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Active Vibration Control of a Plate When Subjected to Aerodynamic Loading

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Abstract—*This research study deals with the utilization of piezoelectric actuators in controlling the structural vibrations of flexible structures when subjected to aerodynamic excitation. Active vibration control of a cantilevered plate has been considered using piezoelectric sensor and actuator and simulated using finite element analysis. The strain at the sensor mounted on a vibrating plate was measured in terms of voltage at the designated nodes. A controller with suitable gains is used to apply voltage to the actuator thereby controlling the vibrations. Highlight of this study is that the voltage is directly sensed using the piezo element and the control voltage is directly applied with appropriately designed controller to dampen the vibrations. The damping behavior improved with the increase of controller gains up to an extent.*

1. INTRODUCTION

Flexible structures are lightly damped due to material and structural properties. This may sometimes lead to instability and affect the behaviour and performance of structure .The project investigates a new structural damping technique to suppress transient and steady state vibrations of flexible structures. A model of flexible structure has been designed and subjected to simulated aerodynamic loading. Active vibration control (AVC) is used to eliminate undesired vibrations using piezoelectric structures for sensor and actuator applications.

Wind is a randomly varying dynamic phenomenon. The wind velocity 'V' can be taken as mean plus fluctuating component responsible for creating gustiness. While dealing with rigid structures, the consideration of equivalent static load is adequate but in the case of flexible structures, the consideration of the wind energy spectrum as well as frequency of the structure becomes important. The wind load introduced by wind turbulence on vertical beam was numerically generated as a random pressure field obtained by the multiplication of squared velocity field by the pressure coefficient and the air density Betti et al [1]

$$P(x, y, t) = \tfrac{1}{2}\rho c_p v^2(x, y, t)$$

The spectral function of the velocity has been by means of a von Karman auto-spectral density with exponentially decaying coherence and phase angle by Simiu and Scanlan [2]. Among the more popular advanced optimization techniques for control/robust control are, PD Controller, Linear Quadratic regulator and LQG controller, H_∞ Controller. Baz and Ro [3] demonstrated active control of beam by PD controller. Azvine et al [4] used velocity feedback for a cantilevered beam. The velocity was measured at the tip of the beam whereas actuation was applied at the root of the beam. Rongong et al [5] and Varadan et al [6] have used both velocity and displacement feedback. Naveen [7] used derivative control on ACLD beam and curved panels. Park et al [8] have used proportional and derivative control for controlling first two modes of an actively controlled plate.

2. SIMULATION SET UP

A FE model is utilized in the evaluation of the optimal active vibration control of a cantilever steel plate with an symmetric collocated piezoelectric sensor/actuator pair mounted on the surface (Fig. 1).

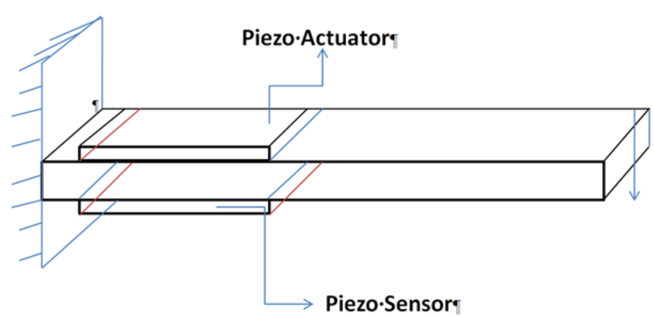

Fig. 1: Plate with Piezo Patches

Furthermore, the displacement time history, for impulse load and a simulated aerodynamic force on the face of beam is, evaluated with the open- and closed-loop systems. The aerodynamic force was simulated for wind velocity of 60m/sec with 5% turbulence.

In this case, the sensing and actuation effects of a collocated sensor/actuator pair are asymmetric with respect to the mid-plane of the beam. The output of the sensor is used for feedback to actuator through PD controller. The proportional gain is g_d and the derivative gain is g_v.

The cantilevered plate is 125 mm long, 1.0 mm thick and 20 mm wide, and the two piezoelectric patches are 45 mm long, 0.4 mm thick and 20 mm wide, and were mounted at 1 mm from the clamped edge.

