RESEARCH STUDIES

on

SMART STRUCTURES and THEIR APPLICATIONS

in the

Department of Aerospace Engineering

MIDDLE EAST TECHNICAL UNIVERSITY,

ANKARA - TURKEY

Dr. Yavuz YAMAN

Aim of the Presentation

As of 13 May 2009,

this presentation summarises:

the studies conducted on Smart Structures and their applications in Active Vibration Control by using the infrastructure of "Structures Laboratory" in Aerospace Engineering Department of Middle East Technical University.

Structures Laboratory

Structures Laboratory

Structures Laboratory Infrastructure

The available software and hardware in "Structures Laboratory" for the research studies are:

- **SOFTWARE**
  - AutoCAD 2000
  - MATLAB 2008a
  - CATIA V5r18
  - ANSYS 11.0
  - MSC PATRAN/ NASTRAN/ Flight Loads 2007r1
  - NI LabVIEW 8.6

Structures Laboratory Infrastructure

- **HARDWARE**
  - B&K 6 channel Pulse portable data acquisition unit with special software of FFT Analysis, Time Data Record, Modal Test Consultant, Operational Modal Analysis
  - B&K modal vibration exciter
  - B&K impact hammer
  - Various B&K single-axis and triaxial accelorometers
  - Keyence laser displacement sensor
  - Agilent signal generator
  - Hameg oscilloscope
  - Various uni-axial strain gauges and installation kits.

Structures Laboratory Infrastructure

- **HARDWARE –** *con't*

  - Dedicated equipment for smart structure applications comprising programmable controller (SS10), high voltage power amplifiers, high voltage power supplies, preamlifiers and piezoelectric (PZT) patches in various size and shape.

Completed Research Studies

Studies focused on smart structure applications with particular attention given to the structural modelling characteristics and active suppression of in-vacuo vibrations.

- *System Identification based on strain measurements*
- *System Identification based on displacement measurements*
- *Application of H_{inf} and mu controllers*
- *Free vibration suppression of smart beam and fin*
- *Forced vibration suppression of smart beam in its first two (first and second flexural) modes and that of smart fin in its first two (first flexural and first torsional) modes.*

Active suppression of in-vacuo vibrations

Published Work

- PhD. Thesis:
  "Piezoelectric Ceramics and their Applications in Smart Aerospace Structures" by Tarkan Çalışkan – METU – 2002.
- MSc. Thesis:
  "Active Vibration Control of Smart Structures" by Fatma Demet Ülker – METU – 2003.
- International Journal Articles: 1
- International Conference Papers: 9
- National Conference Papers: 10

Project Work

- International Research Projects:

✓ "Application of Smart Materials in the Vibration control of Aeronautical Structures" NATO/RTO/Applied Vehicle Technology Panel through the project **T-121** (April 2000 - March 2002), Turkish-Canadian joint project [Project Final Report]

✓ "Development of Control Strategies for the Vibration Control of Smart Aeronautical Structures" NATO/RTO/Applied Vehicle Technology Panel through the project **T-129** (April 2002 - March 2004), Turkish-Canadian joint project [Project Final Report]

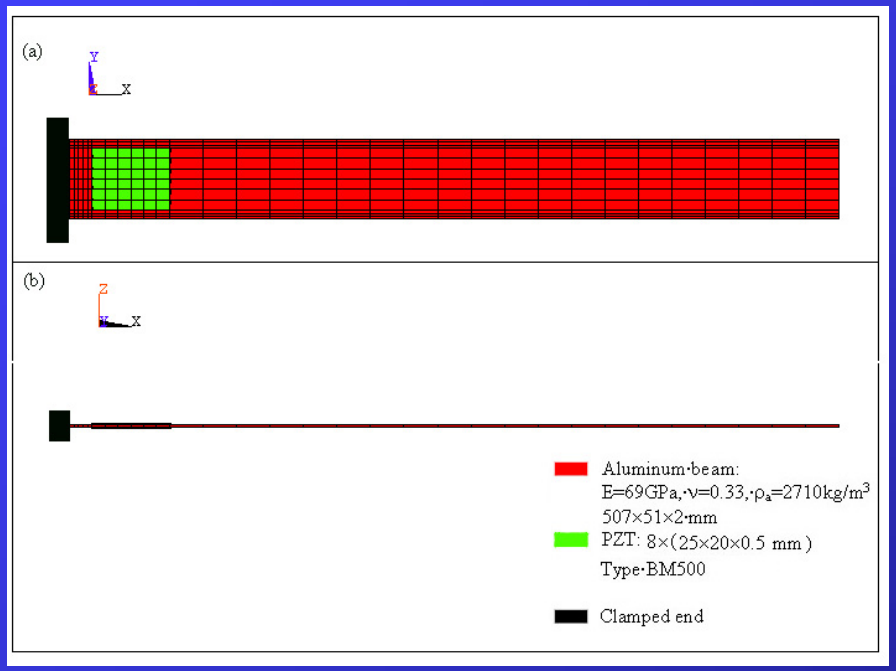
Project Work

- National Research Project:

