

NATO/RTO/APPLIED VEHICLE TECHNOLOGY PANEL

PROJECT

T-129

**Development of Control Strategies for the Vibration Control of
Smart Aeronautical Structures**

STARTING DATE: 01 April 2002

COMPLETION DATE: 31 March 2004

1. PURPOSE AND OBJECTIVES

The subject of project T-129 was the development of new control strategies for the vibration control of smart fins (smart plate-like structures) by using PZT (Lead-Zirconate-Titanate) ceramic actuators. In vacuo conditions were studied.

The following goals were achieved in T129:

- . Application of smart materials (PZT ceramic actuators) in the vibration control of smart fins.
- . Development of passive and active (smart) fin structural analytical models using finite element methods.
- . Development of new control strategies by using H_∞ and μ control techniques for the vibration control of smart fins
- . Experimental verification of analytical predictions.

The theoretical considerations and modelling studies were conducted in METU, Department of Aerospace Engineering, Turkey. Sensor Technology Limited of Canada and Institute for Aerospace Research of Canada provided experimental facilities and acted as consultants.

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3. MAJOR RESULTS

Analytical and numerical modelling of aluminum beam-like structures (smart beams) for in vacuo conditions were completed during the previously supported AVT project T-121.

This study improved those models further for aluminum plate-like structures (smart fin) which included torsional as well as flexural vibrational characteristics. The smart beam and smart fin were analyzed under the effects of various loadings (PZT actuation and externally applied chirp signals through a shaker). By using the developed techniques of T-121, the theoretical studies on the structural characteristics of the smart fin were conducted. The structural models of the passive fin (aluminum fin) and active fin (smart fin) were

completed by using ANSYS® v5.6. The effects of the piezoelectric patch sizes and the patch locations on the static and the dynamic response of the smart fin were studied. The proper locations of strain gage sensors and the laser displacement sensor were determined. The theoretical flexural and torsional resonance frequencies and the mode shapes of the smart fin were obtained.

In terms of the control aspects, H_∞ controllers were designed and implemented for the smart beam (as SISO, Single Input Single Output, being 1 input to PZTs and 1 output from the beam by using strain gages or 1 input to PZTs and 1 output from the beam by using a laser displacement sensor). For the smart fin the controllers were first designed by using μ -synthesis method then were implemented (as SISO, being 1 Input to all PZTs on one face of the fin only and 1 output from one of the strain gages or 1 output from laser displacement sensor and also as SIMO, Single Input Multi Output, being 1 Input to all PZTs on one face of the fin only and 2 outputs from two of the strain gages). Two different implementation procedures were used for the smart beam and the smart fin. First approach used strain gage sensors and utilized a dedicated controller specifically designed for PZT applications by the Sensor Technology Limited called Four Channel Programmable Controller, SS10. In the other approach the laser displacement sensor was used and LABVIEW based .vi programs were utilized to suppress the vibrations. For both applications C algorithms were written.

For the free vibrations of the smart beam only 5 cm tip displacement was given with zero initial velocity. For the forced vibrations a chirp signal was applied which had a frequency range enough to cover the first two flexural frequencies of the smart beam. For the free vibrations of the smart fin a 3 cm displacement was given towards the edge of the free end with no initial velocity. The range of the chirp signal used in the forced vibrations analysis covered the first three frequencies of the smart fin (Actually first two flexural frequencies and first torsional frequency).

Analysis and implementation of various control strategies were studied for the smart fin. LQG active vibration control models were applied to the smart fin by NRC. Effects of different sensors (i.e. accelerometers) and different loading on the smart fin were also studied in NRC Laboratories. These studies provided comparison between the different control algorithms which were applied to the in-vacuo vibrations of the smart beam-like and plate-like structures.