PASSIVE NOISE CONTROL ORIENTED DESIGN OF AIRCRAFT HEADRESTS

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ABSTRACT

Two Passive Noise Control (PNC) concepts were numerically evaluated in terms of their impact on the Sound Pressure Level (SPL) perceived by passengers of an aircraft flight.
A concept was based on the shape optimization of the headrests, whereas the second one was based on the adoption of a high absorbing material, i.e. a nanofiber textile, to improve the acoustic performances of the headrests.
To this aim, an aircraft seat was modelled with the Boundary Element Method (BEM) and loaded with a spherical distribution of monopole sources surrounding the seat. Different configurations of headrest shape and covering textiles were then compared in terms of the SPL calculated at passengers' ears.
The work shows how an acoustic-oriented design of the aircraft headrests could achieve an average SPL reduction for passengers up to 3 dBA.

1 INTRODUCTION

This work presents the development of two Passive Noise Control (PNC) concepts aiming at improving the acoustic comfort inside an aircraft cabin via numerical simulation. A concept is based on the shape optimization of the seats' headrests to reduce the Sound Pressure Level (SPL) perceived by passengers. The second concept is based on the adoption of a high absorbing materials, i.e. nanofibrous textiles, to improve the absorbing performances of the headrests, thus in turn reducing the perceived SPL.

To simplify the Design of Experiment (DoE), the current numerical simulations were performed considering the turbulent boundary layer aero-acoustic load as the unique noise contributor. The related data was available from [1] and has been here adopted as acoustic load applied around a single aircraft seat modelled with the Boundary Element Method (BEM). Such BEM model was then used to evaluate different configurations of headrest shapes and headrest covering textiles, i.e. a nanofiber textile [2-3], in terms of their acoustic performances.

Application of the BEM to problems in solids and structures can be found in [4-5] whereas some applications in aeronautic and railway fields can be found in [6-7]. In particular, in [6] a FEM-BEM modelling technique was used to predict the vibro-acoustic response of an aircraft fuselage, whereas BEM was used in [7] for the acoustic scattering of large and complex aircraft.

2 NUMERICAL ANALYSES

The starting CAD model of two aircraft seats adopted for the acoustic assessments o is shown in Fig. 1a. Such CAD model was imported in VA One [8] and a simplified BEM model was created, see Fig. 1b. Preliminary BEM analyses were aimed at reducing the size of the BEM model to handle and the resulting BEM modelling is here presented. Such "baseline" model comprised only one seat with cushion, backrest and headrest; the whole supporting structure did not give any appreciable contribute to the SPL calculated at passengers' ears height, therefore its modelling was neglected.

The final BEM model comprised nearly 7000 linear boundary elements with an average size equal to 14 mm, thus 6 elements per wavelength were used at maximum frequency of 4 kHz. The BEM fluid was air with bulk modulus equal to 142,4 kPa and mass density equal to 1,21 kg/m^3.

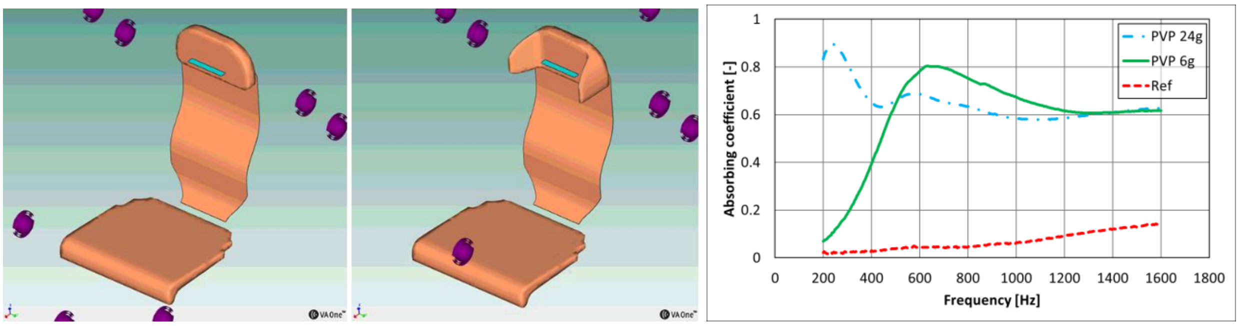
Two different shapes for the headrest were considered on such baseline model (Fig. 2); such shapes were representative of the smallest and largest headrest that were envisaged for such a headrest shape optimization process. Moreover, various combinations of headrest shapes as well as headrest covering textiles were considered as part of the design of experiment. For all the simulations, the same data recovery surfaces (Figs. 1-2) were considered as the areas on which the SPLs were output. Such SPLs were then compared among the various configurations allowing to realize how much the impact of both, geometry and fabric, would be on the passengers' perceived noise.