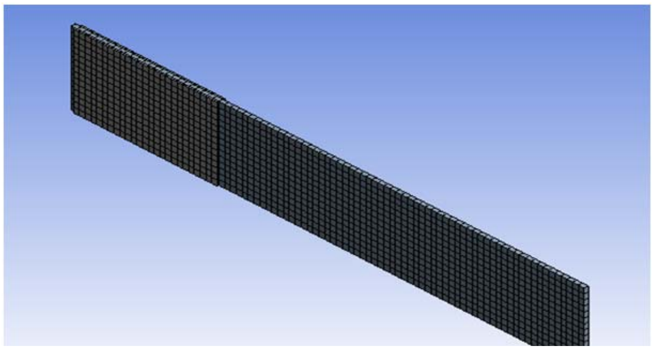

Fig. 2: Model of the plate in ANSYS with Piezo sensor and actuator

The plate was modeled in ANSYS using plate model and the piezo electic-properties are modeled in Piezo-ACT extension.

3. RESULTS AND DISCUSSION

The simulations for control of the plate vibration were run under two cases. First being a simple impulse load, which gives the decay plot of the plate under free vibration condition after the impulse? This can be used to evaluate the damping. Then the results are extended for simulated aerodynamic loading with a mean wind velocity and a gust component of 5% and 10%.

Impulse Load

In the first case, an impulse load in the form of a triangular impulse with magnitude 6 N and a base span of 0.004 seconds was applied to the structure. The impulse load is applied on the tip of the beam at the load which is centrally located width wise. Thus no torsional modes were activated. The response time history evaluated using ANSYS transient package is as shown in Fig. 3.

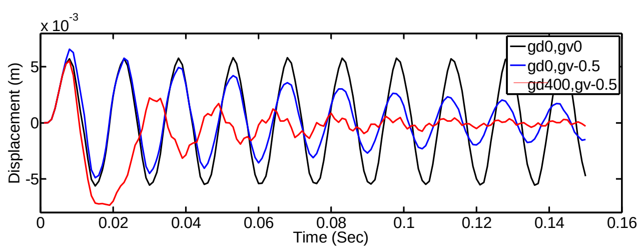

Fig. 3: Time v/s Displacement for Impulse Load

The plots in Fig. 3 has been obtained for impulse load with different values of control gains g_d = 0, 400 and g_v = 0, 0.5

The impulse excitation has been applied to the plate in ANSYS. The decay rate increases with increased in the velocity gain. At zero gain the damping is almost zero, since no passive damping was taken. At g_v= 0.5, the damping ratio obtained is 0.0241 while at g_d=400; g_v= 0.5, the damping value is 0.048. The FFT analysis of above time v/s displacement data is plotted at Fig. 3

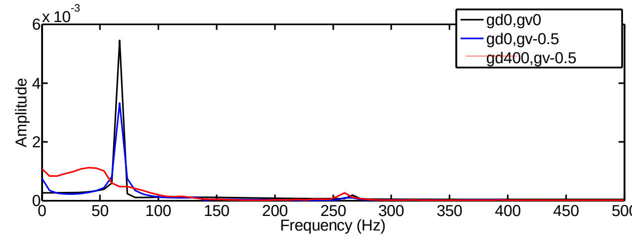

Fig. 4: FFT for Impulse Load

The frequency observed after FFT, as shown in Fig. 4, for gd=0:gv=-0.5 are 66.67 Hz and 260Hz. It is seen that the first two natural frequencies at 66.67 Hz and 267 Hz are present in the signal.

Simulated Aerodynamic Load

The pressure load is applied on lower face of beam. The load time history is at Fig. 4. It can be seen that the load time history contains a steady aerodynamic load along with a gust component which is assumed in the form of a random signal. The signal strength of the random component is taken as 5% and 10% in two different cases.

The corresponding response time history of the plate tip is shown in Fig. 6.

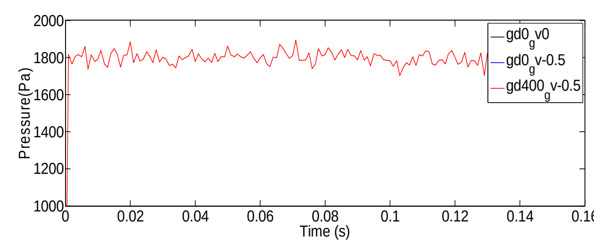

Fig. 5: Aerodynamic Load v/s Time

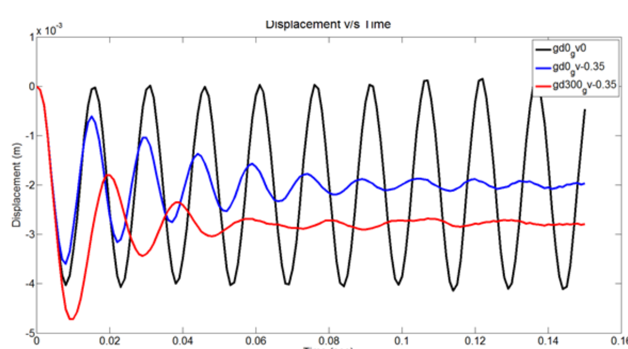

Fig. 6: Displacement Time response for Aerodynamic Load with 5% fluctuation.

