprint), which are critical to ensure the performance of adhesively joined CFRP structures. The BoNDTinspect System is an inline-capable NDT technique, which is suitable to allow distinguishing surface states for adhesive bonding of CFRP. We verify this statement with destructive tests like the single lap shear test.
INVESTIGATION OF TENSILE FAILURE OF DEFECTIVE SINGLE WALLED CARBON NANOTUBES

Seyed Yousef Ahmadi-Brooghani

In this paper, a molecular mechanics based finite element method has been used for analysis of carbon nanotubes. In the finite element analysis, carbon atoms are considered as nodes and C-C bond between them are substituted with the beam element. A three dimensional beam element has been employed that follows nonlinear stress-strain curve based on Timoshenko beam theory. Ultimate stress, ultimate strain and fracture mechanism of the nanotubes have been investigated. Results show that Stone-Wales defect cause reduction in the ultimate stress and strain. The results of the present work show good agreement with experimental and theoretical methods.
TECHNICAL COMPATIBILITY, CERTIFICATION AND DEPLOYMENT OF ALTERNATIVE JET-FUELS

Alain Quignard

The aviation industry has set ambitious targets to reduce its environmental footprint, the reduction of greenhouse gas (GHG) emissions being the most crucial one.

As future technological and operational improvements, leading to higher fuel efficiencies, are likely to continue to be outpaced by the expected growth in air traffic, large-scale utilization of sustainable fuels will play a vital role to reduce GHG. A lot of routes are in development, mainly based on biomass, but not only, with the objective to produce jet-fuels in a sustainable and economically viable way. To date, the only industrially developed value chain depends on biogenic oils (triglycerides), used cooking oils and animal fats as feedstock, through the Hydroprocessing (HEFA) route. If the process is well demonstrated with several industrial units in operation in the world for biodiesel production, we are still at the very early commercial stage for biojet-fuel industrial production and use. This route is certified as HEFA-SPK.

There are also several pathways close to the industrial development and yet certified, such as the Biomass to Liquid (BtL) process (FT-SPK/ Fisher Tropsch Synthesized Paraffinic Kerosene), or routes using fermentation as a preliminary conversion of the biomass to alcohols or olefins, such as the SIP (Synthesized Iso-Paraffins from fermented sugar) pathway or the ATJ-SPK (Alcohol to Jet SPK from fermented iso-butanol) route, both yet certified too.

This presentation will review the numerous pathways yet certified or under certification, and will present recommendations issues from the European CORE-JetFuel project.
APPLICATION OF ELECTRIC SYSTEMS FOR FUTURE AIRCRAFT PROPULSION

Borys Mateusz Lukasik, Witold Wisniowski

Historical data shows that air traffic double every 15 years in terms of revenue passenger kilometer which rises many concerns about energy usage and environment. In response to that both Advisor Council for Aviation Research and Innovation in Europe (ACARE) and National Aeronautics and Space Administration (NASA) set up aviation develop strategies that demand, in the next 3 decades, to achieve a drastic reduction in vehicle energy consumption and emission as well as significant reduction of noise generated by the aircraft. To achieve these demands a big leap forward in aircraft propulsion technology needs to be done. It may be feasible thanks to the electric machines and a huge progress in this field which makes them more available for aviation. That is why Institute of Aviation in collaboration with The Ohio State University conduct research to evaluate the potential performance benefits of using full-electric, hybrid and turbo-electric systems. The purpose of this paper is to present some of the most promising ideas and already accomplished analysis of different kinds of architectures of electric devices conjugate with turbine engine.
In recent decades, flapping wing aerodynamics has attracted great interest, where numerous researchers have investigated the lift generation mechanism of flapping wings analytically, experimentally and numerically. Understanding the physics of biological flyers such as birds and insects can help improve the performance of micro air vehicles.

The present research focuses on the aerodynamics of insect-like flapping wing flight with the approach of numerical computation. Insect model of hawkmoth is adopted in the numerical study with rigid wing assumption currently. The numerical model integrates the computational fluid dynamics of the flow and active control of wing kinematics to achieve stable flight. The computation grid is a hybrid consisting of background Cartesian nodes and clouds of mesh-free grids around immersed boundaries. The SVD-GFD based computational fluid dynamics solver is adapted to study the dynamics of a free hovering flapping-wing flyer.

In present work, a PID controller with two levels governs the wing kinematics of the insect model: a stroke-plane kinematics mode based on rotation of the stroke-plane and an intra-stroke kinematics mode based on adjustments of intra-stroke parameters. The controller is adjusted to acquire desired manoeuvring of the insect flight.

The controllers are proven to be robust and effective at adjust the wing kinematics to stabilize the flyer and control the direction of normal hovering flight. The present modelling approach offers a promising route of investigation that could complement as well as overcome some of the limitations of experiments in the area of free flight aerodynamics of insects.
FINITE ELEMENT PREDICTION OF STRESS TRANSFER IN H-BN SHEET NANOCOMPOSITES

Konstantinos Spanos, Androniki Tsiamaki, Nikolaos Anifantis

In this study a micromechanical hybrid finite element approach is implemented in order to investigate the stress transfer behavior of composites reinforced with h-BN nanosheets. For the analysis of the problem three-dimensional a representative volume element, consisting of three phases, has been used. The reinforcement is modeled discretely using spring elements of specific stiffness while the matrix material is modeled as a continuum medium using solid finite elements. The third phase, the intermediate one, known as interface, has been simulated by appropriate stiffness variations which define a heterogeneous region affecting the stress transfer characteristics of the nanocomposite. The results show good agreement with corresponding ones from the literature and also the effect of a number of factors is indicated in stress transfer efficiency.
While aviation industry has set itself highly ambitious targets with respect to the sector’s greenhouse gas (GHG) emissions, the past, present and forecasted development of global air traffic demand suggests that fuel consumption of commercial aviation will continue to increase steeply, despite substantial improvements in fuel use efficiency. Therefore, the aviation sector considers large-scale utilization of renewable fuels, offering a reduced carbon footprint compared to conventional fossil jet fuel, as one of the main pillars of its strategy to reduce aviation’s GHG emissions [1].

As a consequence of the increasing interest in renewable jet fuel, the research and innovation (R&I) landscape has rapidly grown and diversified during the past years. Various technologies for the conversion of different types of renewable feedstock and energy are currently under development, at different levels of technical maturity. As one of the central tasks of the EU-funded coordination and support action (CSA) CORE-JetFuel [2], this increasingly diverse landscape of technologies and corresponding R&I activities has been mapped and evaluated. Emphasis has been placed on the assessment of the potential environmental benefit (in terms of GHG emissions reduction) associated with a certain production pathway in relation to its current technology readiness as well as to the cost of production.

Selected results, conclusions and recommendations yielded from this work are presented.
PIEZORESISTIVE PROPERTIES OF COMPOSITES FILLED BY CARBON NANO Tubes FOR HEALTH MONITORING OF AIRCRAFT STRUCTURAL PARTS

Patrizia Lamberti, Vincenzo Tucci, Giovanni Spinelli, Liberata Guadagno, Luigi Vertuccio, Salvatore Russo

In recent years polymer composites reinforced with carbon nanostructures, such as nanotubes, nanofibers, graphene platelets, etc., have received a great interest as potential smart materials, particularly in aeronautic applications. Among the different functionalities which can be obtained with carbon-based nanocomposites, a new application concerns the strain sensing for structural health monitoring (SHM). It is well known that in aeronautic components stress/strain sensors play a key role for real time monitoring of the structural integrity of delicate parts (i.e. fuselage, wings, cockpit) constantly threatened by multiple agents, such as temperature changes, impact by birds or hailstones, lightning strikes, etc. The remarkable characteristics of polymer nanocomposites allow to overcome the typical limitations affecting classical materials based on electroactive polymers or piezoelectric ceramics, such as fragility, weight and the need of high voltage or current necessary for their correct use.

This paper analyzes the piezoresistive behavior of nanocomposites, based on a thermosetting epoxy resin for structural aeronautic components reinforced with small amounts of multiwalled carbon nanotubes (MWCNTs, at 0.3 wt%). In particular, the mechanical and electrical properties are investigated for specimens subjected to cycles and different levels of strain applied both in axial tension and flexural mode. The piezoresistive behavior of the resulting nanocomposites evaluated in terms of variation of the electrical resistance is strongly affected by the applied mechanical stress, mainly due to the high sensitivity and consequent rearrangement of the electrical percolating network formed by MWCNTs in the composite matrix. In fact, the variations in electrical resistance that occur during the mechanical stress are correlated to the deformation exhibited by the nanocomposites. Therefore, the present study aims at investigating the possible use of embedded sensor systems in composite structures and assessing the capability of self-sensing which is a fundamental requirement especially for aircraft structural monitoring applications.
In recent years, the fiber reinforced polymer composite industry has grown exponentially in many areas such as automotive, aerospace, marine and construction. There are several types of composites, and their quality depends on the structural and chemical properties of the raw materials that are used, specifically the fiber reinforcement and polymer matrix, on the way how they interact with each other and their processing. Carbon fiber-reinforced composites are gaining importance and are about to play a very prominent role. In structural applications, mainly epoxy resins are used as matrix materials. The diglycidylether of bisphenol A (DGEBA) and tetragnaldehyde dianiline (TGMDA) are the most commonly used epoxy resin in aeronautic industry. In this field, the most representative example is the Boeing 787 Dreamliner, built with more than 50% of composites. More precisely, its fuselage and wings are made of composite. Unfortunately, the epoxy resin used in composites are susceptible to combustion, which affects structural integrity of composites laminates during and after exposure to fire; for this reason FAA certification for Boeing 787 required to demonstrate that the level of fire safety in the B-787 was equivalent to a conventional transport (aluminium) aircraft. This regulation has been extended to all other structural aeronautic materials.

In this paper fire properties of fiber reinforced composites based on both CNT filled and neat epoxy resins were studied. Some of the composites have been obtained via RTM process and others have been manufactured from laying up of carbon fibers prepregs tapes. Oxygen index at 23°C was determined and the cone calorimeter tests on specimens exposed to external flux of 50 kW/m2 were performed.

Flame spread properties of a composite constitutes of 16 plies carbon fiber unidirectional tape and epoxy resin filled with 1% CNT have been determined via IMO/LIFT or spread of flame apparatus which measures the lateral spread of flame along the surface of a material or product, vertically orientated, in response to radiative heat in the presence of a pilot flame. Quintiere and Harkleroad model, for flame spread under thermally thick assumption, has been used to obtain the thermal inertia of the material (Kpc), its ignition temperature (Tig) and a parameters related to the ignition temperature: critical flux for ignition (ϕ) and flame heating parameter (ϕp). These parameters are of fundamental importance to relate test data to theoretical models. The lower is the flame heating parameter and the higher are the thermal inertia and critical flux for ignition, the better are the fire properties of a material.
Vegetable Oils (VOs) in the EU by far represent the most used feedstock for transport biofuel production, namely FAME/biodiesel. In recent years, Hydroprocessing of Vegetable Oils to biobased hydrocarbons came to the scene, and a significant production capacity has been installed by Neste Oy and UOP/ENI (NExBTL and ECOFINING processes). These routes based on hydrotreatment not only produce high quality, diesel-like biofuels, but also bio-kerosene/aviation biofuels. Used Cooking Oil (UCO) offers high sustainability, according to the EU RED and ILUC Directive, even if the amount of residue potentially available in the EU is not estimated above 1 MTOE/y. In addition, the use of UCO as feedstock for biofuels production is not trivial in HVO reactors, as catalysts are sensitive to impurities and contaminations, which are typical of waste oils and the chemical composition of UCO is variable regionally as well as seasonally. Given this situation, catalytic pyrolysis is an interesting alternative route to the production of hydrocarbon fuels from lipids. The present paper reviews past works in the field, discussing catalysts used in R&D works, and describes the results obtained through catalytic conversion of UCO in a 1.5 l/h pilot pyrolysis unit available at RE-CORD and operated within the ITAKA project in 2014-2015. The characterisation of various batches of UCOs is also discussed. Pyrolysis oil was qualitatively and quantitatively characterized through GC-MS and GC-FID. The main product of the process is a bio-intermediate of very high quality, compared to the very pyrolysis and oxygenated pyrolysis oils that are obtained from lignocellulosic biomasses. Very promising mass yield, and considerable amounts of hydrocarbons, were obtained by the catalytic thermochemical conversion of UCO which have been developed: therefore, this route represent an interesting approach to decentralised conversion of lipids, including UCO, to transport fuels.
THE FUTURE OF PROPULSION TECHNOLOGY IN THE 21ST CENTURY

Mike Benzakein

The presentation will deal first with the needs of the customer, which are low fuel burn, low emissions, low cost, etc. This will be followed by an analysis of technology requirements and programs to address these needs. Technologies being developed in the US and Europe will be outlined emphasizing the gas turbine development, aircraft engine integration, electric propulsion, as well as alternate fuel. A path forward will be recommended.
FATIGUE BEHAVIOUR OF COLD SPRAYED AL ALLOYS

KLARA PETRACKOVA, MARIO GUAGLIANO, JAN KONDAS

Cold spray is a novel coating technique that is receiving a continuously increasing attention in many industrial fields.

Repairing is one of the most promising one: anyway, to enlarge the possible applications of cold spray not only to aesthetic repairs but also to functional and structural repairs, it is important the ability to maintain the original mechanical properties.