"Establishment of an Aerospace Research & Development Centre" METU:AFP.03.13.DPT.98.K.122630" supported by Turkish State Planning Organization (DPT) (1998-2002)

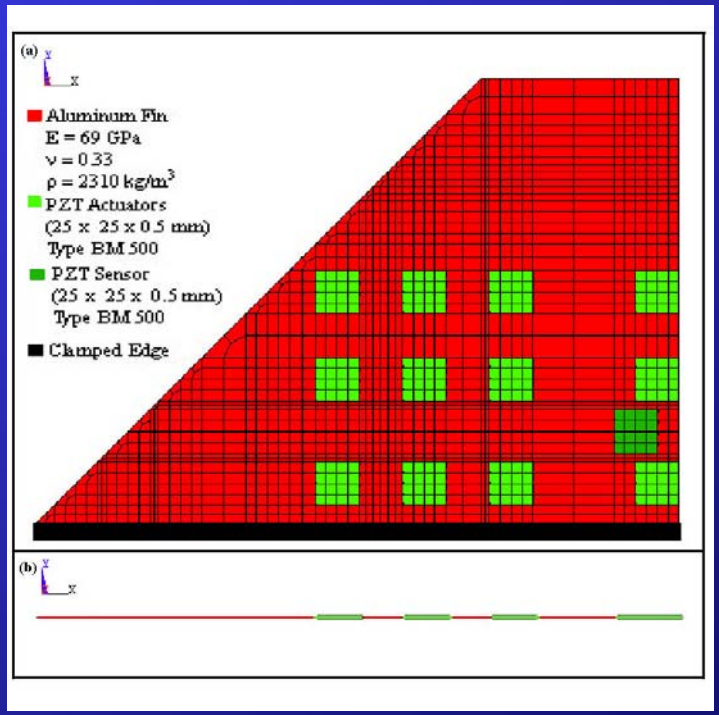
Active suppression of in-vacuo vibrations

Aluminum beam-like structure (Smart Beam)



FEM of the smart beam

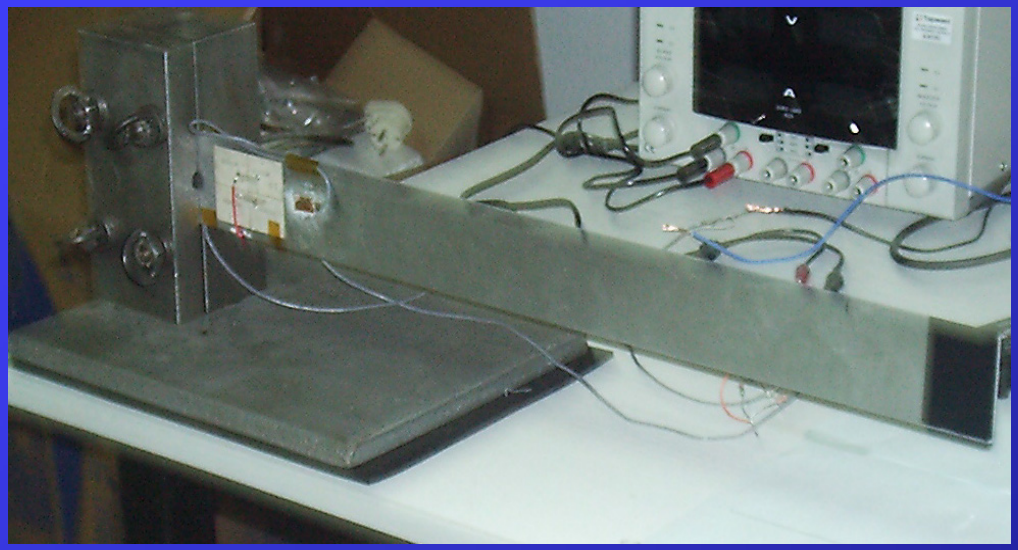
Aluminum plate-like structure (Smart Fin)



FEM of the smart fin

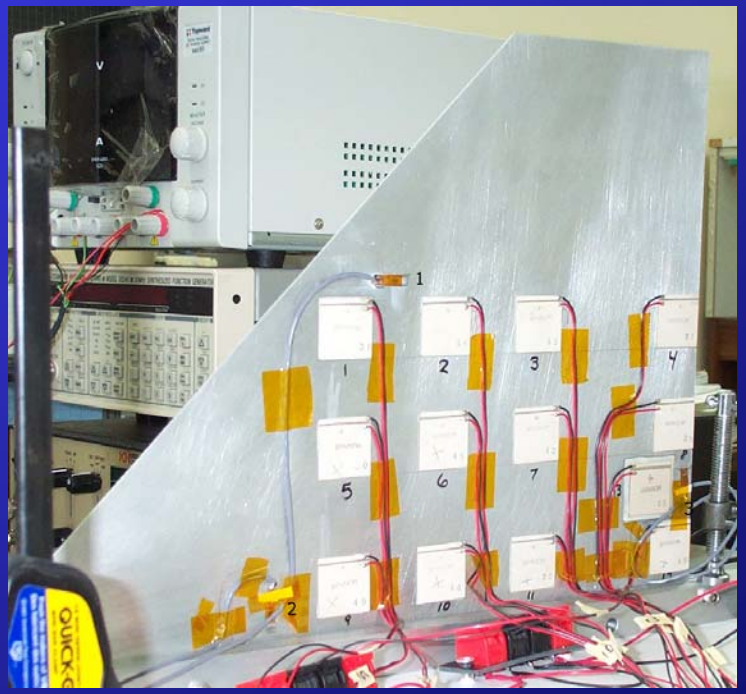
Active suppression of in-vacuo vibrations