The headrest was considered as covered by different textiles: a traditional one, termed "reference", and two new-generation nanofibrous textiles [2-3], whereas the backrest and cushion were covered with the reference textile for all the analyses. The related absorbing coefficients are shown in Fig. 2c. All the material data were obtained experimentally using a Kundt's tube.

The BEM simulations were performed across a frequency domain of 200 ÷ 4000 Hz, with a 200 Hz constant bandwidth. All the analyses were based onto several uncorrelated monopole sources located at equal distance of 2 m from the centre of the backrest's surface. Such sources were positioned spherically, so as to reproduce a diffuse acoustic field surrounding the seats. All the monopoles were set up in such a way to generate a pressure distribution providing a SPL at the data recovery surfaces equal to that calculated by the full SEA modelling of the fuselage [1].

(a) (b)

Figure 1: (a) CAD model of two aircraft seats; (b) simplified BEM model of one seat surrounded by the monopole sources.



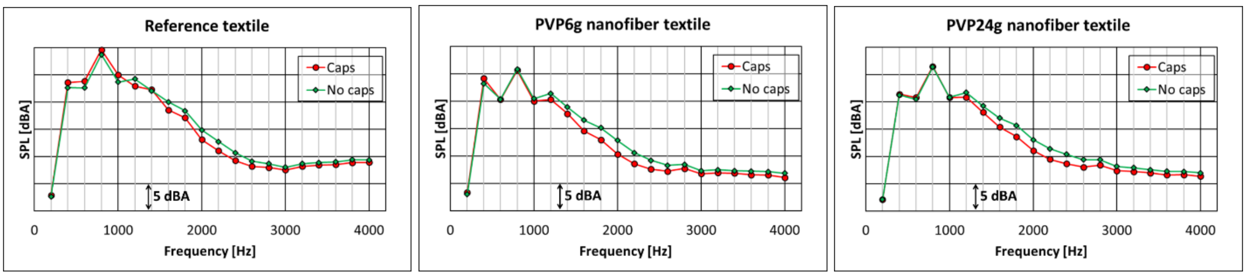
(a) (b) (c)

Figure 2: BEM model with headrest (a) without caps or (b) with caps; data recovery surfaces to output the SPLs shown in azure; (c) acoustic absorbing coefficient for textiles.

3 RESULTS

Results in terms of SPL were calculated on the data recovery surfaces (Figs. 1-2), so as to represent the average SPL that the passenger perceives as cabin interior noise. Fig. 3 shows the aforementioned SPL values for various configurations of headrest shape and headrest covering textile.

Such results demonstrated that using both, a headrest and an appropriate absorbing material, it was possible to reduce the SPL values perceived by the passengers. In particular, the usage of a headrest with lateral caps seemed to provide significant advantages only when used in combination with high absorbing covering textiles such as the here considered nanofibrous textiles.



(a) (b) (c)

Figure 3. SPL [dBA] on the data recovery surfaces considering headrest with/without caps and surface impedance of: (a) reference textile, (b) PVP6g nanofiber textile, (c) PVP24g nanofiber textile

4 CONCLUSIONS

The two PNC concepts of headrest shape optimization and covering textiles demonstrated to be effective in lowering the noise perceived by the passengers inside the cabin of an aircraft turboprop.

The adoption of a headrest with lateral caps seemed to play a positive effect for all the frequencies higher than 1 kHz. The adoption of high absorbing materials, such as the nanofibrous textiles, turned out to be effective in lowering the SPL perceived by passengers.

It is worth noting that the adoption of the PVP24g nanofibrous textile allowed an interesting noise reduction (-1 dBA) even at frequency as low as 200 Hz, thus foreseeing the possibility to adopt PNC even at such low frequencies. At higher frequencies, the adoption of a nanofibrous textile allowed a reduction in SPL up to nearly 3 dBA. For high frequency, the adoption of PVP6g seemed to be the most effective since the it demonstrated to be the most performant and also lightweight textile.

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