In this presentation fatigue is considered. The results of fatigue tests carried out on specimens made with an Al alloy are reported and critically discussed.
SMALL AIR TRANSPORT CHALLENGES

Krzysztof H. Piwek

The paper focuses on the Small Air Transport (SAT) challenges. The Future European Integrated Transport system should be based on an environmentally sustainable, cost efficient, seamless and co-modal passenger friendly system aiming at ensuring mobility and cohesion for the Europeans. The challenge is to create a new component of European transport by wider use of small aircraft using regional airports, to enable access to more communities in less time. This is in line of Flight Path 2050 challenge demanding that by 2050, 90% of the travellers are able to reach any location in Europe within four hours. The Small Air Transport (SAT) system must be optimized for short distances and for multiple, but narrow passenger flows. This paper will present goals, necessary research focused on aircraft family concept, future technologies, and next steps.
LOGISTICS CHALLENGES IN SEGREGATED AND NON-SEGREGATED FUELING SYSTEMS

Renco Beunis

One of the challenges within the further development of the bio jet fuel industry is to make use of existing jet fuel infrastructure. Until now, most bio jet fuel projects made use of segregated supply chains. This makes sense for supplying small volumes or when supplying to dedicated aircrafts, which could be an airline’s desire or in case specific research is to be performed. However, this is expensive and the preparations and operations are cumbersome.

An important step to take the bio jet fuel industry to the next level and allow for growth, is to have the distribution done efficiently via existing jet fuel infrastructure and make the supply at airports part of the airport’s common storage and distribution system. Internationally accepted standards and guidelines like ASTM, DefStan, JIG, EI, etc., all allow bio jet fuel in existing and commingled jet fuel infrastructure. This year, ITAKA has demonstrated the feasibility by systematically delivering bio jet fuel into Oslo Airport’s common storage, which was subsequently supplied to all aircrafts fueling via the hydrant system.

The next step is to also make use of existing infrastructure towards airports, for example to get access to large pipeline networks like CEPS (Central European Pipeline System), and to develop sustainable accounting methods.
PRELIMINARY DESIGN AND SIZING OF A CABIN ESCAPE SYSTEM FOR A SUBORBITAL VEHICLE AIMED AT PARABOLIC FLIGHTS

Roberta Fusaro, Nicole Viola, Marco Fioriti, Davide Ferretto

The commercialization of space transportation is a crucial topic in space domain but it is becoming very attractive also for aeronautical industries because they are trying to enter this competition proposing very high-speed (hypersonic) vehicles, frequently referred to as spaceplanes. In this context, suborbital flights are emerging for the interest of noticeable number of stakeholders due to the wide range of applications that makes them enviable for different perspectives. Indeed, they could offer touristic experiences (with an astronaut-like flight) as well as the possibility of carrying out scientific experiments in microgravity conditions.

However, this increasing demand is in clear contrast with the lack of well-defined international regulations. Only few national efforts could be observed, like for example the FAA initiatives about space transportation system in US (Sloan J., 2016), the UK proposals for spaceplane and related operations (Civil Aviation Authority, 2014) and the Italian initiative lead by ENAC (Italian National Airworthiness Agency) (ENAC, 2015).

The imbalance between market and regulation forces the designer developing solutions with an ever higher level of safety in order to maintain or increase the public consensus and, as direct consequence, to create more profits (i.e. to sell higher number of tickets for parabolic flights). In this context, several studies have been carried out in order to increase the safety level related to this kind of innovative transportation system. In particular, in accordance with the IAASS, the International Association for Advancement of Space Safety, the Risk of Loss of Life connected to these missions should have commercial aviation as target (1/106 flight hours), starting from a currently accepted value closer to Human Spaceflight Missions (1/102 flight hours).

In order to reach this target, it is necessary to envisage solutions aimed at increasing the safety level since the beginning of the design process. In particular, the authors are firmly convinced that additional redundancies do not represent the best way to reach the goal and thus, they propose to integrate a detachable cabin escape system. This high-level design choice deeply affects both the architecture of the vehicle and its systems and subsystems integration.

This paper starts from a previous work of the authors (Fusaro R., 2016a) in which the concept of an escape system was addressed and qualitatively assessed. In this article, the already proposed solution is considered from a quantitative perspective. In order to ease the understanding, a specific suborbital reference case has been selected and used as application (see Fig. 1) (Fusaro R., 2015, 2016b) (Viola N., 2015) but the paper aims at providing a general methodology to guide the designers through the design and sizing of a cabin escape system.

In detail, for each analyzed subsystem, mass, volume and power budgets are obtained and verified with the exploitation of CAD and simulation models. Particular attention is devoted to the definition of Environmental Control and Life Support system, pyrotechnic mechanisms required for the separation, descent and landing devices and guidance and navigation systems. Then, the on-board integration should be verified in terms of available volume and weight and balance.
Furthermore, considering the high level of complexity of the operations, the main results of mission simulations of nominal and contingency scenarios are reported and commented providing adequate feedbacks on the vehicle design and trajectory analysis.

Eventually, different cases of application for this safety system are envisaged.
THERMAL RESISTANCE OF TIALN COATINGS DEPOSITED VIA HIPIMS ON A GAMMA-TIAL ALLOY

Silvia Maria Deambrosis

γ-TiAl-based alloys are continuing to attract attention from the industry due to their exceptional combination of low weight and good mechanical properties. High specific strength and elastic modulus facilitate their use in a wide range of applications, such as turbine blades in aero-engines [1].

In order to use this class of materials at elevated temperatures, additional oxidation protection capability is required. Overlay coatings deposited by High Power Impulse Magnetron Sputtering (HiPIMS) [2, 3, 4] represent a possible solution.

HiPIMS is an emerging PVD technology, which produces an ultra-dense plasma leading to high-density coatings with enhanced adhesion [5] (especially for complex-shaped surfaces), [6] improved toughness, reduced columnar structure and deposition temperature [7].

For this work, three different Ti-Al-N films were deposited under the same process conditions but progressively changing film/substrate interface (i.e. a) surface polishing; b) surface polishing plus strong plasma etching, c) surface polishing plus weak plasma etching and TiAl metal interlayer deposition). Then they were cyclically heat treated using a burner rig facility and analyzed after 40 cycles at 850°C, 100 and 200 cycles at 950 C. Average residual stress, morphology, composition, microstructure, hardness, modulus, film/substrate adhesion and wear resistance were investigated before and after each burner rig test.


MULTIVARIABLE FLIGHT CONTROL SYSTEMS ROBUSTNESS EVALUATION THROUGH GAIN AND PHASE MARGINS

Eduardo Liceaga-Castro, Marco Polo Torres-Reyna, Ulises Alvarez

Robustness is the main aspect a flight control system has to guarantee in order to comply with flight safety regulations. In the case of flight control this task turns to be difficult to assess due to the fact that aircraft are dynamical multivariable processes. It is well known that robustness for single input single output (SISO) systems can be effectively established by the classical gain and phase margin concepts. Although there are nowadays several theories on multivariable control systems design an effective robustness assessment, equivalent to the phase and gain margins for SISO systems, is still not well known.

This article presents a constructive design procedure for multivariable flight control systems. These designs are based on the achievement of robustness which in this case is defined in terms of the classical phase and gain margins set in the multivariable context. It should be remarked that the flight control system design is treated as a multivariable task. That is, no simplifications are assumed in this sense.

The issue in the examples presented are the use of Bode and Nyquist plots for control design in the multivariable flight control setting. Such a framework is referred to as Individual Control Analysis and Design which in spite of being known has not received the attention of most control designers. The aim of this article is to show the design procedure of multivariable flight control systems using classical tools and to demonstrate its effectiveness.
INTEGRAL IMPROVEMENT OF MECHANICAL AND SURFACE PROPERTIES OF METALLIC MATERIALS OF INTEREST IN AEROSPACE APPLICATIONS BY LASER SHOCK PROCESSING

J.L. Ocaña, J.A. Porro, M. Díaz, L. Ruiz-de-Lara, D. Peral, I. Angulo, F. Cordovilla

Laser Shock Processing (LSP) is based on the application of a high intensity pulsed Laser beam on a metallic target forcing a sudden vaporization of its surface into a high temperature and density plasma that immediately develops inducing a shock wave propagating into the material.

LSP is demonstrating to be an effective technology for the improvement of surface and mechanical properties of metallic alloys and is an emerging technology in its way to production engineering in direct competence with other established technologies as, i.e. shot peening.

The effects induced by the LSP treatment on the mechanical properties of key target materials (concretely Al and Ti alloys of interest in aerospace applications) have been characterized. In particular, an analysis of induced residual stress fields together with its range of variability has been performed as a basis for the estimation of the practical protection degree against tensile load provided by the treatment. Additionally, the influence of the treatment on associated surface properties as wear and corrosion rate has been analysed.

The observation of these results clearly leads to the consideration of the LSP technique as really effective and controllable within wide limits for the induction of engineered residual stresses fields in critical components, a fact that has been widely demonstrated by the authors (see, i.e. references [1-2]).

As a final remark concerning the practical significance of the LSP technique, it is considered that the life cycle improvement achievable by the application of the treatment to specific high reliability components in different sectors as, primarily, aerospace, has an evident positive incidence on their long-term ecological balance, so that the technique has to be considered, additionally, as a sustainability-supporting one.

ACKNOWLEDGMENTS
Work partly supported by MICINN/MINECO (Spain; Projects MAT2012-37782 and MAT2015-63974-C4-2-R).

DESIGN ASPECTS OF CYCLE-INTEGRATED PARALLEL HYBRID POWER PLANTS

Patrick C. Vratny, Sascha Kaiser

Hybrid electric propulsion systems seem to be one possible approach to reduce in-flight fuel burn and thus CO2 of future transport aircraft to achieve ambitious emission reduction targets (set by Europe, North America). This paper focuses on a special variant of the parallel hybrid topology, the cycle-integrated parallel hybrid (CIPH), and which design aspects have to be considered when integrating and coupling a battery powered electric system with a gas turbine. In the classical parallel hybrid configuration, an electric motor assists the power shaft of a gas turbine. In case of the CIPH power plant, the electric power supplies one or several stages of a compressor, which are powered by a turbine in a conventional power plant. Initial studies have shown that as long as the electric power train offers a higher efficiency than the gas turbine driven by a chemical conversion process, an increase in overall propulsion system efficiency can be expected. The major drawback of such a configuration is that even with aggressive technology assumptions for the battery system, the additional (battery plus electric system) mass is significantly lowering the range of a hybrid aircraft. Nevertheless, the potential of in-flight fuel burn reduction of such a configuration of the order of 40% was already identified in a previous study at reduced range capability. Beside the in-flight emissions, the emissions during production of the used energy carriers have to be considered for an overall assessment of the hybrid propulsion potential. Therefore, this study will serve as baseline for the investigation of the CO2 reduction potential considering the entire production chain from fuel and electric energy.
POWER TRAIN OPTIONS FOR A PROPULSIVE FUSELAGE AIRCRAFT LAYOUT

Julian Bijewitz, Arne Seitz

The introduction of a more closely coupled propulsion-airframe integration has been recognized in various recent studies as a possible avenue towards significant enhancements in vehicular efficiency. As a particularly promising configurational candidate, the Propulsive Fuselage Concept (PFC), an aircraft layout featuring a fan encircling the aft part of the fuselage and serving the purpose of boundary layer ingestion and wake filling has been described in References [1-5]. In previous studies an arrangement with two underwing podded turbofan engines in conjunction with a fuselage fan has been identified as a most realistic concept implementation when it concerns technical feasibility and appropriate system redundancy aspects.

This presentation will discuss options for the fuselage fan power train. This includes arrangements where the fan is driven by a dedicated gas turbine. In addition to these mechanically driven solutions, an array of layouts featuring electrification of the power train will be outlined. Here, the fuselage fan is driven by an electric motor with power extracted from the underwing podded power plants. Such a turbo-electric configuration is expected to facilitate enhanced design freedom in the fuselage aft section, simplified aero-structural integration and hence a potentially even more beneficial energy balance of the overall aircraft in comparison to a mechanical power train option. The presentation will discuss the most promising solution for both the mechanically and a turbo-electrically retrofitted propulsive fuselage concept, and present corresponding aircraft level assessment results. Finally, the presentation will highlight future activities regarding the exploration of the PFC.

References:
QUALITY ASSURANCE CONCEPTS FOR ADHESIVE BONDING OF AIRCRAFT CARBON FIBRE REINFORCED PLASTIC (CFRP) STRUCTURES BY INNOVATIVE EXTENDED NON-DESTRUCTIVE TESTING (ENDT)

Kai Brune, Mareike Schlag, Bernd Mayer

Quality assurance concepts for adhesive bonding of aircraft composite structures are crucial in order to strengthen production and material testing processes in all stages of the life cycle of aircrafts. The development of innovative extended non-destructive testing (ENDT) can strongly contribute to enable an overall quality assurance concept for adhesive bonding like the detection of multiple contaminants, kissing bonds and bonds weakening. Fast and precise detection of surface contaminations and defects like kissing bonds in bondline can help to save time (up to 70% time savings by using ENDT) during production, maintenance, overhaul, repair, and retrofit. Within the on-going Horizon 2020 funded project Quality Assurance Concepts for Adhesive Bonding of Aircraft Composite Structures by Advanced NDT (ComBoNDT) activities regarding the development of extended non-destructive testing (ENDT) are performed.

ENDT techniques such as Optically Stimulated Electron Emission (OSEE) and Laser Induced Breakdown Spectroscopy (LIBS) are applied for the investigations of surface and bondline quality assurance. Carbon Fibre Reinforced Plastic (CFRP) test coupon samples were successfully produced considering a series of single contaminations characterizing typical manufacturing and repair scenarios. The ENDT techniques were explored, matured and optimized showing great capacity of detecting the presence of the single contaminants in both considered scenarios of manufacturing and repair.
THE EFFECTS OF PRE-BOND CONTAMINATION WITH DE-ICING FLUID ON THE MODE-I AND MODE-II FRACTURE TOUGHNESS OF COMPOSITE BONDED JOINTS

Elli Moutsompeka, Panagiota Polydoropoulou, Konstantinos I. Tserpes, Christian Tornow, Mareike Schlag, Kai Brune, Bernd Mayer, Spiros Pantelakis

Damaged CFRP aircraft parts may have been subjected during service to a range of hostile chemicals before being repaired by adhesively bonded patches. One chemical that could contaminate aircraft parts is the de-icing fluid used to maximize the runway friction during all plane movements at airports in winter. The scope of the present work is to experimentally investigate the effect of pre-bond contamination with de-icing fluid on integrity of CFRP bonded joints by conducting mode-I and mode-II fracture toughness tests on both reference and contaminated specimens.