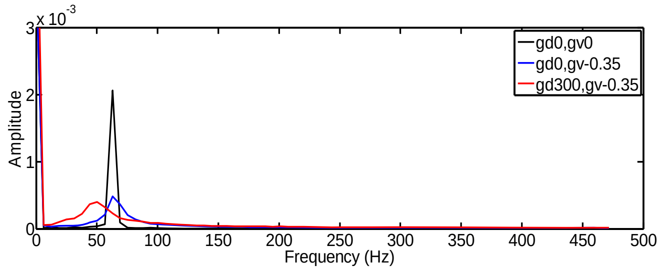

Fig. 7: FFT for Impulse Load

The frequency observed at Fig. 7after FFT for gd=0: gv=0 ,-0.35 is 62.89 Hz. The frequency observed after FFT for gd=300: gv=0.35 is 50.31 Hz. One can notice that the steady values dominate the Fig. the random fluctuations are seen quite small especially when the controller is active. For a wind sample with 10% amplitude of the random fluctuation and a gain set of g_v=0.35 and g_d = 0, the random fluctuations are slightly higher as seen in Fig. 8.

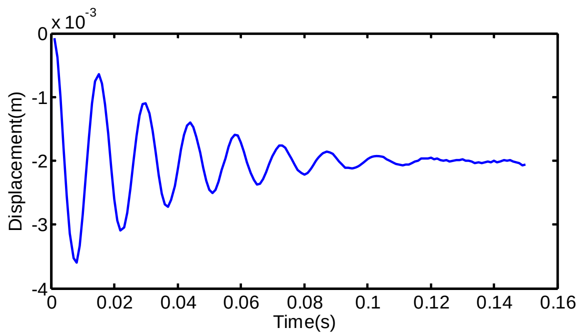

Fig. 8: Displacement Time response for Aerodynamic Load with random variations at 10% of steady amplitude, gd=0: gv=0.35.

4. CONCLUSIONS

The above simulation was carried out using ANSYS software.

The plate is subjected to impulse loads and random loads simulating air loads on plate at 60m/Sec with 5% turbulence.

The feedback force is applied using proportional and derivative gains. The feedback with proportional gain is voltage whereas it is rate of change of voltage with derivative gain. The derivative gain shows improvement in performance over proportional gain. Under the action of random loading, the response of the plate tends towards a steady value as governed by the steady load while the small random fluctuations keep operating and die out. However in the absence of the controller, the transients take a lot to time to die out fluctuating response persists for a long time. Further work is being needed to improve the control algorithms.

REFERENCES

[1] Betti M., Baniotopoulos C.C.,Stavroulakis G.E.,2006,*Topics on Mathematics for Smart Systems; proceedings of the European conference*, Rome, Italy, Oct 26-28,2006, pp 61-75.

[2] Simiu E.,Scanlan R.H.,1996, Wind effect on structures *John Wiley & Sons, New York.*

[3] Baz A.,Ro J.,1994,The concept and performance of active constrained layer damping treatments, *Sound and Vibration magazine*,20,18-21.

[4] Baz A.,Ro J.,1994,The concept and performance of active constrained layer damping treatments, *Sound and Vibration magazine*,20,18-21.

[5] Azvine B., TomlinsonG.R.,Wynne R.,1995,Use of active constrained layer damping for controlling resonant vibrations, *Smart Materials and Structures* , 4(1),1-6.

[6] Rongong J.A., Wright J.R., Wynne R.J., Tomlinson G.R., 1997, Modeling of a hybrid constrained layer/piezoceramic approach to active damping, *Journal of vibration and Acoustics* , 119(1), 120-130.

[7] Varadan V.V.,Lim Y.H.,Varadan V.K.,1996,Close loop finite element modeling of active/passive damping in structural vibration control, *Smart materials and Structures* 5(5), 685-694. [8]

[8] Kumar Naveen,2007,Vibration control of panels using hybrid active-passive constrained layer,*Ph.D. thesis, Department of Mechanical Engineering*, IIT Delhi, India.

[9] Park C.H., Baz A., 1999, Vibration control of bending modes of plates using active constrained layer damping, *Journal of Sound and Vibration*, 227(4), 711-734