Aluminum beam-like structure (Smart Beam)



Smart beam test specimen

Aluminum plate-like structure (Smart Fin)



Smart fin test specimen

Completed Research Studies

The videos related to the achieved vibration suppression of various Smart Beams and Smart Plates can be viewed/downloaded from the Smart Structures Laboratory link in

http://ae.metu.edu.tr/~yyaman/

Completed Research Studies

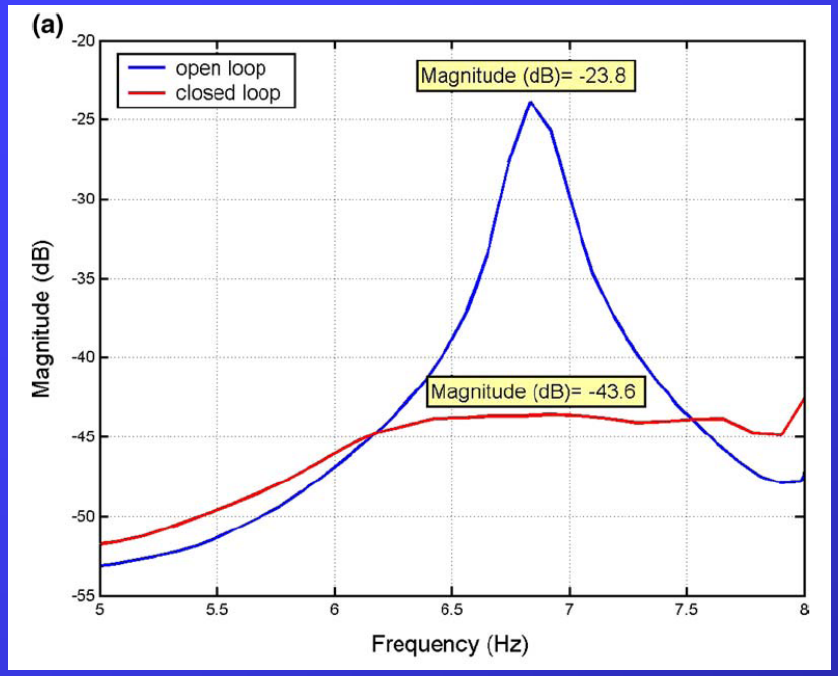
Studies focused on smart structure applications with particular attention given to the spatial control of in-vacuo vibrations.

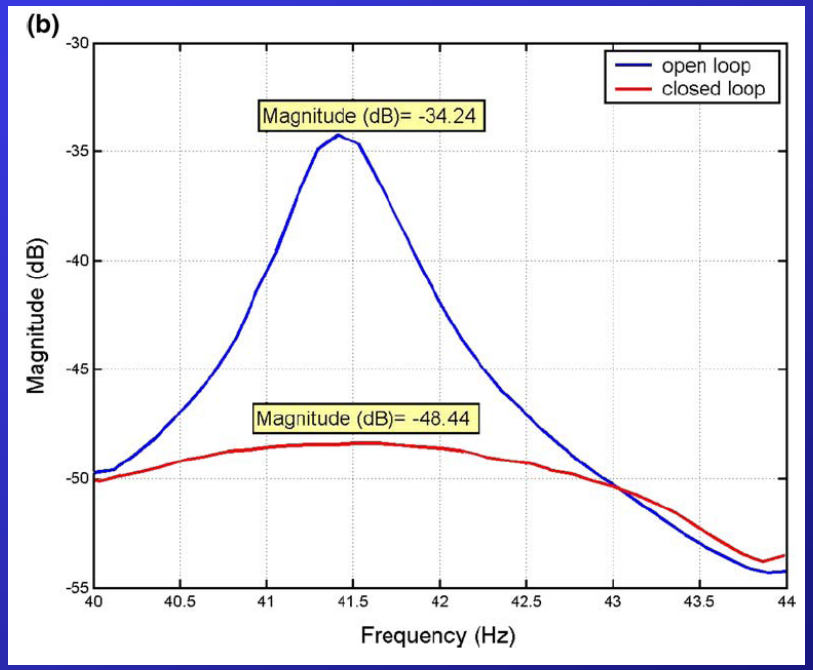
- *To suppress the vibration over entire beam by means of spatial control approach*
- *System identification based on displacement measurements*
- *Modeling of the smart beam by the assumed modes method*
- *A spatial H_{inf} controller designed for suppressing the first two flexural vibrations of the smart beam*

Published Work

- MSc. Thesis:
  "Active Vibration Control of a Smart Beam: A Spatial Approach" by Ömer Faruk Kırcalı – METU – 2006.
- Chapter in Book: 1
- International Journal Articles: 1
- International Conference Papers: 2
- National Conference Papers: 3

Structures Laboratory





Frequency responses of the open loop and closed loop systems of the smart beam within excitation of

(a) 5–8 Hz (b) 40–44 Hz

(Spatial approach for the active vibration control)

Completed Research Studies

Studies focused on smart structure applications with particular attention given to the active flutter suppression.

