AVT/ T-133
Development and Verification of Various Strategies for the Active Vibration Control of Smart Aerospace Structures Subjected to Aerodynamic Loading

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PURPOSE:

The aim was to consider the effects of true aerodynamic loading in the vibration control of Smart Aerospace Structures.

OBJECTIVES:

• Application of smart materials (PZT ceramic actuators) in the active vibration control of smart beam-like (smart beam) and smart plate-like (smart fin) aerospace structures subjected to aerodynamic loading.

• Development of passive and active (smart) beam and (smart) fin structural models by using different finite element packages (ANSYS and MSC/PATRAN/NASTRAN) and comparing the effectiveness of different modeling strategies.

• Development of new control strategies by using $H_{infinity}$ and/or other control techniques for the active vibration control of smart beams and smart fins subjected to aerodynamic loading.

• Theoretical and experimental verification of developed models based on testing to compare the effectiveness of the control strategies developed.

The theoretical considerations and modeling studies were conducted in METU, Turkey.
Sensor Technology Limited of Canada acted as consultant.
Institute for Aerospace Research of Canada provided experimental facilities and also acted as consultant.

Smart Fin Model

RESULTS:

The response of the smart fin to aerodynamic loads was investigated and studies on active flutter suppression were performed. To obtain state-space representation of the aeroelastic model, the unsteady aerodynamic loads acting on the structure were calculated for a range of reduced frequencies and a Mach number by using a linear two-dimensional Doublet-Lattice Method and the loads were extracted using Direct Matrix Abstraction Programme (DMAP) from MSC®/NASTRAN. In order to verify the state-space approach, flutter characteristics of the smart fin were investigated with root-locus analysis.

Flutter control was performed in order to stabilize the system over a wide range of operating conditions and to attenuate disturbances throughout the operation envelope. The wind tunnel experiments were conducted and they aimed to suppress the vibrations of the smart fin by designing two different robust $H_{infinity}$ controllers. The performance of these controllers was verified in the wind tunnel experiments at the Institute for Aerospace Research of Canada. The smart fin was located inside the wind tunnel and exposed to both free stream and turbulent flow which was created by a tubular Von Karman vortex generator located up stream of the smart fin. The vibrations were monitored by using accelerometers. It was observed that the pole locations and damping levels of the modes of the structure change with the variations in the free stream conditions and angle of attack.