The de-icer used was to contaminate the surface of one adherent was diluted with demineralized water to obtain solutions with the following concentrations in vol%: 2% (low level contamination, DI-1), 7% (medium level contamination, DI-2) and 10% de-icer (high level contamination, DI-3). Then, it was applied on the surfaces by dip coating and dried in the oven for 2h at 40°C. Afterwards, acclimatization at RT was allowed for at least 24h. The dip coating results were controlled by XPS measurements. Since the de-icer contains potassium formiate, the potassium content on the surface was taken as a measure for the degree of de-icer contamination. XPS-results showed mean values and standard deviations from two dip coated samples with three measuring positions each: DI-1: 6.4(±1.8) at% K, DI-2: 10.9(±2.3) at% K, DI-2: 12.0(±1.4) at% K.

The experimental results revealed a detrimental effect of de-icing fluid on the integrity of the joints. Specifically, for DI-1 a reduction of 30% and 56% is observed for $G_{IC}$ and $G_{IIC}$ respectively, with regard to the reference values (non-contaminated joints), for DI-2 the corresponding values are 37% and 62% and for DI-3 it is 56% and 83%. Regarding the fracture surfaces, it was observed that with increasing the contamination level the presence of light-fiber-tear failure mode increases, which indicates that the de-icing fluid has a deleterious impact on the composite material.
The permanent incorporation of sensors in composite structures is becoming a new trend in aeronautics, to facilitate strain monitoring and damage detection, often in conjunction to existing NDT methods. Except from classical electrical strain gauges and OFBG sensors, new magnetostrictive (i.e. coupled magnetic-mechanical) elements have been developed, to be attached on the external surface of composite structures, in order to monitor through-thickness strain/damage development. One of the main advantages of this methodology is the absence of connection or even contact of the sensing elements (magnetostrictive wires) to the measuring device. Using a single magnetic transducer, strain measurements are retrieved at any point of the concerned structure in a contact-free manner, thus facilitating inspection, especially in cases of monitoring of large areas. The proposed method could serve for fast – low cost components’ inspection at regular maintenance intervals, as well as for the improvement of aircraft certification procedures, providing part’s “strain signature” in a continuous manner (mapping), instead of spot measurements achieved today using strain gauges or OFBG sensors. Retrieved strain signature is subsequently compared against either previous readings or theoretical models, in order to trace potential differences and / or anomalies, indicating damage. In this paper, the latest developments of this novel strain sensing method are presented, together with results from its application on actual aeronautical structures.
DEVELOPMENT OF THE SYMMETRICAL LASER SHOCK TEST FOR THE WEAK BOND INSPECTION

Maxime Sagnard, Laurent Berthe, Romain Ecault, Fabienne Touchard, Michel Boustie

This study deals with the Laser Shock Adhesion Test (LASAT) and its use for the weak bond detection. This paper presents a new configuration called symmetrical laser impact. It consists in impacting the material target by two laser beams on its two free surfaces. The results of the preliminary tests conducted on the carbon fiber reinforced plastic (CFRP) samples are presented. After a quick explanation of the different Non Destructive Technics (NDT) used to assess the structural health of a sample, the first results on the LASAT in this configuration are analyzed. By playing with laser parameters (energy and delay between the two laser), the mechanical loading can be adjusted inside the material to test selected interfaces. A general outlook of the technology will be given, as well as the foreseen improvements of the LASAT process for bonded assemblies integrity assessment.
SURFACE QUALITY INSPECTION WITH THE AEROSOL WETTING TEST

Célian Cherrier

More and more carbon-fibre-reinforced plastics (CFRP) are being used in lightweight constructions. Before these components can be processed further by adhesive bonding or painting, laborious cleaning is necessary to remove residues of release agents or other contaminants, which otherwise would strongly decrease the stability of an adhesive bond. Often, surfaces are additionally treated (activated) after cleaning, in order to further increase the strength of an adhesive bond.

Here we present a system which determines the wettability of a surface by an aerosol wetting test. Originally patented by Fraunhofer IFAM, we put a strong focus on automated industrial testing applications during industrialization and product development. At this stage our system provides a reliable process for fast surface inspection of large components during the production process.

The surface condition is investigated through the nebulization of a very fine water mist. The contact angle of the water droplets with the surface depends on its bonding characteristics. The distribution of the droplets size along with other parameters is analyzed through image processing. The analysis is reference based and hence can be calibrated, with various “reference samples” in order to achieve a reliable “ready to bond” signal. This technique is not only limited to CFRP parts, however it can be applied to numerous materials and industrial applications – in consequence leading to an increase in product quality, process reliability and thus enhanced cost effectiveness.

In summary our work including the latest studies show an enhanced capability to detect local contaminations as well as global pre-treatment steps. The latest results even indicate a capability to differentiate activation/contamination levels and concentrations.
INFLUENCE OF REPAIR-RELATED MODIFICATION OF ADHESIVE BONDS ON ELECTROMECHANICAL IMPEDANCE CHARACTERISTICS

Paweł H. Malinowski, Wiesław M. Ostachowicz, Kai Brune

Numerous techniques of non-destructive testing (NDT) of structural parts of CFRP are investigated. In this research we focus on electromechanical impedance (EMI) technique. This is a technique often considered as NDT or Structural Health Monitoring (SHM) method. It is based on a piezoelectric sensor that is surface mounted to the inspected structure. The electrical quantities of the sensor are measured in wide frequency range. Due to direct and converse piezoelectric effects the electrical response of the sensor is related to mechanical response of the structure to which the sensors is bonded to. In the reported research adhesively bonded CFRP samples were investigated. Within the investigation properly bonded (referential) samples were consider together with samples with modified bond. The adhesive bonds were modified in order to simulate repair-related defects. Following modifications were considered: pre-bond thermal treatment, pre-bond contaminated with a de-icing fluid, and faulty curing of the adhesive. The electromechanical impedance spectra were investigated searching for anomalies and changes caused by modification of the adhesive bond. These spectra for different cases were compared with reference measurement results gathered from pristine samples. Numerical indexes for comparison of the EMI characteristics were proposed. The sensitivity of the EMI method to modified bonds was observed.
SOLVING THE TWO EVOLUTIONARY SHAPE OPTIMISATION PROBLEM OF A NATURAL LAMINAR AIRFOIL (NLA) AND SHOCK CONTROL BUMP (SCB) WITH GAME STRATEGIES

Zhili Tang, Yongbin Chen, Jacques Periaux

In order to improve the performances of a civil aircraft at transonic regimes, it is critical to develop new computational optimization methods reducing friction drag. At high Reynolds numbers, Laminar Flow Control technologies and Natural Laminar Flow airfoil/wing design remain efficient methods to reduce the turbulence skin friction. However, the existence of wide range of favorable pressure gradient on a laminar flow airfoil/wing surface leads to strong shock waves occurring at the neighborhood of the trailing edge of the airfoil/wing. Consequently, the reduction of the friction drag due to the extension of the laminarity surface of the airfoil is compensated with an increase of the shock wave induced drag.

In this study, the “Linear Stability Theory” (LST) method is used to predict the transition location on the airfoil at transonic flight conditions: \( M=0.729, \ AOA=2.31^\circ, \ Re=1.5\times10^7 \).

The laminar turbulent transition prediction module which consists of a boundary layer method with the well known eN based method for the Tollmien-Schlichting instabilities is coupled to a flow solver in order to predict automatically the transition location. The RAE2822 airfoil is the baseline airfoil shape. An Evolutionary Algorithm (EAs) hybridized with different games (cooperative Pareto game, competitive Nash game or hierarchical Stackelberg game) is implemented to optimize the airfoil shape with a larger laminar flow range and a weaker shock wave drag simultaneously due to a Shock Control Bump (SCB).

Numerical experiments demonstrate that each game coupled to the EAs optimizer can easily capture either a Pareto Front, a Nash Equilibrium or a Stackelberg solution of this two-objective shape optimization problem.

In order to solve simultaneously the Natural Laminar Airfoil (NLA) optimization with a coupled Shock Control Bump (SCB), the following two objective optimization problem is run with the numerical implementation of expression (1)

\[
\begin{align*}
\max_{X} & \quad J_1 = X_{t-p} + X_{t-w} \\
\max_{X} & \quad J_2 = C_{D}, \\
\max_{b} & \quad b : C_{x} \geq C_{x} \\
X & = A + B
\end{align*}
\]

Then, numerical solutions of the three games are analyzed with respect to the physics of the problem comparing drag reduction performances of airfoil trade offs between the delay of the profile’s transition location and the increased intensity of shock wave varying with the position and shape of a bump installed on the upper surface of the airfoil, computational efficiency of the three games solutions of the hybridized Game-EAs software versus their quality design. Numerical/physical behavior of the three games: analysis and synthesis of results from available numerical and physical data. From the analysis/synthesis of 2-D results it is concluded that a variety of laminar flow airfoils with greener aerodynamic performances can be significantly improved due to optimal SBC shape and position when compared to the baseline airfoil geometry. This methodology illustrate the potentiality of such an approach to solve the challenging optimisation of the Natural Laminar Flow of Natural Laminar Wings in industrial design environments.
MODELING OF TILTWING AIRCRAFT DYNAMICS AS LINEAR PARAMETER-VARYING SYSTEM

J. Holsten, P. Hartmann, D. Moormann

Institute of Flight System Dynamics, RWTH Aachen University, Deutschland

Aircraft in tiltwing configuration combine the advantages of helicopters, such as hovering and vertical take-off and landing capabilities, with the advantages of conventional fixed-wing air-craft. Such a system was successfully demonstrated during a three month DHL parcelcopter campaign in the Alps in winter 2015-2016. During transition of tiltwing aircraft between hovering and aerodynamic horizontal forward flight, tilting the wing from vertical to horizontal position (and vice versa) poses a significant change in configuration. In combination with the given large velocity range this influences the control device effectiveness significantly. At the same time, tilting the wing provides an additional control variable. These aspects result in significant complexity of tiltwing controller design. For controller design and analysis linearization of an aircraft as an LTI- Model allows direct analysis of its stability margins. Even for conventional aircraft the linearization depends on the operating point. Linear parameter- varying (LPV) systems describe the dynamics of the system as a function of time-varying parameters. In this study the dynamics of a tiltwing aircraft and corresponding controller are linearized at different operating points and described as LPV system. The zero-input dynamic over the complete flight envelope as well as the corresponding transfer functions with and without controller are derived and analyzed. The analytical models are validated against a 6- degree of freedom non-linear aircraft simulation.
A COMPARISON BETWEEN CZM AND VCCT METHODS IN PREDICTING MIXED-MODE I+II CRACK GROWTH IN COMPOSITE BONDED JOINTS WITH AND WITHOUT CRACK STOPPERS

I.S. Floros, K.I. Tserpes

In the present work, the Cracked Lap Shear (CLS) specimen consisting of two adhesively bonded composites plates of unequal length loaded to axial tension causing a mixed-mode I+II loading to bondline has been simulated and experimentally validated. In addition, the mechanical performance of a hybrid bonded/bolted joint has been simulated by adding a titanium lockbolt with diameter of 4.8 mm. The composite adherents were made from a Hexply IM7/8552 UD prepreg with a stacking sequence of [3x0/45/90/-45]s. The 3 mm thick adherents were bonded using mixed adhesive consisting of EA9395 and EA9396 adhesive. CLS specimen has been modeled using a Cohesive Zone Model and Virtual Crack Closure Technique implemented by means of a FE model developed in the LS-DYNA and the ANSYS FE code, respectively. In case of bonded/bolted model, contact between the composites plates and the lockbolt has been considered. These two approaches were compared regarding their constitutional laws and their capability to simulate the sudden debonding growth that is shown during experiments. The numerical results show that CZM is not capable to simulate the sudden debonding growth rate. On the other hand, VCCT approach shows better correlation with the experiments, concerning the load-displacement curve and the debonding growth. Furthermore, the bonded/bolted geometry, exhibits significant crack growth retardation, comparing to bonded geometry.
The use of adhesive bonding is not allowed for joining primary structures, according to the international Advisory Circular AC-20-107B. The main reason prohibiting the use of adhesive bonding is that with the present state of the art it is not possible to fulfil one of the three Means Of Compliance (MOC):

1. The maximum disbond of each bonded joint consistent with the capability to withstand the required loads must be determined by analysis, tests or both. Disbonds of each bonded joint greater than this must be prevented by design features.
2. Proof testing of each joint to the limit design load.
3. Non-destructive inspection of the bond area to ensure the strength of the bond.

BOPACS concentrates on the first MOC by developing design features (DSF’s) to be integrated into the bonded joint with crack stopping properties.

At project start a number of features were generated divided in four groups. The crack stopping performance of the different DSF’s was evaluated by performing tests on a standard Crack Lap Shear (CLS) test sample. The most promising DSF’s were tested in more realistic low loaded and high loaded configurations by performing tests on a Bombardier CRJ 700 aileron with DSF’s positioned in the skin-spar adhesive bonded joint (low-load configuration) and a large lap shear specimen representing a longitudinal fuselage joint (high load configuration).