- *A thermal analogy method for the purpose of modeling of piezoelectric actuators*
- *The H_{inf} robust controllers designed for the state-space aeroelastic model of the smart fin by considering both Single-Input Single-Output and Multi-Input Multi-Output system models*
- *Satisfactory flutter suppression performance around the flutter point*
- *Significant improvement in the flutter speed of the smart fin*

Active flutter suppression

Published Work

- MSc. Thesis:
  "Active Flutter Suppression of a Smart Fin" by Fatih Mutlu Karadal – METU – 2008.
- International Conference Papers: 2
- National Conference Papers: 1

Active flutter suppression

Project Work

- International Research Project:

"Development of and Verification of Various Strategies for the Active Vibration Control of Smart Aerospace Structures subjected to Aerodynamic Loading" NATO/RTO/Applied Vehicle Technology Panel through the project **T-133** (April 2006 - September 2008), Turkish-Canadian joint project [Project Final Report]

Current Research Studies

Studies focused on smart structure applications with particular attention given to the active vibration control via PZT sensor / actuator pair and self-sensing PZT actuator.

Active vibration control via PZT sensor / actuator pair

Published / Ongoing Work

- International Conference Papers: 2 (2 Abstracts (*accepted*))
- National Conference Papers: 2 (1 Abstract (*submitted*),
  1 Paper (*submitted*))

Current Research Studies

Studies focusing on health monitoring of structures by using operational modal analysis tools.

Project Work

- National Research Project:

"Prediction and Verification of Dynamic Properties of Aerospace Structures via Experimental Modal Testing" METU – BAP1 – 2008-03-13-01 (On going project, Starting Date: 01.01.2008, End Date: 31.12.2009 , Duration: 24 months)

Current Research Studies

Studies focusing on aeroservoelastic analysis of the effects of camber and twist on Tactical Unmanned Aerial Vehicle (TUAV) mission-adaptive wings.

- *A wing optimised and designed for weight reduction, fuel consumption reduction, maneuverability and silent operation*

Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings

Project Work

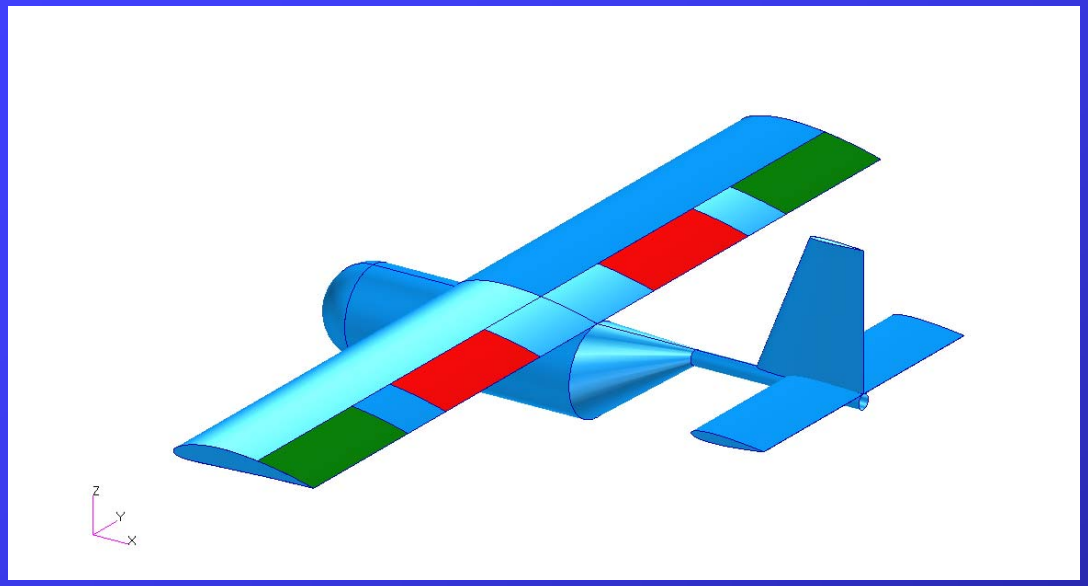
- National Research Project:

  "Aeroservoelastic analysis of the effects of camber and twist on Tactical Unmanned Aerial Vehicle mission-adaptive wings" TUBITAK (Turkish Scientific and Technological Research Center) - 107M103 (On going project, Starting Date: 01.10.2007, End Date: 01.04.2010, Duration: 30 months)

- International Conference Papers: 2 (Abstract *(accepted)*)

