Effectiveness of Adjacent Reactive Absorbers

In some sound absorption applications it is necessary to use more than one reactive absorbers (such as quarter-wave tubes or Helmholtz resonators) all tuned to the same frequency. Close placement of these resonators can have an adverse impact on their effectiveness. When such devices are placed along the direction of variation in shape of the mode targeted for damping, it is recommended that absorbers with similar resonant frequencies not to be located too closely, otherwise the full benefit of multiple resonators may not be realized.

The acoustic coupling between two adjacent resonators produces a shift in the resonant frequencies of the resonators creating two distinct frequencies; one lower and one higher than the original resonant frequency. The distinctness of the two resonant frequencies depends on the size of the resonators. Up to 15% alteration in the resonant frequency of a single resonator in duct has been reported in the literature. The "de-tuning" of the resonators lowers the effectiveness of the acoustic treatment, particularly when resonators are tuned to the same frequency.

To illustrate this effect, the performance of two quarter-wave tubes in adding damping to the 2nd mode of a closed-closed duct is analyzed using finite element modeling

Two quarter-wave resonators are tuned to the 2nd mode of the duct (207 Hz) and placed 0.15 m apart from each other in the middle of the duct. Figure 1 shows the mesh of the duct equipped with two adjacent resonators.

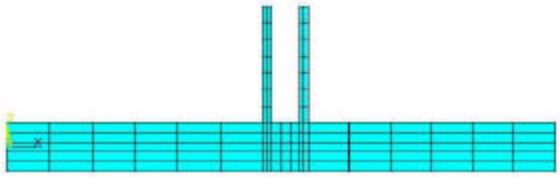

Figure 1 Duct equipped with two adjacent resonators

Figure 2 shows the pressure gradient (proportional to the rate of change of particle velocity) around the opening of the two resonators, at the tuning frequency of 207 Hz. The figure indicates that fluid is moving out of the resonator on the right into the resonator on the left. That is, the two quarter-wave tubes are resonating out of phase with each other. *When two out of phase excitation sources are placed closer than quarter of the wavelength corresponding to their resonant frequency, they tend to lower the effectiveness of one another by a dipole effect.* In other words, the effectiveness of two adjacent quarter-wave tubes is higher but is not twice as high as that of one tube.

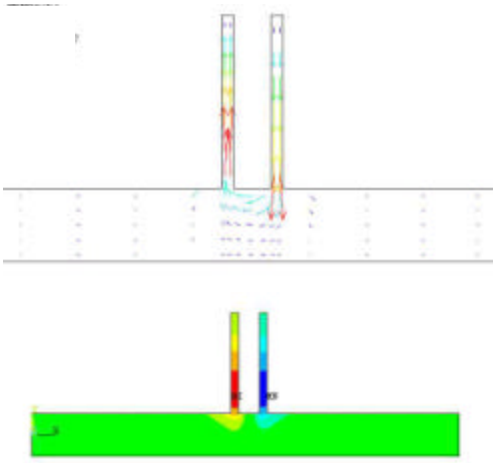

Figure 2 Pressure gradient of two adjacent quarter-wave tubes at the tuning frequency

In a parametric study, the effect of spacing between two quarter-wave resonators on their effectiveness was analyzed. The metric for this analysis was the abatement of pressure pulsation at one end of the duct due to the flow perturbation at the other end. In addition, the analysis was repeated using a single resonator with the equivalent cross-sectional area of the pair of resonators. The resonators were tuned to the 2nd resonant frequency of the duct at 207 Hz and were located at the middle of the duct to have high coupling with that resonance. They were placed 5, 10, and 15 cm apart (distance between the resonators). Since the separation distance were all smaller than quarter of the wavelength of the tuned frequency all three cases of separation of quarter-wave tube pairs had more or less the same effectiveness. A single quarter-wave tube having the equivalent cross-sectional area of the pair of tubes was more effective than the quarter-wave tube pairs.