The BOPACS scientific partners supported the test program by simulating and analysing the different adhesive bonded joint configurations. A fatigue model was developed to simulate the crack propagation in a bonded joint with integrated DSF’s.
Nowadays Aero engines design seems to be more complex project than it used to be over last decades. Complexity of engine’s design can be considered in two aspects: technical and organizational. Technical challenges during aero engines design were known since very beginning as those engineering team needs to deal with. They evolved over the time together with engine design development but were always considered during the process. Today those problems may be bypass ratio, high pressure, high temperature, pollution and noise emissions but also technical solutions’ impact on durability, reliability and maintenance. Organizational aspect however, is not so clear and obvious to determine. The importance of this issue depends on the scale of the project, source of fund or political influences. There is also mid-position aspect connecting technical and organizational once – technological readiness of the organization planning new project.

It is key to consider these challenges, evaluate them and include in risk management plan at the early stage of the design program to ensure that organization will get the final result: operational aero engine that can compete the market.
This paper presents design approach for large passenger aircraft nacelles. It describes nacelle functions, configurations, and major components. Design criteria for particular components of nacelle are presented. Typical materials used for structure build including composites are elaborated. Certification requirements are shown. The paper presents challenges for nacelle design and build, including weight, aerodynamic smoothness, nacelle integration, and cost.
Appropriate engine exploitation is the most important for its reliable performances and thus high level of the flight safety. It concerns particularly airplanes powered by a single engine where each failure can cause a serious event. Aviation events are reported and collected in the ECCAIRS (European Coordination Centre for Aviation Incident Reporting Systems) database. Almost 50% of aviation occurrences in Poland contained in this database and caused by powerplants installed on aircraft powered by single engine can be assigned to the piston engine itself. Engine oil system faults have a significant impact on flight safety. It needs to be mentioned that in 23 cases of the oil system malfunctions in the years 2008 – 2015, 16 of them resulted in aborted flights or emergency landings. Presently in many countries aviation safety regulations are allowing exploitation of piston engines above recommended by manufacturers TBO (Time Between Overhaul). Upon fulfilment of certain requirements TBO extension is granted. NAA’s (National Aviation Authority) have approved exploitation of piston engines to something like quasi on-condition maintenance, but without new technical requirements above already included in the manufacturers documentation. The above descriptions presented lead to the formulation of the thesis that aircraft piston engines TBO extension require changes in the current exploitation system. Present simply way of the engine’s life extension is not the best solution for maintaining flight safety at the required level. The article provides proposal for some new tasks to the exploitation requirements of the aviation piston engines.
Nano- and micro-structured materials such as fiber enforced composites, porous barrier thin films, or crack stop structures in complex microelectronic integrated circuits are widely introduced in state-of-the-art high performance material systems also found in aeronautic and air transport applications. Of huge interest in these materials is the correlation between mechanical behavior, e.g. fracture evolution, elastic modulus, or crack path development, and material topology. With a better understanding of these structure-property relations, new and vastly improved materials can be developed to enable new applications and push the performance and reliability limits of existing systems.

In this study, applications of different in-situ mechanical testing devices in the beam path of lab based high resolution X-ray CT systems with resolutions in the micro- and nanometer-scale are presented. E.g., the crack path introduced by a micro-hardness indentation in a fiber enforced composite is imaged in-situ in an X-ray CT microscope. Another application is the correlation of micro-XCT data of the porous structure of a thin barrier coating with its mechanical properties in different scales, coming from the nano-scale matrix material properties to the macro-scale properties of the porous film. In-situ X-ray microscope fracture experiments using a miniaturized double cantilever beam geometry are also shown. These experiments are used to study the fracture behavior of nano-structured materials such as complex crack stop structures found e.g. in modern micro- and nano-electronic systems.
For the purpose of the BOPACS program; Bombardier will modify and test a current production aileron in order to determine the behaviour and prove the strength of the bonded structure with the introduction of damage and damage-stopping features.

The test article will include varying lengths of disbonded regions at bonded upper skin to spar interface regions – this is to simulate both delamination associated with manufacturing damage and BVID impacts.

Cyclic loading will be applied during the damage tolerance phase of testing. An equivalent constant amplitude reversed loading spectrum will be applied which can be equated to the aileron actual in-service spectrum. Load levels will be increased and damage growth measured using instrumentation located close to the disbonds. Data will be gathered which measures damage propagation under known loading conditions. Detrimental uncontrolled damage growth may be fastened to arrest during test. Strain gauges will be placed throughout the structure to monitor loading and to be used for FEM validation. Strain gauges will also be placed at damage locations in order to collect data on damage propagation.

Inspection techniques will be used to determine if damage can be reliably detected. Strain gauge readings around damage will be monitored in order to show damage growth. As damage propagates into the damage stopping features, strain gauges around damage stopping features will be monitored in order to show damage arrest or slowdown of damage growth. Strain validation gauges will be checked against Test FEM in order to validate the FEM. Disbond lengths in excess of allowable damage limits have been included to demonstrate the large damage capability of the bonded structure.
FATIGUE BEHAVIOUR AND DAMAGE TOLERANT DESIGN OF COMPOSITE BONDED JOINTS FOR AEROSPACE APPLICATION

T. Kruse, T. Körwien, R. Ruzek

Today the application of bonding technology for primary aerospace structures is limited due to the certification guidelines and standard means of comply. State of the art is the widely used chicken rivet which is limiting the benefits of the application of composite bonded joints due to thickness requirements for the bolt. This paper will give an overview of the current research conducted within the European project BOPACS. The project is focussing directly on the application of Means of Compliance within AC-20-107B by investigating crack arrest by design features. Derived from the conclusion of the Cracked Lap Shear (CLS) Coupon, the Wide Single Lap Shear (WSLS) Specimen has been developed. It marks the next level test setup beyond the basic coupon level for demonstration and investigation of crack growth behavior in bonded joints. This specimen is representing the generic geometrical condition of a high load transfer (HLT) joint, representing e.g. a fuselage panel joint. The basic layout of the specimen and first results of the current test program as well as the specifics for the test setup and data acquisition strategy is discussed. Results from the running test program are presented and the influence of individual test parameters highlighted. Finally, the influence on a certification strategy for structural bonding is outlined.
THE CIVIL USE OF SMALL UNMANNED AERIAL SYSTEMS (SUAS): LEGAL AND SAFETY CHALLENGES

Laura Novaro Mascarello, Fulvia Quagliotti

In the last decades, applications of small Unmanned Aerial Systems (sUAS) are rising both for civil and military applications. The sUAS guarantee the performance of Dangerous, Dull, Duly and Dirty missions, according to the 4D rule. At the same time, some ethical, operational and safety challenges occur, due to the use of sUAS over crowded areas or in emergency scenarios.

The unmanned vehicles are nowadays applied for different kind of applications. Search and rescue (S&R) missions, the surveillance and the monitoring of the terrain, like after natural disasters, such as earthquakes and landslides, the transport of medical equipment and cartography are only some examples of the most renowned and important civil missions of a sUAS.

In all these scenarios, some challenges could happen. First of all, the use of sUAS could compromise the privacy of unaware citizens that are in the area of application. Moreover, even if the unmanned vehicle works according to the national and international regulations, there are some hazards both for the ground operators and for the population, because the sUAS could hit the human body after a failure in flight.

In this paper, an overview of the Italian and European regulations will be presented. Moreover, some strategic configuration elements will be analyzed to improve them to define safe and inoffensive the sUAS.
ADVANCED METHODS OF ECONOMY SUPPLIES AND WASTE MANAGEMENT IN ENGINEERING

Maciej Moszumański

The Department of Advanced Technology and Construction CERMET TECHNOLOGY has developed a databank for innovative technologies of economy supplies: technology, components and their solid, liquid and gaseous wastes. For the implementation of new technologies the assembly of unique devices namely evaporators, crystallizers, dryers, furnaces and briquetting presses were designed and built. Experimental prototypes of these devices were tested under laboratory conditions. The methodology of design and experimentation was based on modern simulation programs and computer aid. Following the construction adjustments caused by the test results, a complete waste treatment seating was submitted for use in the aerospace industry.
The aim of the study was to obtain new knowledge about the influence of the operating parameters of the prototype of the universal furnace PK-1200/1600 built in the CRACOW UNIVERSITY OF TECHNOLOGY on the course of the essential process phases of the sintering sliding and tool materials in controlled atmosphere. For the tests conducted in the furnace PK-1200 two characteristic slide shapes were selected: a slim sleeve bearing and flabby stopper ring, whereas tests carried out in the furnace PK-1600 using two tool shapes: the bolt heads trimming die and the nuts segment die. The temperature time-courses were determined during the process of heating of the furancePK-1600 in nitrogen atmosphere: the chamber, the pallet, the ballast and the charge of the slide shapes and during the process of charge cooling with a variable water flow during free cooling. Then the temperature time-courses were determined during heating of the furnace PK-1600 in three states /as before/ and tool shapes charge in low vacuum as well as charge cooling with a variable air flow and also during free cooling.
Airbus were part of the ITAKA consortium investigating sustainable kerosene for aviation. In recent years many new fuel pathways have become available and a number of new fuels have been proposed for approval under ASTM D7566 and ASTM D1655. Much of the analysis for these approvals is done theoretically using the results of laboratory tests. The ITAKA project would take this a stage further and demonstrate the suitability of a sustainable alternative to petroleum based kerosene. This was to have been done in two stages; demonstration flights and laboratory testing using a 50% blend of MCA HEFA with Jet A-1 and secondly using a similar blended HEFA sourced from Camelina. This presentation will focus on the demonstration flights by KLM using an Airbus A330-200 in late 2014/early 2015 running on a 50% blend of MCA HEFA & Jet A-1 in one of the two engines. The direct comparison with pure Jet A-1 will be made by looking at data for the two engines/wings. The effect of the sustainable fuel on gauging properties and accuracy together with engine burn rates and exhaust gas temperatures will be considered. Unfortunately the second phase of the testing had to be scaled down due to insufficient Camelina feedstock being available to fuel the large aircraft. The tests continued using Embraer regional aircraft and they will present their findings.
Design for X (DfX) approaches are of great importance to support sustainable development of new products, since the goal of DfX practises is to improve, for instance, life-cycle cost, life-cycle environmental performance, increased design flexibility and increase efficiency among others. Therefore DfX supports the decision-making process whenever a new complex product is being developed. In this work a new holistic “Lean Design-for-X” approach is presented embracing the principles of Lean Product Development and Modular Design, enabling a straightforward and systematic applicability by design engineers. A new DfX index metric, ranging between 0-100 %, is proposed, assessing both the effectiveness and efficiency for each X Domain and design variable, for consistent and clear decision support in the comparison of different design concepts and/or products. Moreover, a new composed scorecard is presented applying visual management principles for fast assessment of results. A practical example is given in a real design study of a complex system engineering project. The results allowed to validate the new Lean Design-for-X approach, applying different “X” domains (Design-for-Structural Optimization, Design-for-Maintenance, etc.) and a modular design analysis, by the use of the Design Structure Matrix (DSM) methodology.
DESIGN-FOR-X INNOVATIVE APPROACH AS A DECISION SUPPORT TOOL FOR THE CREATION OF SCALED MODELS

C.P. Coutinhoa, A.J. Baptistaa, J. Dias Rodrigues

Design-for-X (DfX) methodologies have been established as important support tools for the development of complex products or systems. DfX allows a structured and systematic design process integrating different “X” domains (e.g. Design-for-Manufacturing, Design-for-Assembly, Design-for-Sustainability, etc), enabling the comparison of concepts, products and solutions, these methodologies provide support for the decision-making through the design process.

In other design perspective, the reduced-scale model testing is an important design tool, particularly when the targeted equipment/system can’t be tested or the costs involved become unreasonable. Indeed, testing of sub-scale models continues to be nowadays a valuable design tool, helping engineers to accurately predict the behaviour of oversized prototypes through scaling laws applied to the obtained experimental results, namely in aeronautics / aerospace. These scaling laws are based on similitude theory: a branch of engineering science concerned with establishing the necessary and sufficient conditions of similarity among phenomena, and has been applied to different fields such as structural engineering, vibration and impact problems.

The objective of this work is to discuss the applicability of a proposed innovative approach “Lean Design-for-X”, embracing the Lean principles and Modular Design, as a support tool for the feasibility decision of an experimental validation based on reduced scaled models, prior to full scale prototyping. In the literature, the feasibility of a scaled model is analysed based only on the structural domain. On the other hand, the presented integrated framework is able to assess multiple “X” design domains, allowing therefore a more complete evaluation of a reduced-scale model.
Tomasz Goetzendorf Grabowski

Today aircrafts are close to excellence. The existing methods of design and over 100-year knowledge allow to build the best aircraft we have ever seen. However natural tendency to do good better causes, that optimization is a tool, which became very popular. It allows to minimize selected characteristics to obtain the best performance, lightest weight, reduced fuel consumption, etc. Aircraft design process requires to connect many disciplines – aerodynamics, flight mechanics, stability, control, structural strength and others. The idea to connect them into one system has resulted in the design of systems in which all or most disciplines are present. Exchange of data and intermediate results between disciplines increased the quality of design process and reducing time and cost necessary to obtain mature design (Fig.1).

![The vision diagram](image)

**Fig.1 – the idea of reducing time and cost in SimSAC [1] project**

Connection of disciplines in one optimization process was not applicable by the years due to very high computational cost. Rapid progress in computer technology and computer science allowed to do it. However there are still many problems with linking the disciplines. First question is what type of connection, interchange data should be chosen [2], next how to exchange data between existing methods - software developed to solve particular problem [3]. Paper presents selected architectures of multidisciplinary optimization and its application to aircraft design. Problem of exchange data was discussed. Selected examples of application of the methods developed in Warsaw University of Technology and the results are presented.

STUDY OF VORTEX ROLL-UP USING DIFFERENT WINGTIP SHAPES

Sebastian Dufhaus, Anna Uhl, Eike Stumpf

Despite several years of research in vortex dynamics still the optimal design of wingtip shapes is an open issue. Seeing the multitude of current wing tip extensions on e.g. Airbus and Boeing airplanes (wing tip fence, blended winglet, raked wing tip, split winglet) it becomes apparent that no stringent design philosophy with all involved disciplines has yet been established. At this stage fundamental aerodynamic investigations might provide useful contribution to an eventually converged, physics-based design philosophy.

