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DESIGN OF A TUNED VIBRATION ABSORBER (TVA) FOR APPLICATIONS IN TRANSPORT ENGINEERING

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ABSTRACT

The control of the response to tonal excitations or to broadband stochastic disturbances of a stiffened cylinder is investigated through the use of a Tuned Vibrating Absorber (TVA). In particular, the study considered both a purely passive device (Mechanical) and a semi-active one with shunt circuit (Electro-Mechanical) to evaluate the efficiencies and differences.

1 INTRODUCTION

Noise can both annoy and have potentially harmful effects on passengers but can also lead to damage and failure of aircraft components. In fact, lightweight structures, such as the aeronautical ones, are characterized by significant vibrations and acoustic radiation problems and hence the adoption of a mechanical and/or control treatment, new material, or control device is needed to mitigate vibrations in structures [1]. Vibration control solution can be classified in three categories with respect to the external energy supply: i) passive control devices and treatments, which aim is to modify the response of the system to make it less sensitive to external excitation; ii) active control devices, which require an external source of power to work; iii) semi - active control devices, which update their parameters with environmental or working changing conditions. Both passive and semi-active solutions do not inject energy into the hosting system [2]. In this paper several numerical analyses, and in particular tonal and broadband optimization [3], have been performed for two different classes of TVA (mechanical and electro-mechanical), different number of devices and for different parameters. The devices have been applied on a stiffened cylinder.

2 NUMERCIAL INVESTIGATION

The structural analyses of the stiffened cylinder were performed using NX NASTRAN solver to obtain Modal Parameters and Frequency Response Functions (FRF). The FRFs of the cylinder were obtained also in MATLAB, by importing NX NASTRAN modal analysis results of the cylinder, using the Modal Formulation and Mobility-Impedance procedures. Furthermore, the latter one, allows to totally control TVAs parameters and for this reason it has been the most used. Different analyses were performed, using a constant additional mass value (5% of total weight) but a different number of devices. This mass value has been divided for the number of the devices used to perform all the analyses and the best results have been obtained in the case of using 16 devices. The structural parameters of the host structure and its model developed in commercial software FEMAP are reported in Table 1 and in Fig. 1.

Length, [mm]	2500
Radius, [mm]	500
Stringer section, 5 series [mm x mm]	10x10
Frame section, 6 series [mm x mm]	20x10
Thickness of panels, [mm]	2

Table 1 – Geometrical parameters of the host structure for TVA application

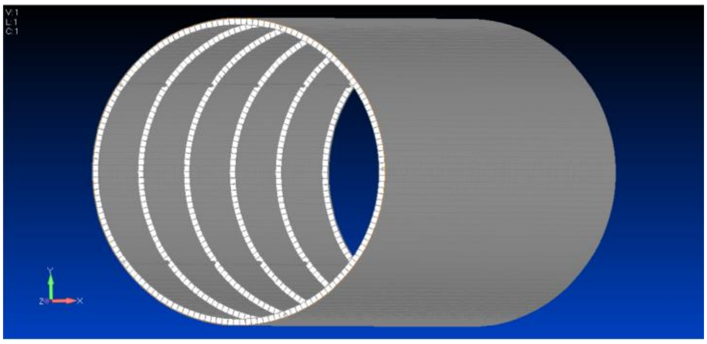

Figure 1 – FE model of the stiffened cylinder

3 TONAL OPTIMIZATION

With the tonal optimization, the device is tuned at a specific frequency which can be either a resonance target frequency or an off-resonance target frequency. In any case, to perform the tonal optimization, with both device classes (mechanical and electro-mechanical) , the following procedure has been adopted:

- Upload the Modal Analysis result in Matlab of the plain structure;
- Use the actual configuration of TVAs to study the kinetic energy variation, at the interested frequency, with the change of critical damping ratio of the device (ζ_{TVA}) parameter;

This procedure has been used for all TVA configurations (2-4-8-16-32 devices) and at specific frequencies of interest (80 Hz, 89 Hz -resonance frequency-, 93 Hz, 97 Hz -resonance frequency-, 105 Hz). The results obtained, by using 16 devices, at resonance target frequencies (89,34 Hz and 97,9 Hz) for mechanical and electro-mechanical (E-M TVA) devices are reported in Figures 2 and 3, respectively. For the E-M TVA, in particular, different analyses have been performed for different values of the mechanical damping.

