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Active Aeroelastic Control – Aircraft

Author: Ray Greene, Assoc. Director, Aeronautics

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Keywords

Active aeroelastic control, Computational aeroelasticity, smart materials, Blade-vortex interaction, flutter stability, Active wing, Fin buffeting, Multi-Disciplinary Design and Optimization, MDDO

Summary

A conference on ***Applications of Adaptive Structures in Active Aeroelastic Control*** was held 25-29 March in Ankara, Turkey under NATO's Research & Technology Organization (RTO). The RTO (successor to AGARD) is the focal point for Defense Research and Technology activities.

Aeroelastic control is the bending and shaping of aerodynamic surfaces during flight. This action alters the camber, local angle-of-attack, lift characteristics and other aerodynamic parameters. Active control of flight vehicles has many military advantages. Active aeroelastic control in particular, provides solutions to potentially hazardous structural problems commonly faced by various aircraft. Recently by the introduction of adaptive structures, the aeroelastic control techniques are beginning to yield promising results. The enhancement of flutter stability, the elimination of vertical tail buffeting, the improvement of roll control, the alleviation of blade-vortex interaction, the introduction of active wing and active tail concepts are some of the recent successful research and development areas in adaptive structures.

The technical subjects focused on the application of adaptive structures in active aeroelastic control of flight vehicles covering:
(1) Computational aeroelasticity,
(2) Experimental aeroelasticity,
(3) MDDO and its applications in active aeroelastic control,
(4) Smart materials, and
(5) Recent trends and applications of adaptive structures in active aeroelastic control.

Introduction

This conference was organized and chaired by Professor Yasuz Yaman, PhD, Department of Aeronautical Engineering, Middle East Technical University, Ankara, Turkey. The recent advances in computational fluid dynamics, verified through experiment, and coupled with smart materials, promise reduced vehicle weight, improved maneuverability, and better control of catastrophic structural oscillations. Smart materials can be excited to produce bending moments across a wide frequency spectrum. This feature allows gross control surface movements for enhanced maneuverability, but also allows higher frequency excitation for damping of unstable oscillatory modes. The potential for active damping is of particular current interest for applications such as the tilt-rotor aircraft, fin oscillation, and other challenging vehicle dynamics problems.

Computational Aeroelasticity

Computational fluid dynamics is intended to accurately predict static and dynamic response and stability of aerodynamic and hydrodynamic vehicles. The benefit is to reduce wind tunnel and tow tank requirements while identifying design parameters early in the development stage. The increased computational power of new processors allows the use of improved (and more complex) modelling. Improved models using mathematically more complex fluid descriptions (Navier-Stokes equations vs. Prandtls' lifting line theory) and more complex structural descriptions (Non-linear Finite Elements vs. Euler beam theory) can be developed tailored for specific vehicles. The output of such models should provide accurate static response data previously available only through wind tunnel tests, including:

- Lift Effectiveness
- Divergence
- Control Surface Effectiveness/Reversal, and
- Aileron Effectiveness/Reversal

Further, accurate data may predict dynamic aeroelastic response, including:

- Flutter
- Gust Response
- Buffet
- Limit Cycle Oscillations (LCO)
- Panel Flutter
- Transient Maneuvers
- Control Surface Buzz

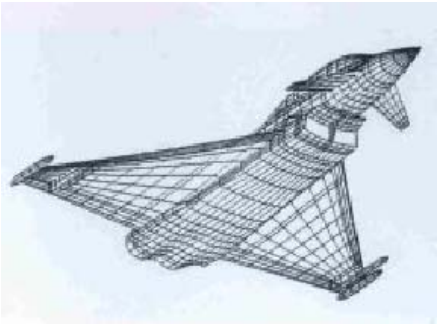
More information on computational fluid dynamics may be found at the Middle East Technical University web site www.ae.metu.edu.tr/~yyaman/avt086 by Dr. Ray Kolonay, PhD, GE Corporate research and Development, Niskayuna, NY.

Experimental Aeroelasticity

Experimental aeroelasticity covers the structural response of flight vehicles, typically accomplished during the developmental stage of a new aircraft or vehicle. Because the harmonic response of a vehicle may be unexpected, relatively large-scale models have been wind tunnel tested during and after development. Despite testing, unexpected dynamics sometimes occur in vehicles. For example in the P3 aircraft, early models had a rotary, torsional mode which resulted in an unstable, divergent oscillation of the turbo-prop engines (resulting in the engine breaking away from the wing). The current state-of-the-art testing conducted by NASA Langley Research Center in Virginia was presented by Mr. Stan Cole, Aeroelasticity Branch. More information on experimental elasticity may be found at the Middle East Technical University web site www.ae.metu.edu.tr/~yyaman/avt086 by Mr. Cole.