The underlying assumption of the paper is that the axial velocity component within vortices developing at side-edges of lifting surfaces is a key element for designing optimal wingtip shapes. The presented work aims at better understanding the phenomenon of axial velocity component within the vortex core and at analyzing two hypotheses: that specific tip design characteristics and flow features cause an axial velocity 1) that either is linked to an instable vortex downstream development or 2) that allows to realize an enhanced lift to drag (L/D) ratio. If valid, the axial velocity component might serve as an integral design parameter which is to be formalized in engineering relationships. These fundamental research questions will be investigated on a simple generic wing model. This approach supports the goal to obtain clear cause-effect relationships. The expected outcome of the investigation in principle is universal and relevant for all propeller or rotor blades as well as planar or non-planar wing or flap tips.
NEW DEVELOPMENTS FOR INITIAL BOUNDARY VALUE PROBLEMS INVOLVING MULTI-PHYSICS AT LINKÖPING UNIVERSITY

Jan Nordström

During the last decade, stable high order finite difference methods and finite volume methods applied to initial-boundary-value-problems in aeronautics have been developed. The stability is due to the use of so-called summation-by-parts operators, penalty techniques for implementing boundary and interface conditions, and the energy method for proving stability. In this talk we discuss new aspects of this technique including the relation to the initial-boundary-value-problem. By reusing the main ideas behind the development, new time-integration procedures, boundary conditions, boundary procedures, multi-physics couplings and uncertainty quantification, have been derived. We will present the theory by analyzing simple examples and apply to very complex problems.
Aeroelasticity concerns the interaction between inertial, structural and aerodynamic forces. In the development process of aircraft and space vehicles, aeroelasticity plays a key role in assessing the dynamic stability of the system inside a given flight envelope.

Aerodynamic forces are modelled in various ways and different degrees of fidelity: the most common approaches include doublet lattice methods, system identification techniques applied to response data acquired in wind tunnel or in flight and CFD.

Traditionally, CFD simulations rely on the RANS approach. Since simulations are always time-accurate, the approach is often referred to as URANS. In theory, the RANS and URANS approaches are justified only in the presence of a sufficient scales separation in time and space between the unresolved turbulent scales of motion the resolved scales of motion. The frequency content of the latter is related to the "mean" flow as in conventional aerodynamic problems but also to the underlying aircraft dynamics. This condition is normally met when the flow is attached; however, an interaction between turbulent scales and the resolved scales of motion may not be excluded in the presence of separated flow.

Among the test cases proposed by the recent second AIAA Aeroelastic Prediction Workshop, one of the Test Cases include shock-separations and large turbulent scales of motion generated by the wake. The aim of the Workshop's organizers is to investigate the behaviour of various turbulence modelling techniques, understand if the RANS/URANS approach is anyway sufficient or more sophisticated techniques, such as hybrid RANS-LES modelling must be applied.

This paper describes the simulations carried out for the Test Case in question with the SA-DDES model and a conventional (U)RANS approach. The study shows that, provided sufficient spatial and temporal resolution are available, the hybrid approach does provide a physically more consistent solution: the spectra of the resolved oscillations are closer to the correct energy cascade.

However, a proper assessment of the results would require more test cases and much more experimental data than is currently available.
The current work introduces AGILE (Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts), an EU funded project under the research schema Horizon 2020 and coordinated by the German Aerospace Center (DLR). AGILE is developing the next generation of aircraft Multidisciplinary Design and Optimization processes, which target significant reductions in aircraft development costs and time to market, leading to cheaper and greener aircraft solutions. To meet the challenges of the AGILE project a team of 19 industry, research and academia partners from Europe, Canada and Russia are collaborating together. The composition of the Consortium reflects the heterogeneous structure that is characteristic for today’s aircraft design teams. AGILE ambition is to advance the state of the art in solving complex, challenging design problems, such as large scale optimization of novel aircraft products, by integration of MDO techniques, collaboration and knowledge based technologies. AGILE has set ambitious performance targets to achieve by the end of the project in 2018: a reduction of 20% in time to converge the optimization of an aircraft and a 40% reduction in time needed to setup and solve the multidisciplinary optimization in a team of heterogeneous specialists, as illustrated in Figure 1. This will lead to improved aircraft designs and a 40% performance gain, compared to aircraft in service today, is expected for large passenger unconventional aircraft configurations. AGILE is set also to quantify benefits of different optimization approaches and architectures for systems with a high number of heterogeneous analysis modules, with multiple levels of fidelity ranging from empirical correlations till high fidelity analysis codes, in all the disciplines. Further, multiple design campaigns are setup in AGILE targeting aircraft concepts with a diversified maturity level to demonstrate the impact of the developed AGILE technologies and configurations on medium-term, and long-term aircraft products.

In order to realize the ambitious target an AGILE design system is deployed. The main elements are illustrated in Figure 2: a common product model based on the CPACS data representation, multiple engineering and optimization frameworks enabling distributed design competences, and a collaborative architecture is which enables to perform cross-organizational MDO processes.
The current paper presents status and results of AGILE collaborative design environment at the end of the first project year, which is concluding the first MDO design campaign activities. Use case is a large regional transportation aircraft, and the setup of a distributed MDO process making use of analysis modules suitable for the early design stages.
AGILE DC-1 MDO PROCESS USING AN EFFICIENT GLOBAL OPTIMIZATION APPROACH

Thierry Lefebvre, Nathalie Bartoli, Rémi Lafage, Pier Davide Ciampa

AGILE H2020 project aims at developing the next generation of aircraft Multidisciplinary Design and Optimization processes, which target significant reductions in aircraft development costs and time to market, leading to cheaper and greener aircraft solutions.

One of the main activities of the 1st year of the project was to generate a state-of-the-art, distributed MDO system, making use of pre-existing analysis codes, interfaces, frameworks and optimization software. Subsequently, an optimization workflow according to today’s best-practice methods, was formulated for the optimization of a large regional transportation aircraft.

The reference MDO formulation for AGILE was therefore based on a two levels design approach. At each level a set of disciplinary tools, with increasing fidelity among levels, were selected for the setup of the multidisciplinary analysis (MDA) design process. For each level the MDA was setup as a distributed workflow, taking advantages of each partner’s tool. Figure 1 provides an overview of the 2nd MDA level where each “block” is a design competence provided by the individual partners in the network, and each block is accessed as a “remote service” within the overall design process.

The proposed optimization process illustrated on Figure 2, is based on a sequential enrichment approach (typically Efficient Global Optimization [1] or Super EGO [2] for handling constraints), using an adaptive mixture of kriging-based models. The strategy relies on an improvement of the kriging model that enables the handling of a large number of design variables whilst maintaining rapidity and accuracy [3]. A key feature is the use of mixture of experts technique (MOE as [4] and [5]) to combine local surrogate models to approximate both the objective function and the constraints. The overall strategy, called SEGOMOE, is a very promising algorithm for expensive black-
box optimization under constraints in high-dimensions that extend the applicability of kriging-based methods [6].

This paper presents the AGILE implementation of this state-of-the-art, distributed MDO and focuses on the optimization approach with the use on enrichment techniques. The results obtained on the AGILE reference aircraft are analyzed.

AUTOMATED MESHING AND DATA FUSION APPLIED TO CREATE AERODATASET FOR AGILE DC-1 AND BEYOND

M. Zhang, A. Rizzi, J. B. Vos, A. Jungo

Assessment of maneuverability and agility in the conceptual design stage brings great challenges in the design process regarding the stability and control analysis over the entire flight envelope. A large lookup table of forces and moments must be constructed by Computational Fluid Dynamics (CFD) and we have to address the computational cost: A useful look-up table for stability and control analysis, the so-called aerodynamic database, needs thousands of entries because of the high dimensionality of the parameter space.

“Brute-force” calculation would be far too costly. But there are ways to reduce the computational time. The first is to use different CFD methods, from Large-Eddy Simulation (LES) via Reynolds-Averaged N-S models, down to potential flow models, or even empirical methods from handbooks. Using the simplest method and geometry compatible with the level of accuracy required for each flight state can dramatically reduce the computational cost.

The whole spectrum of computational models is widely used in modern aerospace industry. In order not to lose much accuracy while saving computational cost, the simplifying assumptions made to solve the standard Navier-Stokes equation should be as reasonable as possible for each single entry. For example, if one is flying at low speed and non-accelerated small angles of attack, the incompressible potential flow models can give reasonable predictions with significant time saving compared with Euler equation models or RANS.

Second, all the data obtained by the different CFD methods over the entire flight envelope must be fused, with dense low-cost & low-fidelity data indicating the trend and sparse high-cost & high-fidelity data correcting values [1].

Multi-fidelity modeling method (data fusion) is concerned with finding the means to navigate the flight state parameter space and cover the entire flight envelope in an effective way. This means to devise a procedure to integrate the results from different simulation tools based on different methods and having different complexity levels. In order to formulate aerodatasets in a reliable and robust way, the following issues shall be considered:

1. Data fusion technology for multi-fidelity models;

The full paper will show these above technologies in details and how these applied to AGILE DC-1 configurations.

1.1 Data fusion based on robust sampling technique
1. Initialization. Initialize the samples, start from the lowest fidelity samples and populates over the whole domain.
2. Sampling. Add new samples and evaluate the new sample points (at higher fidelity level if variable fidelity model is available) based on robust sampling method.
3. **Surrogate modeling.** Make a surrogate model from the above samples.
4. **Go to next the fidelity level.** Use the surrogate model obtained from previous step as lower fidelity samples. Iterate from 2-4.
5. **Stop** if the convergence criteria is met at the highest fidelity level.

### 1.2 L1 Tool Tornado and Beyond

1.2.1 L1 tool Tornado in Design Campaign 1

The Vortex Lattice Method (VLM) Tornado [2] remains in New CEASIOM as a potential solver, provides the aerodynamic coefficients & first order derivatives (a central difference calculation) over lifting surfaces at low speeds. The lifting surfaces are modeled at the camber lines, i.e., no thickness. The modification to the horseshoe vortices, namely, the vortex slings, which has 7 segments instead of 3, brings flexibility to model trailing edge movable surfaces. The leading edge movable surfaces can be modeled like-wise, but it is of less interest since it only changes the maximum lift which VLM cannot predict anyway. The steady wake can be chosen fixed in the body coordinate system or flowing the free stream. Overall effects of compressibility at high Mach number (<0.75) are assessed by the Prandtl-Glauert correction [3]. The induced drag can be calculated by both Kutta-Joukowski law (default) and Trefftz-plane integration [4].

For fuselage modeling, we tried several simple body models in old CEASIOM with no encour- aging results, including the cruciform bodies, and the slender body theory [5]. It is clear that in order to include body effects, we must move to higher-fidelity solvers. We decide to go to Euler solvers instead having some panel codes in between. In New CEASIOM, some new features of Tornado are included:

- Directly import/export CPACS XML file format, including the automatic paneling for Tornado from the CPACS XML description;
- Graphic aircraft configuration visualization including fuselage representation and control surfaces identifications;
- Time saving by mex-version of core-functions for matrix computations;
- All-moving surfaces and overlapped movable surfaces.

Figure 2 shows the configuration visualization and panel distributions in Tornado for the DC1- MDA aircraft, which will be described and used in the following section as a test example. The I/O for Tornado are in CPACS format. The aircraft configuration in Fig. 2(a) includes the fuselage read from CPACS which is only for visualization.

### 1.3 Automated Meshing Tool sumo for Aerodynamics

Sumo is a graphic tool aimed at rapid creation of aircraft geometries and automatic surface mesh generation [6]. It is not a full-fledged CAD system, but rather a easy-to-use sketchpad, highly specialized towards aircraft configurations. It is actively developed in order to streamline the workflow as much as possible to the intended use: rapid surface modeling of aircraft configurations; automatically unstructured surface meshes generation without user intervention. The unstructured volume meshes can be generated from the surface mesh, using the tetrahedral mesh generator TetGen [7]. Within New CEASIOM, the following features are included:

- Automatic CPACS-sumo Python converter to read/convert CPACS format geometry into sumo naive .smx file, with all the flaps /trailing edge devices information preserved and converted. CPACS very flexible user-defined node feature (cpacs.toolspecific)
allows the related manual-tuning parameters (if not default) for mesh generation to be saved and imported by sumo in CPACS format.  
• Automatic Euler (tetrahedron) and RANS (pentahedron) meshes generation. To generate the RANS mesh, pentagrow [8] needs to be run before TetGen in batch mode by executing a configuration file with a list of user-defined parameters to set up the prismatic layers such as the first cell height, the total number of layers, the growth rate etc. A short user guide and a template for the configuration file with the recommendation setting of parameters are provided within CEASIOM package.  
• The output file (the volume mesh) can be of variable formats, including CGNS, a bmsh file as CFD solver Edge [9] naive format, a su2 file as CFD solver SU2 format, or TetGen’s plain ASCII format.
AIRCRAFT SYSTEM ARCHITECTURES SELECTION FOR AIRCRAFT DESIGN OPTIMIZATION IN AN AUTOMATED PROCESS

MARCO FIORITI, LUCA BOGGERO, SABRINA CORPINO, ROBERTO D’IPPOLITO

In aeronautics, nowadays many innovations are pushed by the high demanding requirements of fuel savings and lower emissions. Major aircraft industries as Boeing, Lockheed Martin and Airbus are developing new solutions to reach these objectives. These solutions regard new fuel-efficient engines, new aerodynamics and new materials. A fiber-carbon structure weights less than a traditional one, hence comporting a reduction of the aircraft weight and therefore of the fuel consumed.

