RESEARCH STUDIES

on

.SMART STRUCTURES APPLICATIONS

in the

Department of Aerospace Engineering

MIDDLE EAST TECHNICAL UNIVERSITY

ANKARA – TURKEY

As of 22 June 2011
Structures Laboratory Infrastructure

SOFTWARE
- AutoCAD 2000, MATLAB 2009a, CATIA V5r18, ANSYS 11.0
- MSC PATRAN/ NASTRAN/ Flight Loads 2007r1
- NI LabVIEW 8.6

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 accelerometers
- Keyence Laser Displacement Sensor
- Agilent Signal Generator
- Hameg Oscilloscope
- Various Uni-axial Strain Gauges and Installation Kits
- Dedicated equipment for smart structure applications comprising programmable controller, high voltage power amplifiers, high voltage power supplies, preamplifiers and piezoelectric (PZT) patches in various size and shape.
### Structural Health Monitoring

Seventh Framework Programme (FP7) - Collaborative Project
Submitted on 07 May 2010

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<th>Participant No.</th>
<th>Participant Organisation Name</th>
<th>Short name</th>
<th>Country</th>
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Structural Health Monitoring

The project aims to develop a new system for performing Structural Health Monitoring for Airborne structures.

It is believed that the use of this technique will result in increased confidence in the detection ability and will have the following beneficiary effects:

- Increased safety, longer life at lower costs
- Less frequent structural maintenance procedures
- Less time on ground for the Aircraft
- More time in the air for the Aircraft
- Lower danger of accidents resulting from structural damages.
METU Responsibilities

WP1: Identification and definition of target end cases
WP3: Design and manufacturing of the laboratory test set-up for Composites/Laminates
WP5: Numerical simulations and sensitivity analysis for Composites/Laminates
WP7: Tests in Laboratory for Composites/Laminates
WP8: Target end case verification and fine tuning
WP9: System Implementation
WP10: Dissemination and Exploitation
WP11: Project Management
Active Vibration Control

Active Suppression of in-vacuo Vibrations

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

Active Vibration Control

Active Suppression of in-vacuo Vibrations

- International Research Project:
  “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]

- International Research Project:
  “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]
Active Vibration Control

Active Suppression of in-vacuo Vibrations

Aluminum beam-like structure
(Smart Beam)

Aluminum plate-like structure
(Smart Fin)
Active Vibration Control

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 $H_{\infty}$ controller designed for suppressing the first two flexural vibrations of the smart beam

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
Active Vibration Control

Active Flutter Suppression

- A thermal analogy method for the purpose of modeling of piezoelectric actuators
- The $H_{\text{inf}}$ 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 Vibration Control

Active Flutter Suppression

Comparison of the open-loop and closed-loop frequency responses of the smart fin for the SISO model for
(a) 70 m/sec (b) 83 m/sec
Active Vibration Control

Active Flutter Suppression

- 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]
Active Vibration Control via PZT sensor/actuator pair and Self-sensing PZT Actuator

- To suppress the vibration of beam by means of PZT sensing and actuating pair and a self-sensing PZT actuator
- System Identification based on PZT sensor and PZT actuator signals
- The \( H_{\text{inf}} \) robust controllers designed for suppressing the free and the first resonance frequency forced vibration of the smart beam
- Effective vibration suppressions with both PZT sensor/actuator pair and self-sensing PZT actuator

Active Vibration Control

Active Vibration Control via PZT sensor/actuator pair and Self-sensing PZT Actuator

Frequency Responses of the Open Loop and Closed Loop Systems of the Smart Beam obtained via Self-sensing Actuator within the bandwidth of 2Hz - 115 Hz.
Active Vibration Control

Active Vibration Suppression with various control strategies via PZT sensor/actuator pair

- To suppress the vibration of beam by means of PZT sensing/actuating pair
- System Identification based on PZT sensor and PZT actuator signals
- The LQG controllers designed for suppressing the free and the first resonance frequency forced vibration of the smart beam
- The fractional controllers designed for suppressing the free and the first resonance frequency forced vibration of the smart beam
- Effective vibration suppressions achieved
Active Vibration Control

Active Vibration Suppression with LQG Controller via PZT sensor/actuator pair

Open and closed loop experimental frequency responses of the smart beam.
Active Vibration Control

Active Vibration Suppression with Fractional Controller via PZT sensor/actuator pair

Open and closed loop experimental frequency responses of the smart beam.


Publications


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