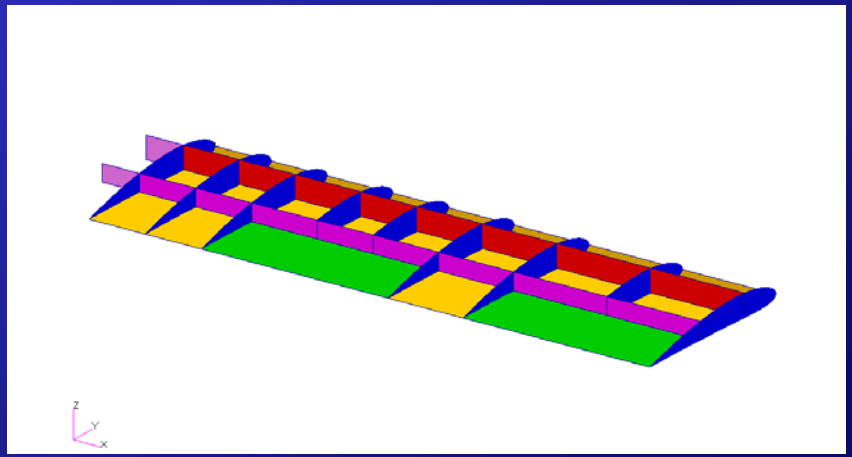
- National Conference Papers: 3 (1 Abstract *(accepted)*)

Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings

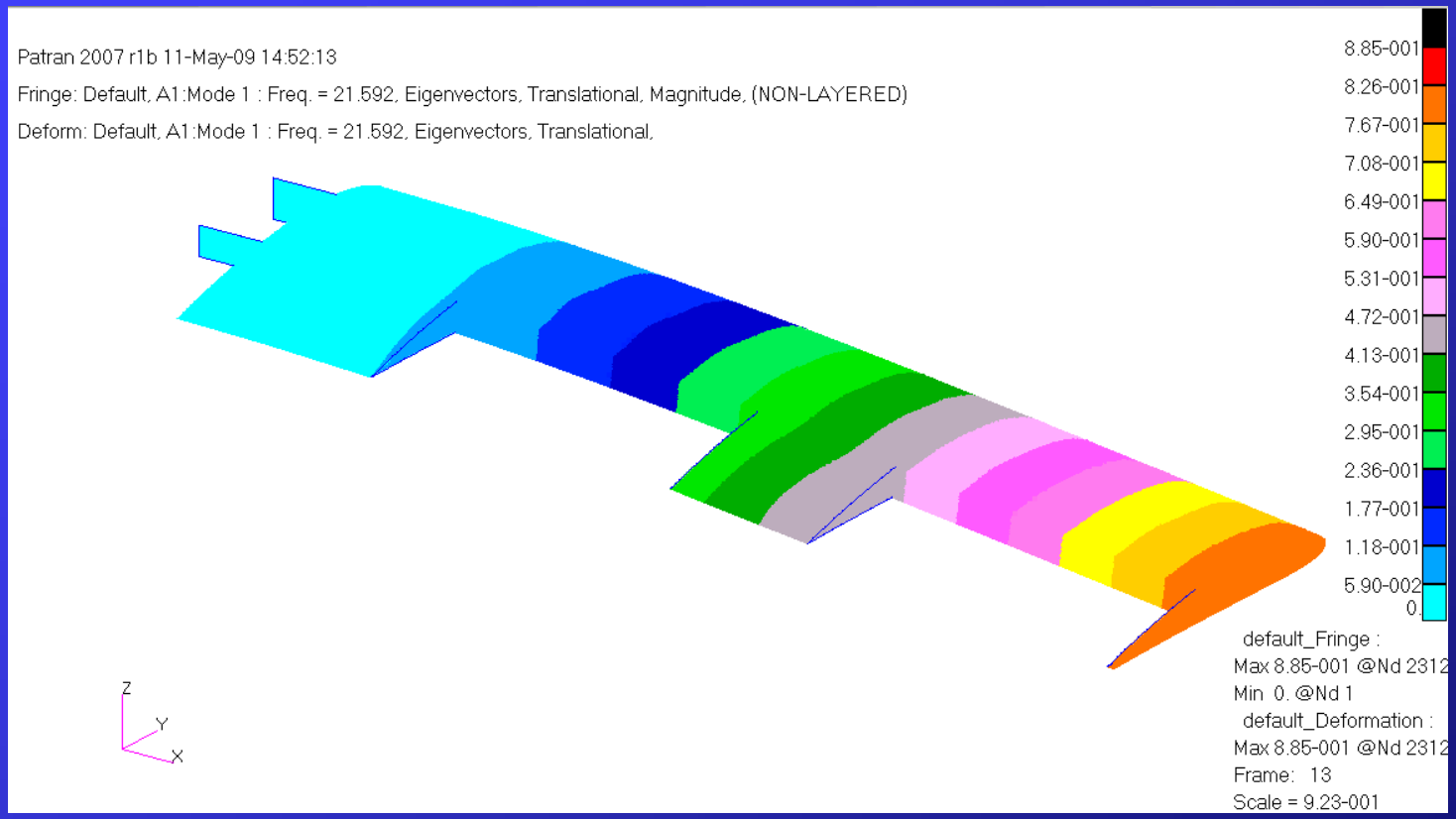


Tactical Unmanned Aerial Vehicle (TUAV)