New trends aim to lower the required mission fuel concern the aircraft on-board systems, too. Both in civil and in military field new technologies and system architectures have been introduced to reduce the fuel required to supply power to the users (i.e. secondary power) and/or to lower the entire mass of the airplanes. In particular, new trends are moving towards an “electrification” at various levels of the secondary power. Innovative solutions are characterized by the following features: suppression of the hydraulic system, removal of the pneumatic system, growth of electric voltages, “electrification” of actuators, anti-ice system and Environmental Control System. Various aircraft concepts could be designed adopting one or more combinations of the expressed features. Some of these solutions could bring benefits – as lower Maximum Take-Off Mass (MTOM) and reduced fuel consumption – others may be disadvantageous. The Boeing Company claims a fuel reduction of about 3% due to the innovative electric air-conditioning system installed aboard the brand new Boeing 787 (Sinnet, 2007). The compression of external air done by dedicated electrically-driven compressors, instead of the tapping of pressurized air from the engines entails a more efficient – and therefore a more fuel-effective – generation of secondary power. In the military sector, example of more electric aircraft are well represented by both the Lockheed Martin F-22 Raptor and F-35 Lightning II, due to the adoption of the primary electric voltage up to 270 V DC, comporting a weight reduction of electrical conductors and machines (Moir and Seabridge, 2008).

In the preliminary design of a new aircraft, great attention should be placed on the architecture selection and sizing of the on-board systems, due to their impacts – fuel consumption, weights, volumes, space constraints – on the overall airplane. Thus, it is mandatory to size the aircraft systems since the first phases of the airplane design. The European research project H2020 AGILE (AGILE “Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts”) is focusing on the set up of an innovative framework for the Multidisciplinary Design and Optimization (MDO) of conventional and future air-vehicles. The current paper exploits some of the results obtained by AGILE project with the aim of proposing an innovative workflow for the on-board systems design integrated within the overall aircraft design process.

The aim of this workflow is the automated selection of the best systems architecture designing an aircraft with the objective of minimizing the MTOM. A system architecture is characterized by one or more of the following features:

1) The actuators of the Flight Control System and the landing gear could be conventional hydraulic or electric (i.e. Electro-Mechanical Actuators EMAs and Electro-Hydrostatic Actuators EHAs).
(2) The anti-ice system could be aerothermal, i.e. protecting the wing leading edge and the engine cowls with hot pressurized air tapped from the turbofans, or electric, hence preventing the ice accretion by means of electric resistances.
(3) The Environmental Control System ECS could be conventional – hence cooling and expanding pressurized air bled from the engines – or innovative. In this case, the external air employed for cabin conditioning is pressurized by dedicated electric-driven compressors.
(4) The pneumatic system could be removed if both the anti-ice system and the ECS are electric. Thus, the engines should be electrically started, entailing more powerful electric starter-generators connected to the High Pressure shaft of the turbofans.
(5) The hydraulic system – if present – is typically characterized by oil pressurized at 3000 psi (~20.7 MPa). Innovative trends are moving towards an oil pressure increment up to 5000 psi (~34.5 MPa) causing a reduction in volumes and weights of the hydraulic generation and distribution systems.
(6) The electric system could be characterized by traditional 28 V DC and 115 V AC 400 Hz voltages or by the innovative higher voltages: 270 V DC and 235 V AC variable frequency. This increase may entails a global reduction in weight of the system.

The introduced workflow is arranged in NOESIS OPTIMUS, a process integration and design optimization environment that provides design engineers with a complete solution for system and product improvement. Optimus is based on a simulation workflow management system that captures and federates different design tools and automates their execution in a seamless and efficient way at different levels, depending on the multi-disciplinary assessment and optimization architectures selected for the product design process at hand. Once the workflow is created, design exploration and optimization algorithms can be applied out of the box to address the design challenges of reducing mass, and respecting the various aircraft configuration constraints. This multidisciplinary design optimization environment based on Optimus will be used in this context to perform MTOM minimization using machine learning based algorithms for adaptive space exploration, modeling and optimization.

The tool ASTRID (Chiesa et al.) has been integrated within the workflow. ASTRID is composed by two modules; the first one is aimed at the preliminary overall aircraft synthesis and design (i.e. weight estimation, aerodynamics, propulsion and flight mechanics). The second module is focused on the sizing of all the aircraft on-board systems, as avionics, Flight Control System, landing gear, air-conditioning, anti-ice system, fuel system and the power supply systems, i.e. pneumatic, hydraulic and electric systems.

The workflow implemented within Optimus is depicted in Fig. 1. The tool ASTRID is integrated through the Matlab Interface (see the block with the red borderline). The software receives the inputs from both an xml file (“cpacsInput.xml” block) and a Matlab script (Matlab Interface block with the blue borderline). In detail, the inputs downloaded from the xml file are generic of the entire aircraft – e.g. Top Level Aircraft Requirements, weights, dimensions, performances – while the data saved in the Matlab external file are specific for the systems design. Finally, the results obtained by ASTRID are stored in the file named “cpacsOutput.xml”.

160
At University of Naples Federico II (UniNa) the AGILE paradigm has been assumed as guideline to develop new methodologies, tools and software applied to the aircraft design. A heterogeneous team work cooperates to find and develop more reliable methods, updating the older, implements them into state-of-the-art framework and software language, and integrates these new procedures into a cluster of partners in order to perform MDO on innovative aircraft configurations, such as in the AGILE European project1 context. In general, the AGILE paradigm consists in a set of principles in which both requirements and solutions evolve through the collaborative effort of self-organizing cross-functional teams [1]. It promotes adaptive planning, evolutionary development, early delivery, and continuous improvement, and it encourages rapid and flexible response to change [2].

At UniNa has been created a team work well versed in different disciplines. The supervision of the workflow is entrusted to the “Architect”, which is an aircraft designer or an aircraft design team. The architect points out the requirements, solutions and procedures to the team specialists. Subsequently the specialists elaborate the methodologies, implement them into software algorithm and finally integrate into the design loop framework (see Figure 1). In particular, the architect aircraft design specialist elaborates an analysis method which is implemented in an executable tool (for instance .jar in Figure 2) by the software specialist; subsequently the integrator specialist assembles a workflow into the framework in order to perform analyses on a specific aircraft or for instance MDO calculations. All the implemented methodologies can be easily modified, improved and reviewed adopting a typical AGILE procedure.

The methodologies and approaches have been well tested inside the context of the AGILE European project. In the initial design campaign (named Design Campaign – L0), the design space for a future transport jet aircraft has been evaluated (see Figure 3). Then, in the design Campaign 1(Design Campaign – L1), the developed modules have been used in first remote, collaborative MDO application. The adoption of the AGILE procedures has revealed the capability of the UniNa team to develop e release updated methods and tools in a fast and reliable manner. The AGILE approach is very suitable for aircraft design and it allows reducing time also in the conceptual and preliminary design phases. Moreover inside the UniNa team of specialists the philosophy of tools commonality and interchangeability resulted a successful way to develop and implement methods for aircraft design.

**Acknowledgment**

The research presented in this paper has been performed in the framework of the AGILE project (Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts) and has received funding from the European Union Horizon 2020 Programme (H2020-MG-2014-2015) under grant agreement n° 636202. The authors are grateful to the partners of the AGILE consortium for their contribution and feedback.
Reference
AGILE MDO METHODOLOGY FOR A 3RD GENERATION MDO FRAMEWORK SUPPORTED BY A GRAPH-BASED PROBLEM FORMULATION PACKAGE

Imco van Gent, Gianfranco La Rocca, Andreas Makus, Leo L. M. Veldhuis

In the AGILEa EU project a 3rd generation MDO framework1 is under development. In relation to this framework, we define the MDO design process, refer to Figure 1, to consist of two main phases that are continuously iterated. Where most of the recently developed MDO technologies for the new framework focus on the second phase to improve the execution of the workflow, research into MDO methodologies2,3 has indicated that a big step can also be made in the problem formulation step by exploiting these new technologies in an earlier phase of the MDO design process. The execution-focused technologies are the centralized data schema (CPACS) and cross-network workflow execution (BRICS, Optimus, RCE). As these technologies enable the execution of large, complex MDO problems within a heterogeneous team of experts, we argue that they also offer the opportunity for an improved design methodology. It is this new MDO methodology that is under investigation at Delft University of Technology (DUT). To support the methodology, a graph-based problem formulation package has been developed, called KADMOS (Knowledge-based Agile Design with Multidisciplinary Optimization System). KADMOS improves the agility of the design team by reducing the set-up time required for large and complex MDO models, by automating the creation and reconfiguration of workflows, and by predicting the performance of different MDO architectures. These capabilities are achieved by means of a graph-based analysis system that supports and largely automates a three-step MDO methodology, see Figure 2: 1) A web of data is created based on available tools, their links to the centralized data schema, and the tool properties (e.g. fidelity level, accuracy, etc.) 2) The MDO problem to be solved is formulated, 3) The MDO process is automatically determined based on the MDO problem and the selected MDO architecture using graph manipulation algorithms. As a final step, the result of the last step can also be implemented automatically in a simulation workflow package (RCE) using workflow scripting. The current version of KADMOS has shown great potential in supporting the full chain from MDO problem to MDO workflow, as defined in Figure 1, and demonstrated the agility offered by the graph-based approach in the formulation phase of the first AGILE design campaign. This will form the basis for further developments in future MDO design campaigns of the AGILE project.

Acknowledgments

The research presented in this presentation has been performed in the framework of the AGILE project (Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts) and has received funding from the European Union Horizon 2020 Programme (H2020-MG-2014-2015) under grant agreement n° 636202. The authors are grateful to the partners of the AGILE consortium for their contribution and feedback.
It is the strong understanding in the community of the large commercial aircraft industry that the introduction of step-changing technologies and advanced aircraft configurations being beyond the state-of-the-art requires as an absolute “must-have” delivery an intensive and reliable phase of testing at representative scale and operational conditions. Many of these innovations with high potential for overall efficiency improvement and a highly favorable environmental impact require a significant modification of the aircraft configuration, which in turn entails tremendous challenges even for large demonstrator flight testing on existing conventional test aircraft.

The most recent wave of advanced technologies being under development for a potential integration in the next generation aircraft will most likely lead to an unprecedented need for large-scale flight testing. This also requires a level of modification which is very demanding in terms of cost, effort and technical realization. Thus, large-scale flight demonstration for a combination of new technologies may even be impossible with available test vehicles. The intention of this activity in Clean Sky 2 is therefore to develop advanced aircraft concepts based upon a design strategy targeting a perfect synthesis between innovative airframe concepts and the enabling or associated technology architecture plus its comprising individual technologies. It is the objective that through such a development approach the next generation of large short- and medium-range transport aircraft will directly benefit from this.
STUDIES TO CONFIGURE A NON-CONVENTIONAL RUDDER ON A COMMERCIAL TRANSPORT AIRCRAFT: AERODYNAMICS, STRUCTURES AND LATERAL-DIRECTIONAL STATIC AND DYNAMIC STABILITY

M.-A. Castillo-Acero

The history of aviation is linked to the research and development of different physical and mathematical scientific fields. In the literature many examples can be found of studies of new unconventional aircraft configurations to be lighter and stronger. Also new developments are available in the prediction of the aerodynamic loads that size an airplane to be safe, stable, controllable, and with adequate flying qualities.

Today there is a growing social demand to minimize environmental impact in all industrial sectors. Our aviation industry is also under this scrutiny. This is the reason why new requirements are emerging as eco-sustainability, in addition to compliance with the safety and certification requirements together with the challenges of being global competitive in an increasingly demanding world. Fuel consumption, and thus emissions of carbon dioxide, is directly linked by three key aircraft parameters, Breguet formula related: weight, drag and specific consumption of the power plant.

This contribution focuses on studying the influence of aerodynamic improvements resulting from the introduction of a non-conventional curved rudder in a transport aircraft configured with under the wing podded engines, and its influence on the stability and control of the airplane.

The opportunity to consider an unconventional rudder arises from the observation of nature: birds can fly and manoeuvre modifying the curve of the trailing edge of the wings. Our commercial aircraft control surfaces are flat and rotate around its hinge line with a deflection angle in a simpler manner. There is an opportunity to improve, imitating nature, and make these control surfaces to be controlled by acting on their mean curve. The research on additive manufactured materials together with new actuators, enable new airfoils controlled deformation.
This talk is about applying Active Flow Control (AFC) at the junction between Ultra-High Bypass Ratio (UHBR) turbofan engines and the wing. The reported research and development work is ongoing and part of the European programme CleanSky2 (Large Passenger Aircraft, Platform 1).

In civil aviation, Ultra High Bypass Ratio (UHBR) turbofans with very high “Bypass Ratios” (BR) have a considerable potential for ecologic and economic benefit. However, already for the current slightly smaller Very High Bypass Ratio (VHBR) engines the integration under the wing is challenging but becomes even more when the UHBR engines with corresponding larger nacelles are considered.

For modern aircraft with closely coupled engines the flow at the pylon/wing junction is very susceptible to local flow separations, which are triggered by interfering vortices originating from the engine nacelle and slat ends. This susceptibility is even increased by the fact that close engine coupling requires slat-cut-backs in this region in order to avoid clashes of the deployed slat with the nacelle. This flow separation degrades the high lift performance at landing conditions.

In the scope of the CleanSky2 project active flow control is applied to overcome flow separation and thus high lift degradation.

Within this scope the demonstration objective is the following:

“Flight test an integrated solution of advanced flow control means installed at the engine/wing junction while demonstrating the high-lift performance recovery suitable for enabling future UHBR engines installed under the wing”.