The experimental frequency response functions of the closed and open-loop systems were obtained from the designed controllers 1 and 2 aiming to suppress the vibrations due to the first mode and first three modes respectively. The designed controllers were implemented by using xPC Target Box and both achieved the desired performance levels and robustness properties.
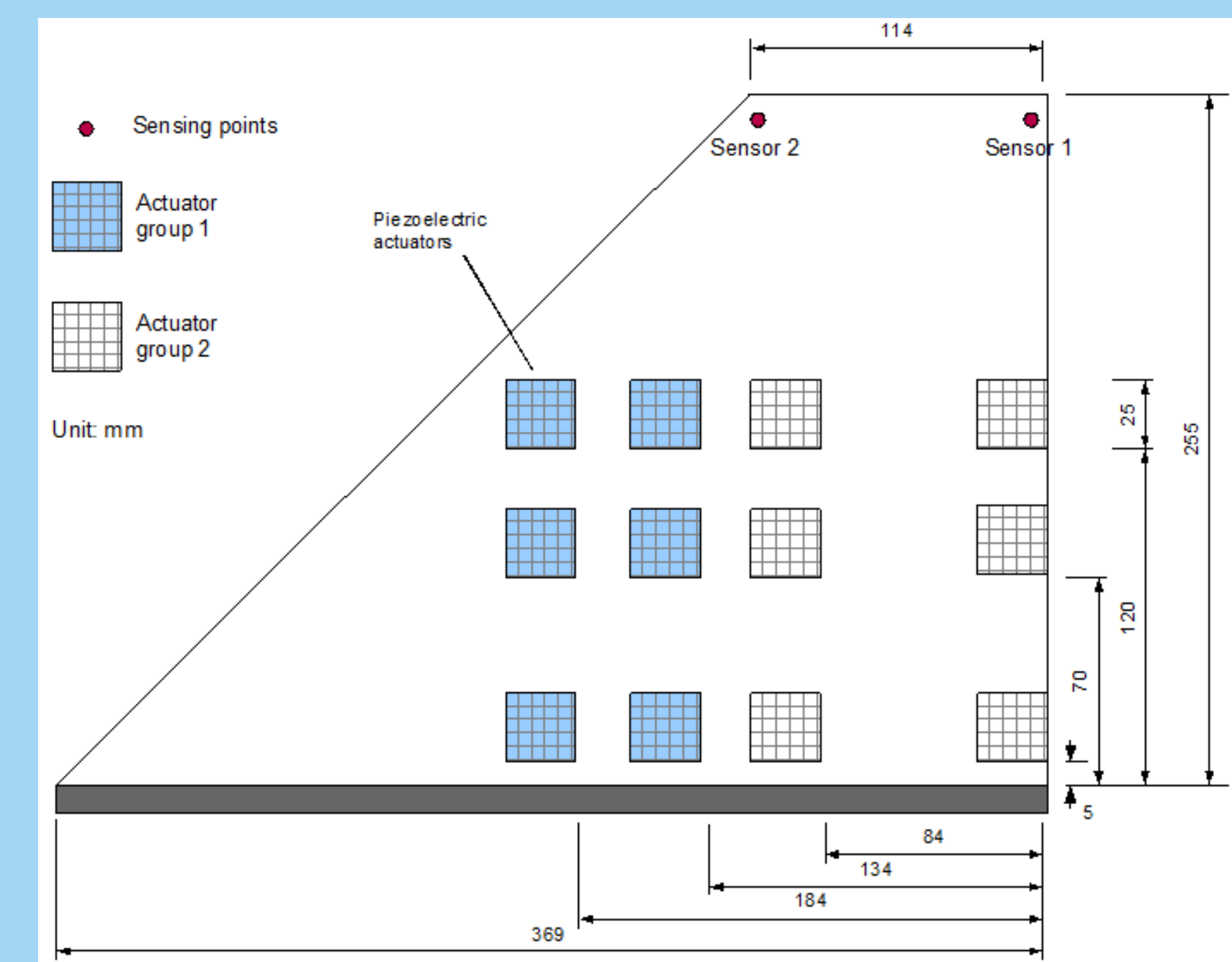

Smart Fin and Tubular Von Karman Vortex Generator in the Wind Tunnel

PUBLICATIONS:

The following Journal and Conference papers were published:

1) Şahin, M., Karadal, F.M., Yaman, Y., Kırcalı, Ö.F., Nalbantoğlu, V., Ülker, F.D. Çalışkan, T.,
"Smart Structures and Their Applications on Active Vibration Control: Studies in the Department of Aerospace Engineering, METU",
Journal of Electroceramics, 20(3-4): 167-174, 2008

2) Karadal, F.M., Nalbantoğlu,V., Şahin, M., Seber, G., Kırcalı, Ö.F., Yaman, Y.,
"Active Flutter Control of a Smart Fin",
ICAST 2008, 19th International Conference on Adaptive Structures and Technologies,
6-9 October, 2008 Ascona, Switzerland