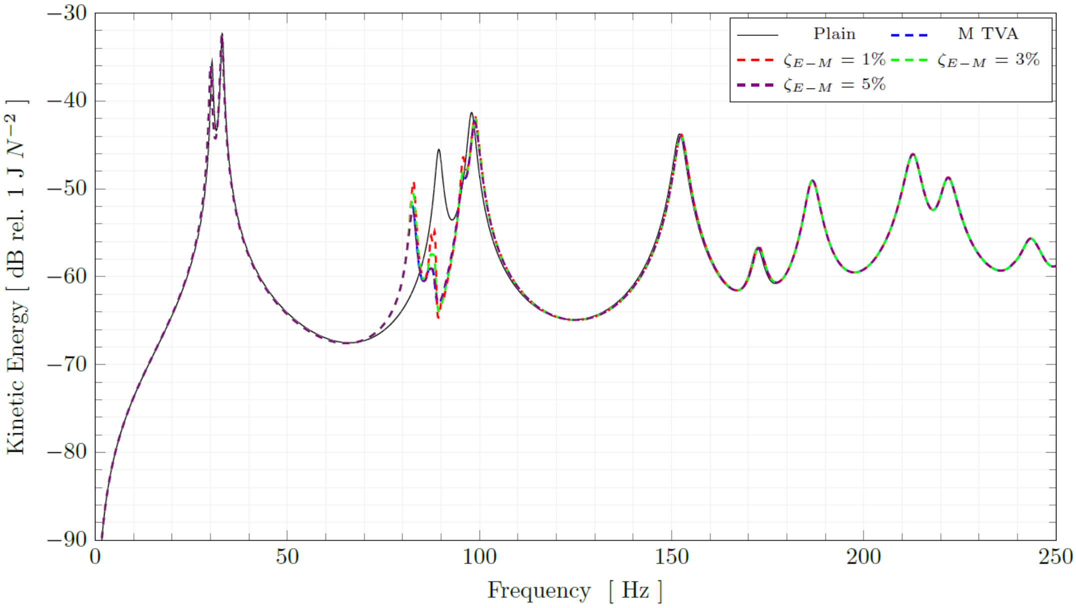

Figure 2 - Tonal optimization results obtained at 89.34 Hz with M-TVA and E-M TVA

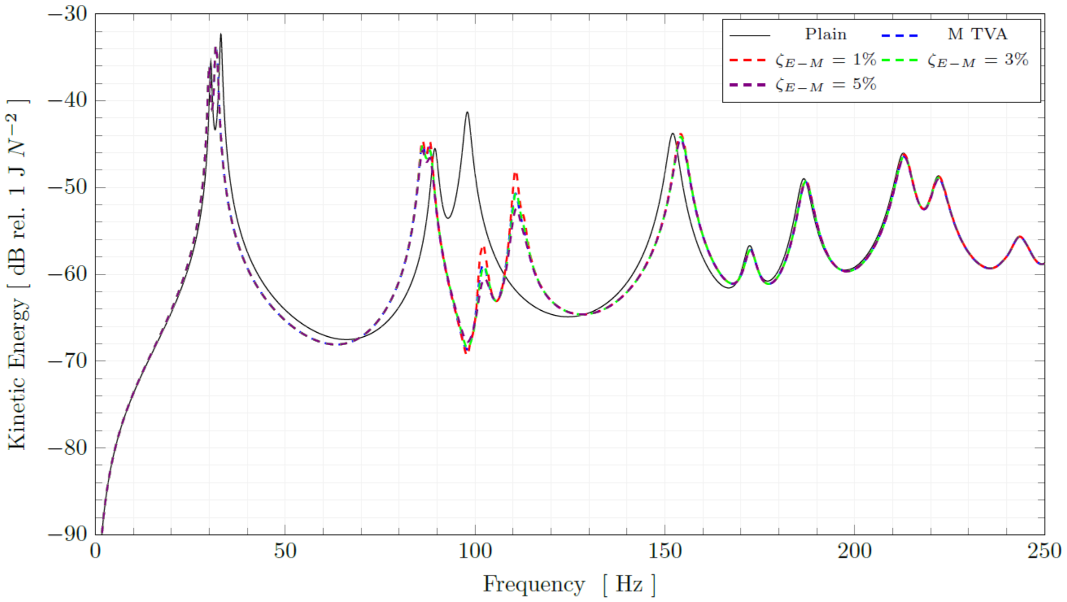

Figure 3 - Tonal optimization results obtainet at 97.9 Hz with M-TVA and E-M TVA

3 BROADBAND OPTIMIZATION

In case of Broadband optimization, the energy content within a specific frequency content is controlled. In this application, two different bands have been analyzed : 70-110 Hz and 75-115 Hz. The procedure adopted to perform this study is almost the same with respect to the previous case. The only differance concerns the variable to be investigated. In fact, in this case, the mean integral value of the kinetic energy is studied with the change of the ζ_{TVA} value of the actual TVA configuration used. The results obtained, by using 16 devices, for the 70-110 Hz and 75-115 Hz bands are respectively reported in Figs. 4 and 5.