Inner details of the right wing

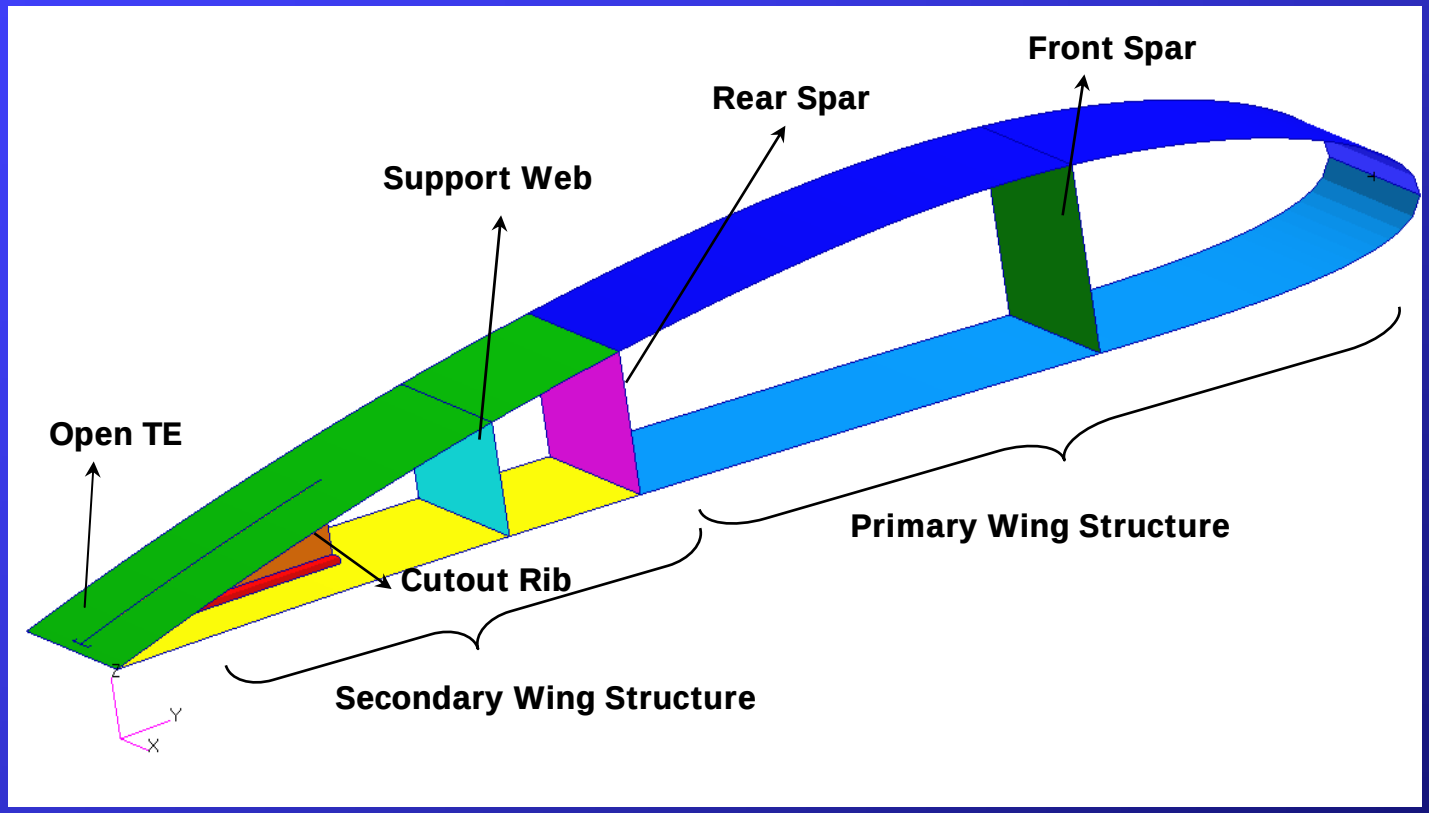


Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings



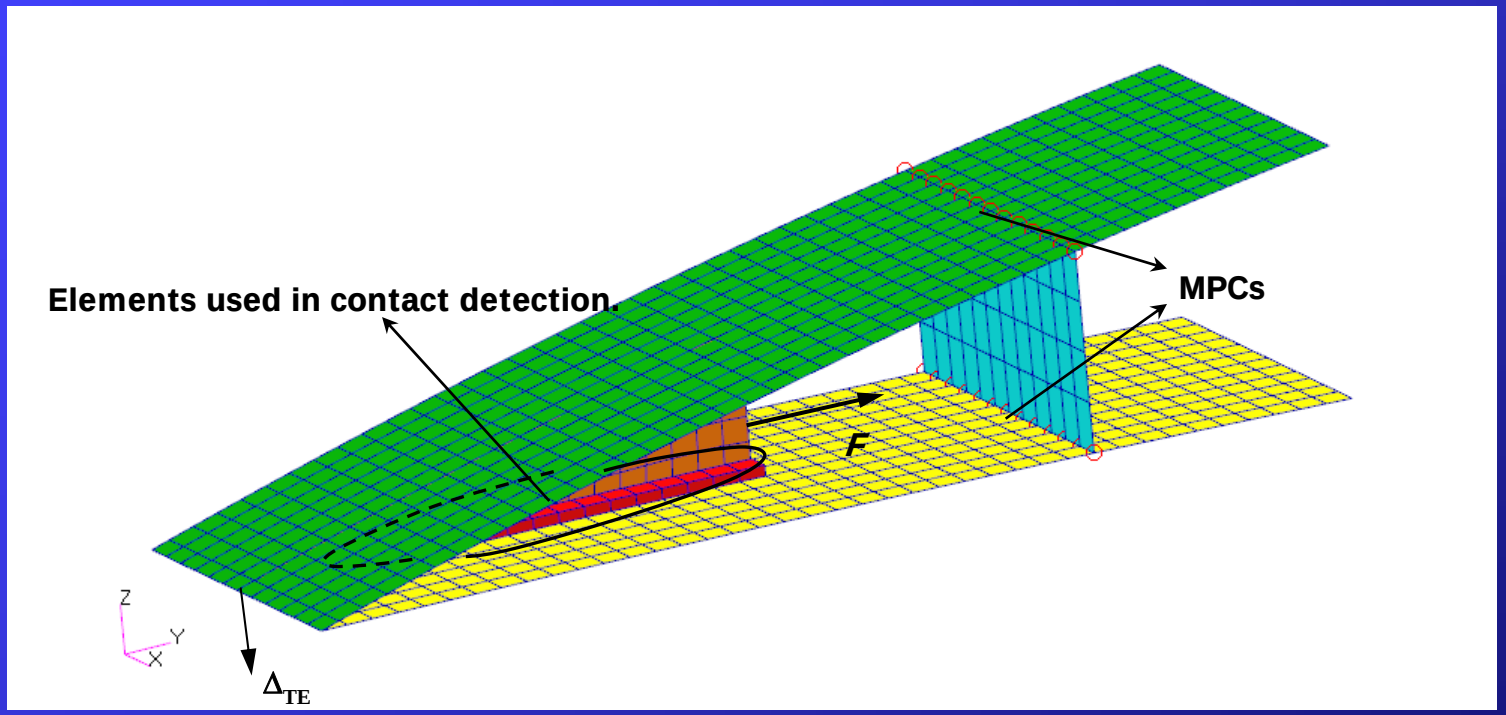
1. Flexural mode shape of the torque-box (f = 21.59 [Hz])

Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings



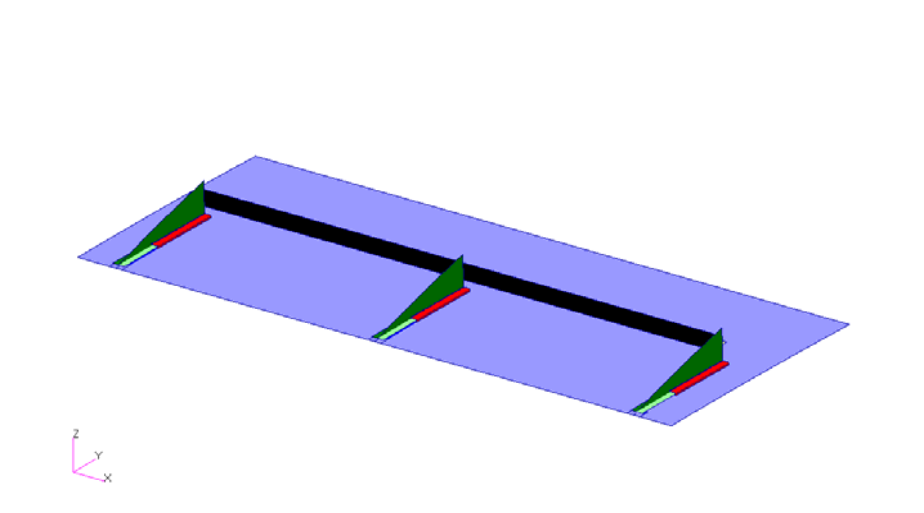
The hingeless control surface concept

Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings



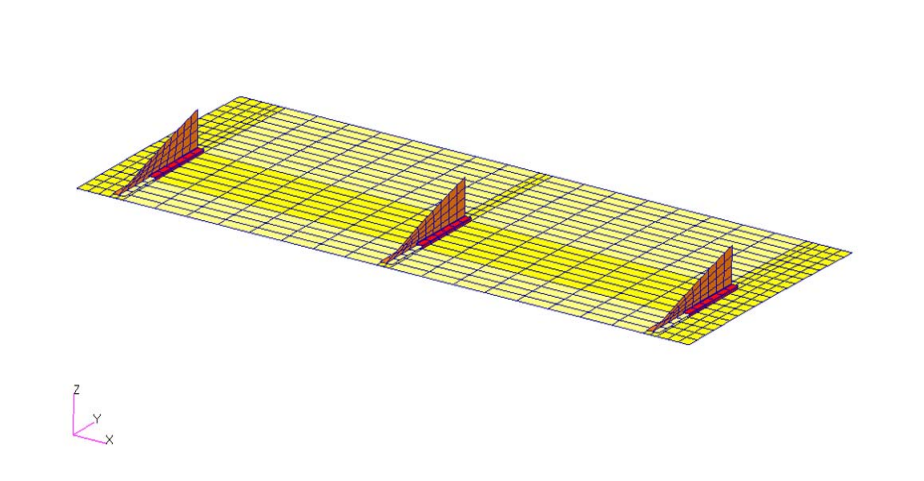
The FEM of the hingeless control surface

Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings

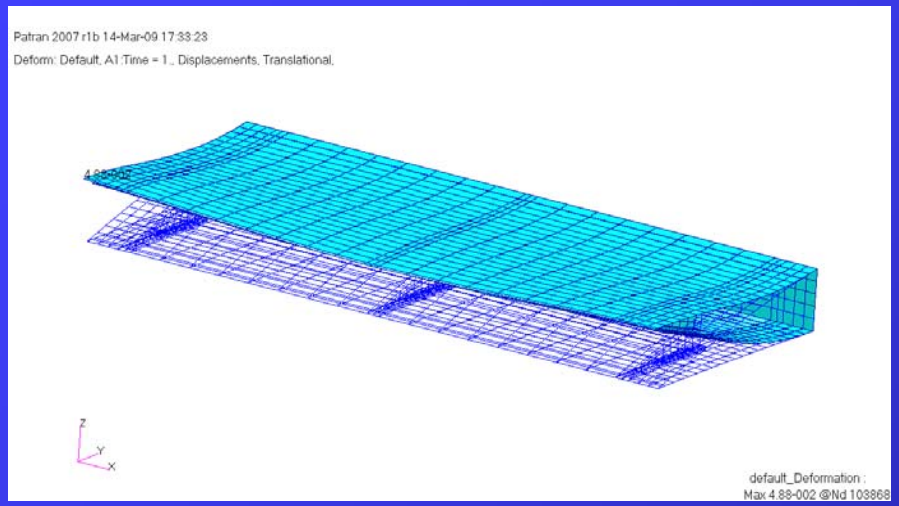


Flap internal structure (wedges always move together)

Aileron internal structure (wedges *<u>can</u>* move independently)

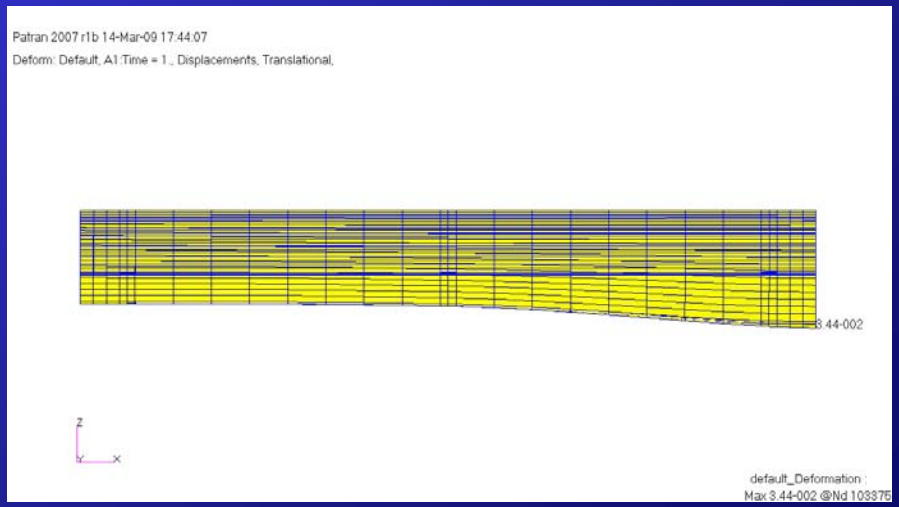


Aeroservoelastic analysis of the effects of camber and twist on TUAV mission-adaptive wings



Aileron
(wedges move together)

Aileron
(wedges move independently, causing twist)



Future Research Commitments

Studies focusing on smart structure applications with particular attention given to the fully morphing wing applications.

- *Manufacturing and testing of the wing which can sense the optimum aerodynamic force distribution required by the mission with its sensors and create the wing shape that will produce the required force distribution by actuators.*

Future Research Commitments

Intended Project Work

- National Research Project:

"Design, manufacturing and flight testing of a UAV with fully morphing control surfaces"

Fully morphing wing applications

Published / Ongoing Work

- National Conference Papers: 1 (*accepted*)
- National Article on non-technical Magazine: 1

Contact Details:

Prof. Dr. Yavuz YAMAN
yyaman@metu.edu.tr

Assist. Prof. Dr. Melin ŞAHİN
msahin@metu.edu.tr

Department of Aerospace Engineering
Middle East Technical University
06531, Ankara – TURKEY