The talk highlights some technology development aspects covering numerical simulations, flow control hardware developments and preparations of wind tunnel and flight test campaigns.
BIOFUELS IN AVIATION: TRENDS, FUEL DEMAND AND CO2 EMISSIONS EVOLUTION IN EUROPE

Marina Kousoulidou, Laura Lonza

This work presents the results of a scenario-based study carried out at the European Commission’s Joint Research Centre aimed at analyzing the future growth of aviation, the resulting fuel demand and the deployment of biofuels in the aviation sector in Europe. Three scenarios have been produced based on different input assumptions and leading to different underlying patterns of growth and resulting volumes of traffic. Data for aviation growth and hence fuel demand have been projected on a year by year basis up to 2030, using 2010 as the baseline. Data sources are Eurostat statistics and actual flight information from EUROCONTROL. Relevant variables such as the number of flights, the type of aircrafts, passengers or cargo tonnes and production indicators (RPKs) are used together with fuel consumption and CO2 emissions data. The target of the European Advanced Biofuels Flightpath to ensure the commercialization and consumption of 2 million tons of sustainably produced paraffinic biofuels in the aviation sector by 2020, has also been taken into account. Results regarding CO2 emission projections to 2030, reveal a steady annual increase in the order of 3%, 1% and 4% on average, for the three different scenarios, providing also a good correlation compared to the annual traffic growth rates that are indicated in the three corresponding scenarios. In absolute values, these ratios correspond to the central, the pessimistic and the optimistic scenarios respectively, corresponding to 360 million tonnes CO2 emissions in 2030, ranging from 271 to 401 million tonnes for the pessimistic and optimistic scenarios, respectively. This article also reports on the supply potential of aviation biofuels (clustered in HEFA/HVOs and biojet) based on the production capacity of facilities around the world and provides an insight on the current and future trends in aviation based on the European and national policies, innovations and state-of-the art technologies that will influence the future of sustainable fuels in aviation.
I-VISION: IMMERSIVE SEMANTICS-BASED VIRTUAL ENVIRONMENTS FOR THE DESIGN AND VALIDATION OF HUMAN-CENTRED AIRCRAFT COCKPITS

L. Rentzos, A. Karvouniari, C. Vourtsis, S. Antoniou, G. Chryssoulouris

The aerospace industry aims at reducing product development times and costs but needs to build several physical prototypes for verifying various factors during design. Human factors considerations in the design process play a critical role for the reliability and resilience of the systems involved. However, in existing systems the analysis and the analysed artefacts are decoupled and implemented as separate entities. Such separation leads to high manual effort for integration, while missing chances for automation and thus cost-reduction. Existing systems fail to implement a closed loop between semantics and 3D geometries and generally suffer from scalability and real-time performance issues. i-VISION progresses the current status of human factors analysis of operations in aircraft cockpits using Virtual Reality technologies, by advancing the methodologies with requirements from modern operating conditions. The i-VISION project has delivered three distinct and complementary technological results. First the development of an advanced human factor method for analysing the human procedures and tasks during various phases and operating conditions in a virtual reality (VR) based aircraft cockpit. Second the implementation of semantic technologies for enabling engineers and human factor experts to assess a virtual aircraft cockpit in a timely and cost-effective way and finally the integration of the previous two in a VR environment serving as a reusable and low-cost simulation test bed for experimenting with various configurations allowing the human–cantered assessment of future cockpit architectures.
Within i-VISION project, a human factors analysis method has been developed which is based on Virtual Reality technology in order to analysis human-cockpit operations. This method is implemented as the Human – Cockpit Operation Analysis Module (HCOAM) which enables the i-VISION tool to perform human analysis methods designed specifically for human – cockpit interactions. HCOAM is operated using a web-based application interface. Using HCOAM, a human factors analyst can access and edit stored Hierarchical Tasks Analyses (HTA), create new and perform error and time analysis on selected procedures. The HCOAM uses a semantic repository to manage the data from the VR environment and a semantic query engine to process the data and return to the user the requested information. Within this work, an industrial test case demonstrates the applicability and functionality of the i-VISION HCOAM.
LIFE-CYCLE APPROACH TO ASSESS GREENHOUSE GAS (GHG) EMISSIONS OF ALTERNATIVE AVIATION FUELS: METHODOLOGICAL CONSIDERATIONS

Laura Lonza, Adrian O’Connell

This keynote speech aims at outlining methodological considerations relevant to the analysis and the assessment of the GHG reduction potential of alternative fuels for aviation. It equally provides insights on the energy efficiency profiles for representative options of alternative aviation fuels. When assessing alternative options – not a simple task due to varied levels of technology maturity – it is important to consider whether the energy efficiency of each alternative fuel option is justified by the benefits in terms of emissions’ reductions within a reasonable timeframe.

The keynote speech is focussed on alternative drop-in jet fuels, e.g. non-fossil hydrocarbon fuels characterised by the same chemical structure as conventional jet fuels that can be blended with conventional jet fuels, can use the same jet fuel supply infrastructure, and do not require adaptation of the aircraft or its engines.

The energy and GHG savings of drop-in biofuels for aviation are critically dependent on manufacturing processes and the fate of co-products. Methodology choices are therefore crucial to determine results. For purposes of reporting or accounting, emissions from biofuels in the combustion phase are often considered as being zero as the fuels are produced from biomass (i.e., the emissions are biogenic). However, non-biogenic emissions associated with biofuels result from the cultivation, harvesting and transport of the biomass, as well as from its conversion into biofuel.

Selected results from a recent study of the European Commission’s Joint Research Centre will be used to support the methodological considerations on GHG reduction potential and energy efficiency profiles of selected alternative aviation fuel pathways.
VORTEX DYNAMICS IN SUPersonic SHock-Boundary Layer INTERACTION FLOWS

I.W. Kokkinakis, D. Drikakis

We present the increase in accuracy provided by several upwind, high-resolution and high-order, shock-capturing schemes along with any caveats, within the context of a finite-volume ILES approach. The accuracy vs. dissipation characteristics and efficiency of various numerical schemes, namely Monotonic Upstream-Centred Scheme for Conservation Laws (MUSCL) and Weighted Essentially Non-Oscillatory (WENO), ranging from 2nd to 9th order are investigated and their numerical (dis)advantages in simulating supersonic fully turbulent flows is discussed. Previously, a “canonical” quasi-incompressible fully developed turbulent channel flow [1] and double vortex pairing [2] were used to investigate the behaviour of the schemes at a relatively low Mach number of 0.2. Here, we extend the aforementioned studies to the supersonic regime. A typical supersonic turbulent flow over a compression ramp is used for which the scheme order is shown to play a crucial role in the accurate resolution and capture of shock turbulent boundary layer interactions (STBLI). In the latter case, a synthetic turbulence digital filter technique is utilized in order to obtain a turbulent inflow [3]. It is shown that such schemes are particularly well suited for simulating compressible turbulent flows, while also proved to be resilient to the excess artificial dissipation caused at low Mach numbers. Further on, their suitability in ILES with near-wall resolution (ILES-NWR) is examined. Finally, the computational cost associated with the increase in accuracy is investigated in order to assess the “affordability” of each numerical scheme.

References

Figure 1: 24° compression ramp at \( Re_{\delta} = 38,737 \); Streamwise distributions of (a) normalized wall pressure, and (b) friction coefficient.
**Figure 2:** Iso-surfaces of \(Q\)-criterion coloured by Mach number (red=2.2); density gradient magnitude contours plane in grayscale.

**Figure 3:** Density gradient magnitude contour \(x-z\) plane in grayscale ordered vertically with increasing distance from the wall; white=0.1, black=10 using exponential colour function.
INVESTIGATING THE DYNAMIC RESPONSE OF HYBRID-ELECTRIC PROPULSION SYSTEMS

Guido Wortmann

The future development of air traffic brings along an increased demand for autonomy, safety and maneuvrability in a new generation of UAVs and general aviation aircraft. Future drivers such as increased air traffic density, insertion and growth of UAV traffic, promising applications of cooperative multi-platform missions and tight formation flying as well as near-ground operation in turbulent and limited air space require high maneuvrability and hands-off or complementary autonomous control mechanisms. Current research projects address various technologies of environmental sensors, flight state awareness and flight path prediction, inertial-frame-, computer- and GPS-aided navigation and nonlinear adaptive control. The progress in these disciplines enables a vast variety of new mission tasks that brings up new requirements on aircraft maneuvrability and performance. In this talk, an initial analysis of the thrust response of hybrid-electric propulsion systems for UAVs and general aviation aircraft is presented and the potential application for attitude control of fixed and rotary wing aircraft with distributed propulsion concepts is assessed. The focus is set on component modelling as well as the identification of scaling effects, design trade-offs and the sensitivity of the thrust response on component parameters. The objective is to allow the consideration of transient requirements during the preliminary propulsion system design, which is shown in studies on subsystem, system and aircraft level.
As a consequence of dwindling resources, growing world population and climate change the aviation industry has set strong targets to reduce its greenhouse gas emissions. [1] One way to achieve this goal is the replacement of fossil fuel by renewable synthetic alternatives. Currently various biological and even non-biological feedstock are discussed in the scientific community to identify the most sustainable and economically viable fuel production pathways. Algae-based fuel production has several advantages when compared with fuel production from land-based energy crops. Algae can, for example, be cultivated independently of the soil quality using salt or even wastewater as cultivation medium. Furthermore, the biomass productivity of algae can significantly surpass the productivity of land-based energy crops. However, algae cultivation and further processing requires high energy inputs and sophisticated technical equipment. Therefore, the question arises whether the advantages of using algae as a feedstock for renewable jet fuel overcompensate the disadvantages that come along with cultivation and processing. Therefore, a Life Cycle Analysis (LCA) was conducted for a typical production pathway. The LCA clearly shows the impact of the various processing steps on the greenhouse gas balance of the alternative jet fuel. Further, the influence of key parameters, such as the algae productivity, was examined in an extensive sensitivity study. In the context of this study also the impact of the carbon source, a power plant supplying the algae with the required carbon dioxide, is discussed. The results of this LCA clearly show the ecological potential of an algae-based fuel production. The work presented at the EASN Conference is therefore an important contribution to identify the most favorable renewable alternatives to conventional jet fuel.

References

Acknowledgements
We gratefully acknowledge the financial support by the district government of Upper Bavaria (Project: AlgenFlugKraft, LABAY74C) and the support granted by the TUM Graduate School.
VALIDATION OF A NUMERICAL MODEL BASED ON STACKED-SHELL APPROACH FOR BIRD-STRIKE USING NON-DESTRUCTIVE TESTS (NDT)


Bird-strike simulation of composite panels is a challenging task due to the complexity of stress analysis in the matrix happening within the impact event. There has been many works proposed in the literature to model the delamination including significant damage constitutive modelling input through user subroutines, etc. In this work, a numerical model based on stacked-shell approach is developed to simulate the delamination occurring in the CFRP plates during the Bird-Strike event using the commercial software LS-Dyna. The proposed model has been validated by experiments. Non-destructive tests (NDT) shows that the proposed model brings many advantages in comparison the previous existing numerical models.
Afzal Suleman

The computational and experimental research program aims to improve the performance of complex aerospace engineering systems through advances in mathematical and computational models, and experimental methods that incorporate multidisciplinary analysis, design optimization and subscale UAV model flight testing for the synthesis of optimal and novel aircraft designs. The design and development of physical flight test platforms provide a low-cost opportunity to evaluate flight worthiness of new and unconventional aircraft configurations. The presentation will outline some of the experimental UAV flight test programs for evaluation of joined-wing and high-aspect ratio aircraft configurations in collaboration with OEMs. The UAV based flight test programs enable designers to retrieve quantifiable data and to provide a qualitative assessment of the aircraft handling qualities. It provides new perspectives that may lead to identification of design issues early in the development process thus avoiding expensive re-designs at the detailed design phase of the full scale transport aircraft.
INVESTIGATION OF BIRD-STRIKE EVENTS ON COMPOSITE WING PANELS

I. Diamantakos, K. Fotopoulos, M. Jamin, A. Eberhard, G. Lampeas

The BirdStrike project aim is to establish a validated bird strike analysis capability, able to efficiently simulate bird impact on a composite leading edge for a natural laminar flow wing. This is achieved by setting up a combined program of testing and analysis to develop and validate criteria and methodologies to be applied to impact and damage analysis of leading edge composite panels under bird-strike loading.

In the present work, the main scientific and technical results are presented, including:

• Development of a FE numerical methodology based on the stacked-shell approach for the efficient simulation of bird-strike incidents on composite panels.
• Manufacturing of flat un-stiffened and stiffened composite panels that include supporting stringers, sparcaps or other structural features.
• Development of FE models of the un-stiffened and stiffened panels bird-strike tests.
• Validation of analyses and numerical models based on experimental results and measurements.
• Development of a numerical model to predict the extent of damage in a representative Composite LE geometry.

Acknowledgement
The research leading to these results has received funding from the European Union Seventh Framework Programme - FP7-JTI-CS under grant agreement n° 307612.
NON-CONVENTIONAL COMPOSITE MATERIALS FOR AEROSPACE STRUCTURES

Pedro P Camanho, Albertino Arteiro, Carolina Furtado

A combined experimental and numerical investigation of the mechanical response of a new class of advanced composite materials manufactured using thin plies is presented. These materials are manufactured by a process that continuously and stably opens the fibre tows. The manufacturing process is able to produce flat and straight plies with dry ply thicknesses as low as 0.02 mm.

Analysis methods based on micromechanical and mesomechanical models are developed to study the effects of the ply thickness on the loads required to start delamination and transverse cracking. The analysis models are based on cohesive elements and on appropriate material models for the fibre and for the polymer resin.

Tensile and compressive tests in both unnotched and notched specimens are performed using two different lay-ups. The notched tests are based on specimens with central cracks and with circular holes, loaded in tension and compression. Digital image correlation is used to monitor the onset and propagation of damage on the surface plies.