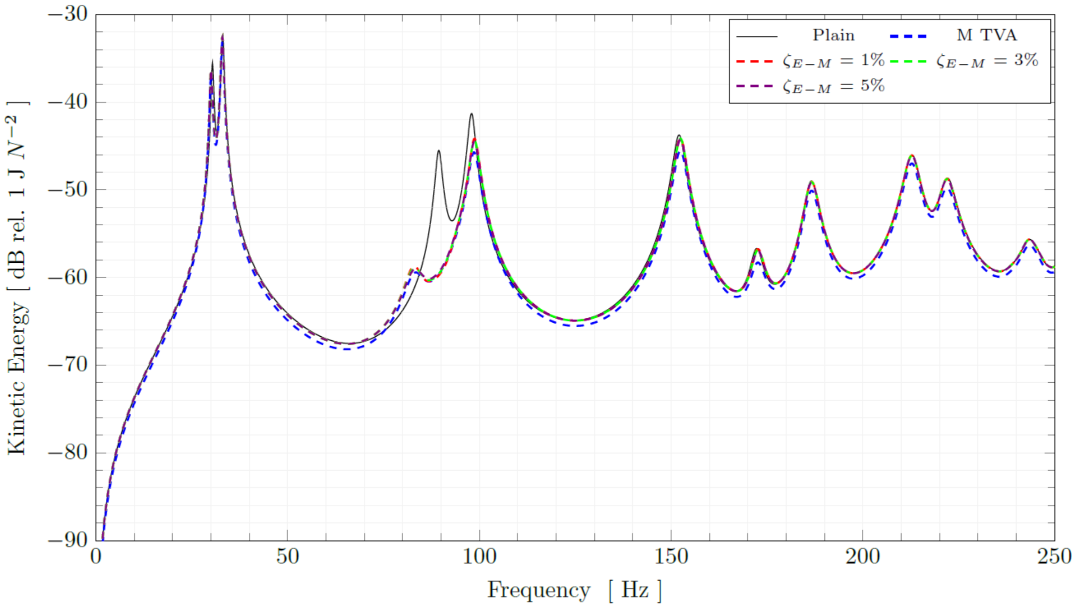

Figure 4 - Broadband optimisation results obtained in band 70–110 Hz with M-TVA and E-M TVA

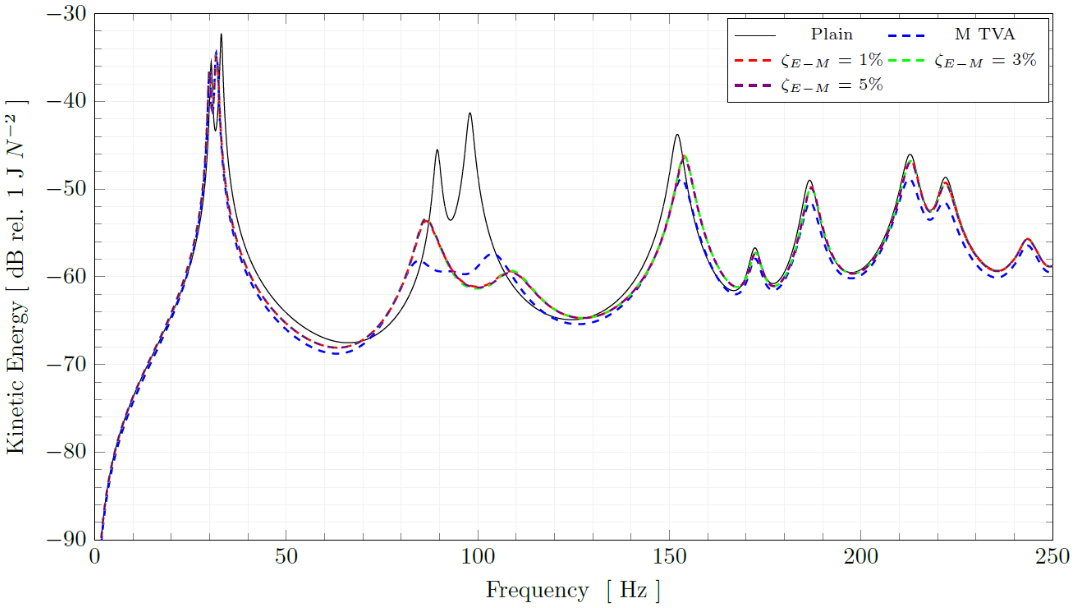

Figure 5 - Broadband optimization results obtainet in band 75 – 115 Hz with M-TVA and E-M TVA in the configuration of 16 devices

4 CONCLUSION

From the observation of the numerical results it can be observed a similar behaviour of M-TVA and E-M TVA when applied on the host structure. The main difference is that the M-TVA is a passive device that does not need any supply energy (i.e. no additional weight for the external power supply).. On the other hand, E-M TVA are semi-active devices and so they do not introduce energy into the system (as in active vibration control), but they anyway need a power sypply for the electrical part of the shunt and are reliable devices. Furthermore, actual technological improvements allow to produce high-performance devices at low cost and with small weight and make them more attractive to this kind of applications. Even because, with electrical control it is possible to change the characteristic parameters of E-M TVA to fit the device to different enviromental and structural conditions.

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