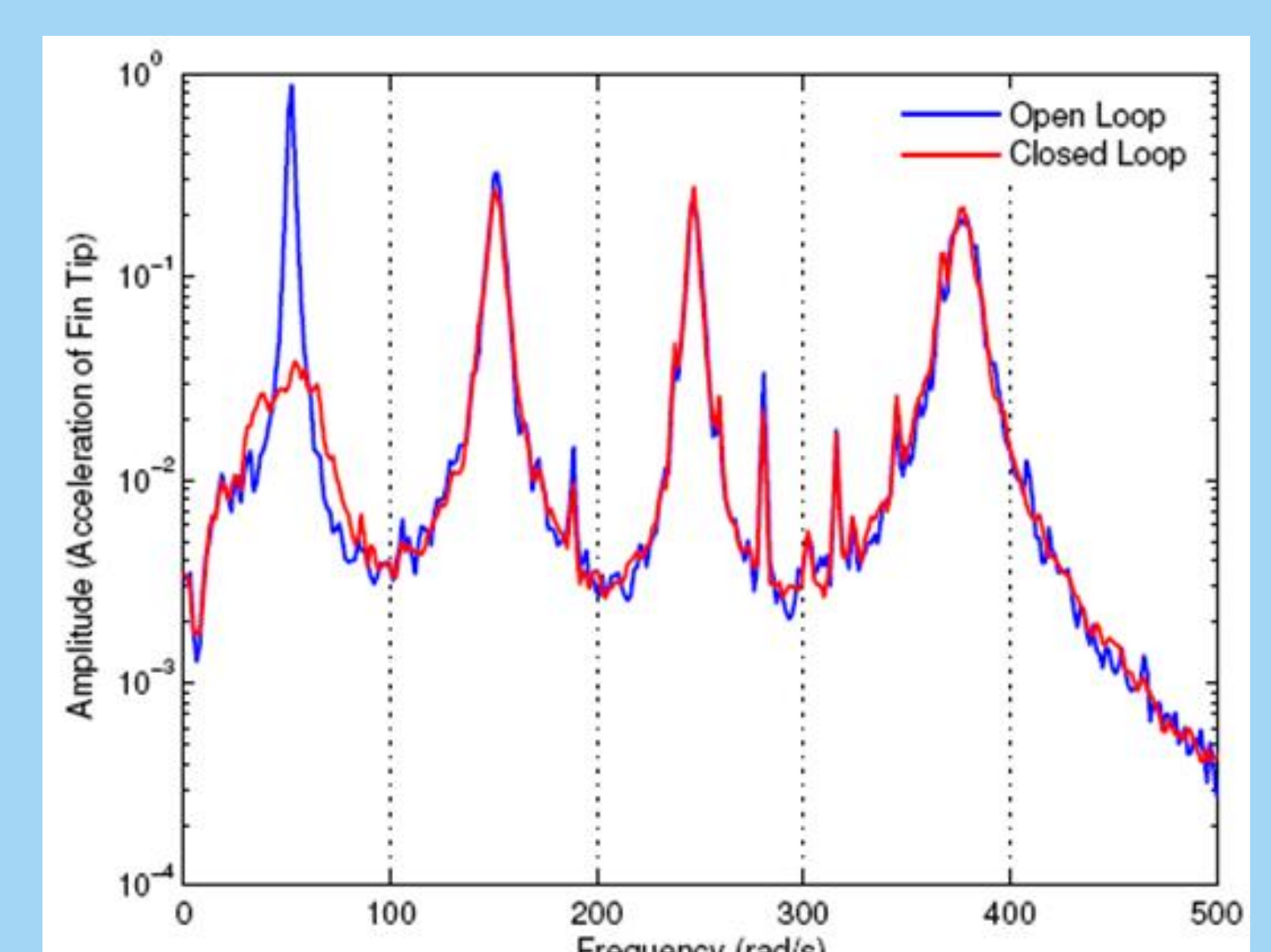The following joint abstract was also submitted to AIAA/SDM Conference :