The results show that the lay-up with blocked plies and with higher differences in fibre orientation angles between consecutive plies has lower unnotched strength. A size effect on the strength is observed for both the open-hole tension and compression tests. The size effect and the associated notch sensitivity of thin non-crimp fabrics are similar to those observed in typical aerospace grade unidirectional pre-impregnated composite materials. It is also concluded that the thin laminates exhibit an improved response to bolt-bearing loads over traditional composite materials.
VIRTUAL TESTING OF COMPOSITE AEROSTRUCTURES

Pedro P Camanho, Albertino Arteiro, Carolina Furtado

One of the most significant barriers to the increased use of composite materials in aerostructures is the inability to predict accurately structural failure, especially when both delamination and intraply failure mechanisms, such as matrix cracking or fiber failure, contribute to the fracture process. Delamination is normally simulated using methods based on Linear-Elastic Fracture Mechanics, such as the Virtual Crack Closure Technique, or using cohesive formulations. The onset of intralaminar failure mechanisms is normally predicted using ply-based failure criteria.

Generally, failure criteria alone are unable to predict the collapse of composite structures. To predict failure initiation, propagation and final collapse it is necessary to combine the ply-based failure criteria with appropriate damage models.

There are several relevant structural applications of laminated composites where both delamination and ply failure mechanisms are relevant energy dissipation mechanisms. For example, in composites subjected to low velocity impact, in skin-stiffener terminations or in ply-scaled notched laminates. The objective of this work is to present a fully three-dimensional damage model at the mesoscale that is able to represent both interlaminar and intralaminar failure mechanisms without previous knowledge of the orientation of the failure planes. The composite material is taken as a transversely isotropic material and accounts for crack closure effects under load reversal cycles.
The development of unmanned aerial vehicles (UAV), in industry and research centers, has increased substantially in recent years. The configurations and features of the new UAVs are limited only by the imagination of designers so that the use of techniques based on design optimization algorithms is an essential tool for making decisions during the conceptual design phase. This work formulates the application of a multi-objective design methodology for the conceptual design of a C wing tip for a flying wing powered by an electric power plant. The design objective is to propose C wing geometric configurations regarding flying wing dynamic characteristics, expressed in terms of the longitudinal flying qualities. The multi-objective optimization will be performed using a Multi-objective evolutionary algorithm (AEM), which uses the so-called meta-heuristic Differential Evolution. The maximum between the short and long frequencies and the time that would take to an unstable aircraft to duplicate the amplitude of the oscillations, after being disturbed, are the optimization objectives. The selection of the solutions that represent the best compromise between the optimization goals is based on Pareto dominance. It is expected that the family of solutions provided by the proposed design method for the C wing may help designers to tailor the appropriate latency of the real-time control system to command the flying wing.
EFFECT OF COMPOSITION AND TEMPERATURE ON THE DEPOSIT-INDUCED DEGRADATION REGIMES IN COATINGS AND STRUCTURAL ALLOYS FOR GAS TURBINES


The components of gas-turbine engines operating in marine environments are highly susceptible to hot-corrosion. The hot-corrosion process is highly temperature dependent and is generally classified as low- and high-temperature attack (650-750°C) and (900-950°C) respectively[1]. Even though hot-corrosion has been widely studied in the last 50 years, several critical questions remain unanswered and new ones have emerged with the increasing complexity of the alloy systems and the sulfate-deposit chemistries. The present work compares the Na2SO4 induced hot-corrosion results of NiCoCrAlY coatings deposited by high-velocity oxygen fuel (HVOF) under three different surface conditions: as-coated, polished and pre-oxidized. Thermal cycling hot-corrosion exposures were conducted every 20 h to complete 100 h at 700 and 900°C using an equilibrium SO2/SO3 atmosphere (100 ppm SO2). The specimens were recoated after each cycle with a 2.5 ± 0.25 mg/cm2 deposit of Na2SO4.

MECHANICAL BEHAVIOR OF A FUSELAGE STIFFENED CARBON-EPOXY PANEL UNDER COMBINED LOADS

Mauricio Torres, Edgar A. Franco-Urquiza, Hilario Hernández-Moreno, Alfredo Arias-Montaño, L. Gerardo Trápaga

The present project sets the analysis out of mechanical behavior of a carbon-epoxy stiffened panel under combined loads. The stiffened panels are the main components of aircraft primary structures such as fuselage or wing. The chosen stiffened panel belongs to a non-airworthiness Boeing 727-200 fuselage, property of ESIME Ticomán. The structural elements of the panel, skin and stiffeners were manufactured by VARTM and glued with high strength adhesive. The aerodynamic loads were calculated and imposed by a structural testing machine in order to emulate, at lab scale, the flight conditions. The strain field was determined by Digital Image Correlation (DIC) and verified with strain gages measurements. At the same time, a FE-Model was developed with the aim to estimate the stress and strains at some key points of the panel. The calculation-test correlation was obtained by comparing the numerical and experimental strain values. Finally, the failure mechanisms were analyzed with the goal to improve the knowledge of the stiffened-skin glued joint solution.
SYNTHESIS AND STUDY OF NIALX (X = CR, CO) INTERMETALLIC ALLOYS
BY MECHANICAL ALLOYING FOR APPLICATION IN GAS TURBINE ENGINES


NiAl intermetallic is a very well-known material for turbine blade applications due to its excellent properties at high temperature, such as corrosion and oxidation resistance and thermodynamic stability in a wide range of composition. Although this compound combines the stiffness and melting point of ceramics with the ductility of metals at high temperature, these nickel aluminides are very brittle at room temperature and fracture relatively easy under thermo-mechanical fatigue tests. This behavior represents a critical shortcoming for turbine blade applications, due to the permanent thermal and mechanical stress fields to which they are exposed. The kinetic, thermodynamic and mechanical properties as a function of the temperature of B2-NiAl y B2-(Ni, Pt)Al alloys have already been addressed, but there is still a lack of understanding in phenomena associated to the failure mechanisms, synthesis and lattice stability. This work presents a methodology for the synthesis of Ni base intermetallics with additions of Cr and Co and their effect on the crystal structure based on Ni antisite and solid substitutional defects. A dependence of the lattice constant and long range order parameter of the B2 phase is found as a function of the content of the ternary element.
EVALUATION OF DISCONTINUITIES IN AMC FRICTION STIR WELDS PRODUCED BY DIFFERENT GEOMETRY TOOLS

A. F. Miranda Pérez, C. E. Morales Bazaldúa, G. Y. Pérez Medina, E. Hurtado Delgado

Aluminum matrix composites (AMC) are gaining unlimited interest and special position in aeronautical industry. This is mainly due to their particular properties such as, lower weight, dimensional stability, exceptional wear and abrasion resistance and stiffness. In the joining of aeronautical components, solid state welding processes are more suitable option. Friction Stir Welding arises as a promising welding process with more advantages than traditional fusion process. FSW, consist in a non-consumable rotational tool which generates heat in the base metal in order to produce plastic deformation during the welding, shaped by a shoulder and a pin. The pin, can be designed as many possible geometry. However, the welding quality is not always achieved when varying these pin configuration. The motivation of this study is to evaluate the welding quality of the friction stir joints of Al-SiC with diverse shape tools. Different pin geometry tools were fabricated and employed to weld Al-SiC plates in order to assess some discontinuities produced in the welds. Microstructural evolution was examined by means of optical and scanning electron microscope, resulting in a refinement of the grains in the thermomechanical affected zone, and silica partitioned particles. Microhardness test was performed with variations due to pin different geometry.
The aviation industry has set ambitious targets to reduce its environmental footprint, the reduction of greenhouse gas (GHG) emissions being the most crucial one.

As future technological and operational improvements, leading to higher fuel efficiencies, are likely to continue to be outpaced by the expected growth in air traffic, large-scale utilization of sustainable fuels will play a vital role to reduce GHG. A lot of routes are in development, mainly based on biomass, but not only, with the objective to produce jet-fuels in a sustainable and economically viable way. To date, the only industrially developed value chain depends on biogenic oils (triglycerides), used cooking oils and animal fats as feedstock, through the Hydroprocessing (HEFA) route. If the process is well demonstrated with several industrial units in operation in the world for biodiesel production, we are still at the very early commercial stage for biojet-fuel industrial production and use. This route is certified as HEFA-SPK.

There are also several pathways close to the industrial development and yet certified, such as the Biomass to Liquid (BtL) process (FT-SPK/ Fisher Tropsch Synthesized Paraffinic Kerosene), or routes using fermentation as a preliminary conversion of the biomass to alcohols or olefins, such as the SIP (Synthesized Iso-Paraffins from fermented sugar) pathway or the ATJ-SPK (Alcohol to Jet SPK from fermented iso-butanol) route, both yet certified too.

This presentation will review the numerous pathways yet certified or under certification, and will present recommendations issues from the European CORE-JetFuel project.
NON DESTRUCTIVE TESTING OF CONTAMINATED CFRP SURFACES WITH THE BONDTINSPECT® SYSTEM

André Kraft, Kai Brune, Christian Tornow, Gudrun Mühlhofer, Bernd Mayer, Bernd Valeske
Presenter: André Kraft

Composite materials are already being used in the mass production of structural components in automotive industry in particular at BMW Group. Adhesive bonding is basically the best technique for joining CFRP (carbon fiber reinforced plastics) lightweight structures. The conventional NDT (non destructive testing) methods being used today focus on the detection of material defects, e.g. debonding. In this case there is no information about the surface properties or bond quality. A new ENDT (extended non destructive testing) method is the BoNDTinspect system which is based on a patent held by the Fraunhofer IFAM. A ultrasonic atomizer nozzle create an water-aerosol, these small water droplets are sprayed onto the surface. Depending on the surface properties (surface energy or contamination state) the aerosol will form wide or narrow drops. We determined to test certain contaminations (for example release agent, oil, fingerprint), which are critical to ensure the performance of adhesively joined CFRP structures. The BoNDTinspect System is an inline-capable NDT technique, which is suitable to allow distinguishing surface states for adhesive bonding of CFRP. We verify this statement with destructive tests like the single lap shear test.
As a consequence of dwindling resources, growing world population and climate change the aviation industry has set strong targets to reduce its greenhouse gas emissions. [1] One way to achieve this goal is the replacement of fossil fuel by renewable synthetic alternatives. Currently various biological and even non-biological feedstock are discussed in the scientific community to identify the most sustainable and economically viable fuel production pathways. Algae-based fuel production has several advantages when compared with fuel production from land-based energy crops. Algae can, for example, be cultivated independently of the soil quality using salt or even wastewater as cultivation medium. Furthermore, the biomass productivity of algae can significantly surpass the productivity of land-based energy crops. However, algae cultivation and further processing requires high energy inputs and sophisticated technical equipment. Therefore, the question arises whether the advantages of using algae as a feedstock for renewable jet fuel overcompensate the disadvantages that come along with cultivation and processing.

Therefore, a Life Cycle Analysis (LCA) was conducted for a typical production pathway. The LCA clearly shows the impact of the various processing steps on the greenhouse gas balance of the alternative jet fuel. Further, the influence of key parameters, such as the algae productivity, was examined in an extensive sensitivity study. In the context of this study also the impact of the carbon source, a power plant supplying the algae with the required carbon dioxide, is discussed. The results of this LCA clearly show the ecological potential of an algae-based fuel production. The work presented at the EASN Conference is therefore an important contribution to identify the most favorable renewable alternatives to conventional jet fuel.

References

Acknowledgements
We gratefully acknowledge the financial support by the Free State of Bavaria (Project: AlgenFlugKraft, LABAY74C) and the support granted by the TUM Graduate School.
THE FUTURE OF PROPULSION TECHNOLOGY IN THE 21ST CENTURY

By Dr. MJ Benzakein

The presentation will deal first with the needs of the customer, which are low fuel burn, low emissions, low cost, etc. This will be followed by an analysis of technology requirements and programs to address these needs. Technologies being developed in the US and Europe will be outlined emphasizing the gas turbine development, aircraft engine integration, electric propulsion, as well as alternate fuel. A path forward will be recommended.
SMALL AIR TRANSPORT CHALLENGES

Krzysztof PIWEK

The paper focuses on the Small Air Transport (SAT) challenges. The Future European Integrated Transport system should be based on an environmentally sustainable, cost efficient, seamless and co-modal passenger friendly system aiming at ensuring mobility and cohesion for the Europeans. The challenge is to create a new component of European transport by wider use of small aircraft using regional airports, to enable access to more communities in less time. This is in line of Flight Path 2050 challenge demanding that by 2050, 90% of the travellers are able to reach any location in Europe within four hours. The Small Air Transport (SAT) system must be optimized for short distances and for multiple, but narrow passenger flows. This paper will present goals, necessary research focused on aircraft family concept, future technologies, and next steps.

Keywords door-to-door, small air transport system, small commercial aircraft.
EXERGETIC GREENIZATION FOR BUSINESS AIRCRAFTS: METHODOLOGY AND A CASE STUDY

OZLEM SAHIN, ONDER TURAN

To safeguard against today’s rapidly changing environment and improve profitability, successful airlines must choose an aircraft that minimizes risk and is adaptable to an ever-changing market environment. In addition, passengers demand comfort and service similar to that offered by major carriers. Minimization of the environmental effects of aircraft fuel emissions, conservation of the air transport fuel energy reserves, improvement of energy consumption reduction strategies for airliners, development of economical flight procedures in air traffic management, and achievements in more efficient air transportation in today’s aviation industry substantially depend on an accurate energy modelling for commercial aircrafts. In the present energy and exergy model (ENEX) of a Saab 340 aircraft at maximum power is broadly analyzed based on energetic and exergetic perspectives. Lack of energy and exergy analysis of business aircraft ENEX analysis makes the paper original and becomes main motivation for aircraft during typical flight.

Keywords: Business aircraft, energy, exergy, propulsion, turboprop
A Certified Event

Organised by

EASN
Technology Innovation Services

&

ineqi

Supported by

ROYAL AERONAUTICAL SOCIETY
2016 • CELEBRATING 150 YEARS

&

SkyTagers

At

EASN 2016
European Aeronautics Science Network
www.easn.net
www.easnconference.eu