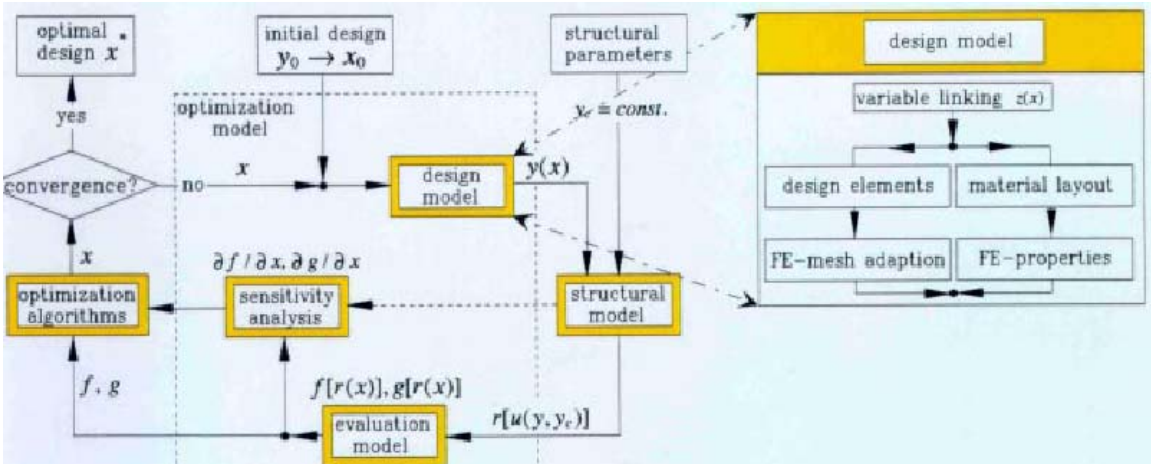
The RTO group also visited the Low Speed Wind Tunnel in Ankara. Although the tunnel is a ~1950 design, it has been upgraded with computer electronics and controls. For flight conditions below 200 mph, the tunnel appeared to be a suitable experimental tool.

Multi-Disciplinary Design and Optimization



Finite Element Model

Design optimisation was presented Mr. Johannes Schweiger, Head of the Structural Dynamics and Aeroelasticity Branch EADS, Munich, GE. The sketch to the right is an example of a finite element model using elements to define the local torsional response, bending modulus, and other structural parameters. This type of structural model is iterated with a fluid dynamics model to produce both the optimized aerodynamic response and the optimised structural response. The general approach to the optimization is depicted in the following chart wherein the finite element model is iterated with a Navier-Stokes flow field to develop the best trade-offs in weight, performance, and structural integrity.



More information on multi-disciplinary design optimization may be found at the Middle East Technical University web site www.ae.metu.edu.tr/~yyaman/avt086 by Mr. Johannes Schweiger.

Smart Materials in Aeroelasticity

The smart structures envisioned for future vehicles are to be a system of structures having intrinsic sensor, actuator, and control mechanisms whereby the system will sense a stimulus, respond to the stimulus, and return to the original; state after the stimulus is removed. In practice the structure is a sandwich construction similar to current composites, but incorporating (for purposes of this conference), piezoelectric actuators and strain gage elements. Potential benefits include faster, lighter control actuation, control of higher frequency stimulus such as flutter. EMI problems and other weather-related effects need further evaluation.

More information on piezoelectric actuation of aeroelastic effects may be found at the Middle East Technical University web site www.ae.metu.edu.tr/~yyaman/avt086 by Dr. Afzal Suleman, IDMEC – Instituto Superior Tecnico, Lisbon, Portugal. Information on smart materials effects may be found at the same site by Dr. Eswar Prasad, Chairman, Sensor Technology Ltd., Ontario, Canada.

Assessment

The conference was well organized and well presented by authorities in the aerodynamics community. I found the CFD (computational fluid dynamics) facilities at the METU to be state-of-the-art and competitive with faculties in elsewhere Europe. As this is an important and growing scientific area, it may be an area suitable for a NICOP. The ONR community has considerable background in harmonic oscillatory phenomena that directly relates to much of the aeroelastic CFD.

Contacts

Dr. Cahit ÇIRAY
Dept. of Aeronautical Engineering
Middle East Technical University
Ankara, Turkey
mailto:cciray@metu.edu.tr

Dr. Carmine GOLIA, Dept. Head
Dept. of Aerospace Engineering
Seconda Università degli Studi di Napoli
Naples, Italy
mailto:carmine.golia@unina2.it

Dr. Prabhat HAJELA
Dept. Mech. Aerospace & Nuclear Eng.
Rensselaer Polytechnic Institute
Troy, New York
mailto:hajela@rpi.edu

Dr. Yazus YAMAN, Dept. Head
Dept. of Aeronautical Engineering
Middle East Technical University
Ankara, Turkey
mailto:yyaman@ae.metu.edu.tr

Dr. Volkan NALBANTOĞLU, Senior Engineer
ANSELAN Inc.
Ankara, Turkey
mailto:vnalbant@mgeo.aselsan.com.tr

Mr. A. Ihsan OTABATMAZ, Chief, Composites
Tusaş Aerospace Industries, Inc.
Ankara, Turkey
mailto:aotabatmaz@tai.com.tr

Contacts

Dr. S. Eswar PRASAD, President
Sensor Technology Limited
Ontario, Canada
mailto:eprasad@sensortech.ca

Dr. Erhan SOLAKOĞLU
Tusaş Aerospace Industries, Inc.
Ankara, Turkey
mailto:esolakoglu@tai.com.tr

Dr. A. Suleman, Associate Professor
University of Victoria
British Columbia, Canada
mailto:suleman@uvic.ca

Dr. Kemal DERVIŞ
Minister of State
Ankara, Turkey
mailto:kemal.dervis@hazine.gov.tr

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Ray Greene, Associate Director, Aeronautics
Rgreene@onrifo.navy.mil

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