1) Ülker, F.D., Nalbantoğlu, V., Chen, E., Zimcik, D., Yaman, Y.,
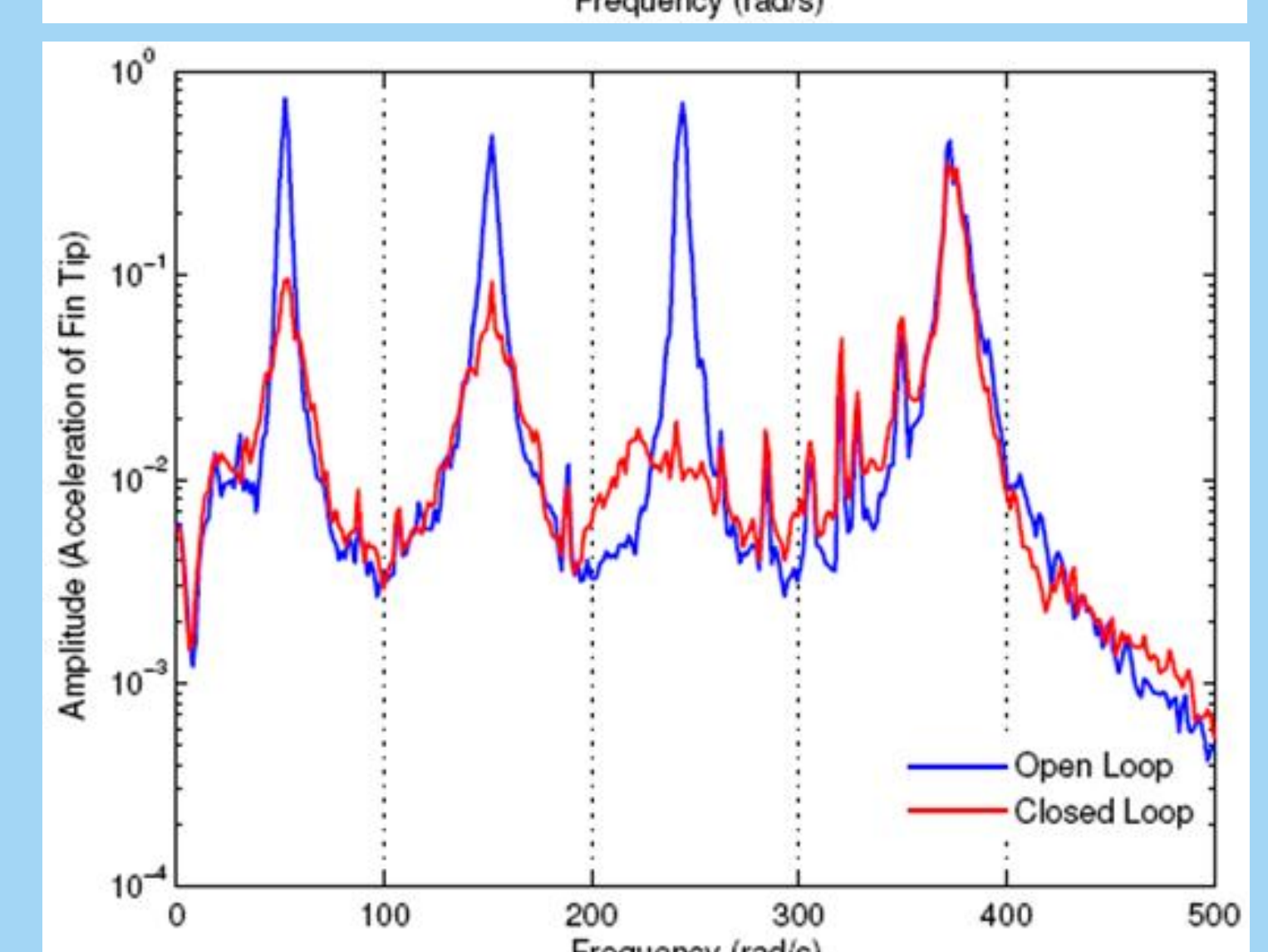"Active Vibration Control of a Smart Fin"

Open and Closed Loop Comparisons for the Vibration Levels at 0º Angle of Attack at V=10 m/s
(a) Controller 1 (b) Controller 2