EXPERIMENTAL AND NUMERICAL COMPARISON OF VISCOELASTIC MATERIAL DAMPING TO EQUIVALENT MASS AS ACOUSTIC TREATMENT TO AIRCRAFT COMPOSITE FUSELAGE STRUCTURE UNDER VARIOUS EXCITATIONS

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1. INTRODUCTION

Passive noise control treatments are used widespread in aircraft industry. A typical passive aircraft noise treatment (or sound package) is made up of a combination of viscoelastic damping and low density porous materials. A sound package is used to minimize the direct transmittance of sound waves (airborne) and radiation of noise (structure borne) into aircraft cabin interior.

Viscoelastic material damping is applied to fuselage skin and/or trim panel to increase transmission loss at natural frequencies and resonances and is normally applied as constraining layer damping (CLD). The viscoelastic damping characteristics are directly linked to material composition and processing, including the degree of cross-linking and the type of fillers such as carbon black [1]. The characteristics also vary with temperature and to a lesser degree with frequency.

Porous materials such as foam and fiber glass are effective noise attenuators at frequencies higher than 500 Hz depending on the thickness. For low frequency sound energy attenuation, heavy damping is used. Increased mass reduces the resonant frequencies. One issue with damping is that since the dampers are uniform materials, at resonant frequencies whole material moves which in turn may result in transfer of energy to coupled structures and cause radiated noise.

Distributed mass in porous material has been found to increase transmission loss and act as damper. Idrisi et al. [2] numerically and experimentally investigated the effect of heterogeneous blankets in reducing radiated noise in a double panel system and found that the performance of the heterogeneous blanket based on the design (location of the masses) varied with the best performer attenuating 12.5 dB and the median performer attenuating 2.6 dB in sound radiation in the 0-500 Hz frequency range. Sgard et al. [3] also investigated both numerically and experimentally the significance of heterogeneous blankets in dissipating vibro-acoustic energy. In this investigation, the major conclusions included: mass inclusions equivalent to 7% of panel weight increased energy dissipation at low frequencies up to 150 Hz. Furthermore, Kidner et al [4] investigated the effect of mass inclusions to poroelastic layer and found that the insertion loss of standard acoustic blankets can be significantly improved at low frequencies. Esteve [5] showed that optimally damped vibration absorbers and optimally damped Helmholtz resonators reduce sound transmission into payload fairing at low frequencies.

The work presented in this paper is part of a research project with a main objective of investigating the effect of equivalent masses within porous materials to the effect of viscoelastic material damping as part of sound packages as treatment to carbon composite panel. In this paper, acoustic performance of sound packages with CLD is compared numerically and experimentally to performance of sound packages with mass layer equivalent to the mass of CLD. The parameters compared were airborne insertion loss (ABIL) and radiation efficiency.

2. METHOD

Transmission loss and radiation efficiency measurements were made in order to compare the sound transfer properties of CLD to equivalent mass layer on a representative fuselage skin composite panel. TL measurements were performed according to ISO 140-3 1995 standard. 2.66 mm thick, 1.13 m by 1.8 m flat composite panel was excited using point force mechanical excitation for radiation efficiency tests and diffuse field excitation for transmission loss tests. Nova software using the FTMM numerical method (developed at the University of Sherbrooke) was used to perform the calculations. Sound package configurations tested are listed in Table 1.

Table 1: Sound package configurations

Sound package ID	Configuration (B: brick, FB: frame blanket, TC: top cover, CLD: carbon constraining layer damping)	% panel weight
cbare	Bare ribbed carbon composite panel	
CLD	Bare with 53% coverage CLD	39%
CLD+B+FB+TC	53% CLD + B(0.75” foam) + FB(1.75” foam) + TC(0.5” foam)	54%
B+FB+mass+TC	B(0.75”foam) + FB(1.75” foam) + 0.06” mass layer + TC(0.5” foam)	46%

3. RESULTS AND DISCUSSION

The comparison of CLD to equivalent mass layer in terms of measured mass corrected ABIL plots is shown in Figure 1. The sound package configuration with mass layer (cbare+B+FB+mass+TC) shows a double wall effect and is superior to the configuration with damping in the frequency range of 250 to 5000 Hz. The double wall resonance effect is seen in the third octave frequency range of 100 to 200 Hz.

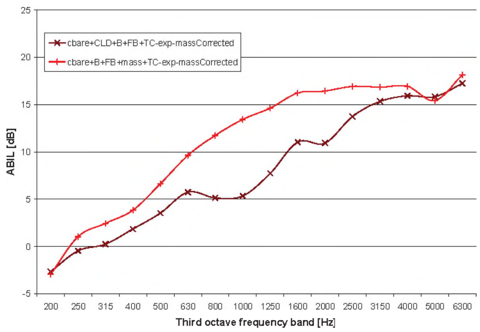

Figure 1: Comparison of experimentally obtained ABIL plots for sound packages cbare+CLD+B+FB+TC and cbare+B+FB+mass+TC

In Figure 2, radiation efficiency plots for cbare+CLD+B+FB+TC and cbare+B+FB+mass+TC are compared. Again, sound package configuration with mass layer shows superior performance with less radiation efficiency in the frequency range of 250 to 6300 Hz.

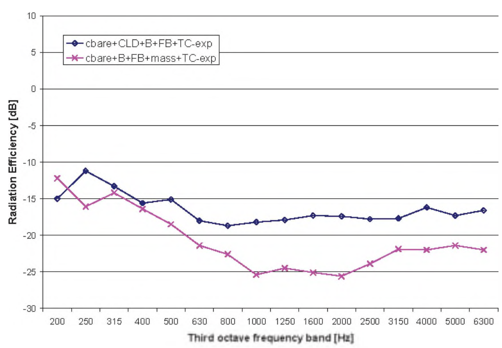

Figure 2: Comparison of experimentally obtained radiation efficiency plots for sound packages cbare+CLD+B+FB+TC and cbare+B+FB+mass+TC

ABIL plots obtained experimentally and numerically are compared in Figure 3 for cbare+B+FB+TC configuration which shows a close match. Similarly, the radiation efficiency plots for the cbare+B+FB+mass+TC sound package configuration shown in Figure 4 are closely matched.

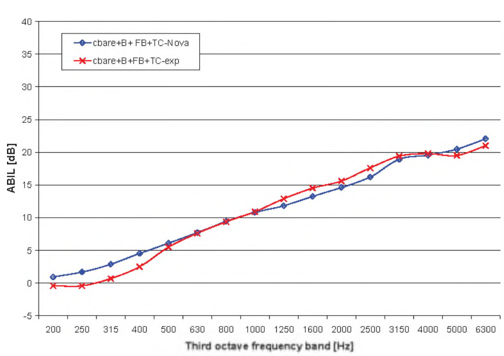

Figure 3: Experimentally and numerically obtained ABIL plots for cbare+B+FB+TC configuration

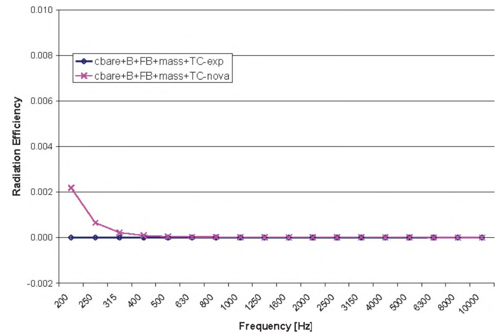

Figure 4: Experimentally and numerically obtained radiation efficiency plots for cbare+B+FB+mass+TC configuration

The sound package configuration with equivalent mass layer produced 3.6 dB measured and 5.1 dB numerical improvement over the sound package configuration with CLD in terms of the average of ABIL at octave 1000, 2000 and 4000 Hz as listed in Table 2.

Table 2: Average ABIL results for the carbon composite panel sound package configurations

Sound package	Average of measured ABIL at 1k, 2k, 4k Hz 1/1 octave	Average of numerical ABIL at 1k, 2k, 4k Hz 1/1 octave
cbare+CLD	8.6	6.5
cbare+CLD+B+FB+TC	19.9	21.7
cbare+B+FB+mass+TC	23.5	26.8

4. CONCLUSIONS

The acoustic performance of sound packages with viscoelastic material damping and equivalent mass were compared. Based on the experimental comparison, equivalent mass acoustic performance was found to be superior to damping. The experimental results were numerically validated to be used in optimization in the future. The experimental set-up was suitable for measurements at frequencies higher than 200 Hz.

REFERENCES

[1] M.D. Rao, *Journal of Sound and Vibration* 262 (2003) 457-474.

[2] K. Idrisi, M. Johnson, J.P. Carneal, *NOISE-CON 2007*, Reno, Nevada, 2007.

[3] F.C. Sgard, N. Atalla, *PACS* subject classification number: 43.50.Gf.

[4] M.R.F. Kidner, C.R. Fuller, B. Gardner, *Journal of Sound and Vibration* 294 (2006) 466-472.

[5] S.J. Estève, Control of sound transmission into payload fairings using distributed vibration absorbers and Helmholtz resonators, Ph.D. thesis, Virginia Polytechnic Institute & State University, 2004.