SUPPRESSION OF ACOUSTIC RESONANCE IN PIPING SYSTEM USING PASSIVE CONTROL DEVICES

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1 Introduction

Generation of pressure pulsations in piping system is often arising from the use of reciprocating pumps and/or the dynamic instability of valves, which leads to unwanted noise and vibration problems [1]. When the frequencies of these pulsations match the resonant frequencies of the piping system, this may result in an acoustic resonance which can produce large pressure fluctuations, often several times the dynamic head of the flow in the main pipe, as well as vibration of the piping system and surrounding components. A commonly used technique to reduce these pulsations in the piping system is the use of passive acoustic dampers such as Helmholtz resonators, and quarter wavelength side-branches. The design of these devices is well understood from a theoretical standpoint [2]. Usually, they are large and problematic to implement at certain locations. Thus, this study aims to investigate the effectiveness of different passive control devices, specifically Helmholtz resonators and quarter wave side-branches for attenuation of pressure pulsations in piping system.

2 Experimental Setup

The experiments were conducted using a 3.740 m long PVC pipe of 0.1016 m internal diameter, Figure 1**.** A speaker (acoustic excitation source) is attached at the end of the pipe to excite its acoustic modes. Pressure fluctuations at two positions are measured using flush mounted condenser microphones. A single or a pair of Helmholtz resonators and quarter wave side-branches can be attached at several positions of the tubes. For the current experiments, two different sizes of Helmholtz resonators are used, one with a frequency of 108 Hz (HR108) and another with a frequency of 178 Hz (HR178). Also side branches (QW108 and QW178) are designed for suppression at the same frequencies.

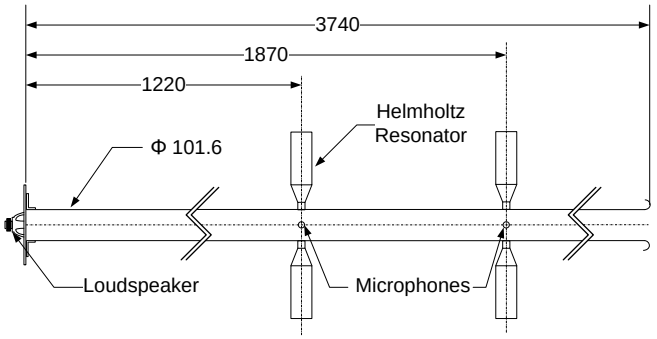


Figure 1 : Pipe parts assembled in one of the possible test configuration.

3 Results

3.1 Experimental results

The response of acoustic modes to attachment of several Helmholtz resonators is measured experimentally for several combinations of resonators at different positions, namely, at the middle of the pipe and at one-third of its length. The experiments show that placing the resonators at the middle of the pipe has a minor attenuation effect on the acoustic modes close to resonators frequencies. For example, with a single HR178 placed at the middle of the pipe, the 4th and 5th acoustic modes pressures, located at 168 Hz and 214 Hz are slightly changed with 16% increase and 10% decrease; respectively, compared to the base case where no Helmholtz resonators are attached. The same trend is also noticed with placing a HR108 at the middle of the pipe. On the other hand, when placing the resonators at one-third pipe length location far from the speaker, a more pronounced effect is obtained as shown in

Figure 2 for different combination of resonators. The attachment of several multiple Helmholtz resonators of the same size enhances the effect obtained from attaching a single resonator. This effect is found not to be a simple superposition as reported by Biswas and Agrawal [3] but it was found to follow a trend similar to a diminishing marginal utility. Also, the effect of attaching two different resonators is found to be a combination of the effect from attaching each of them alone.

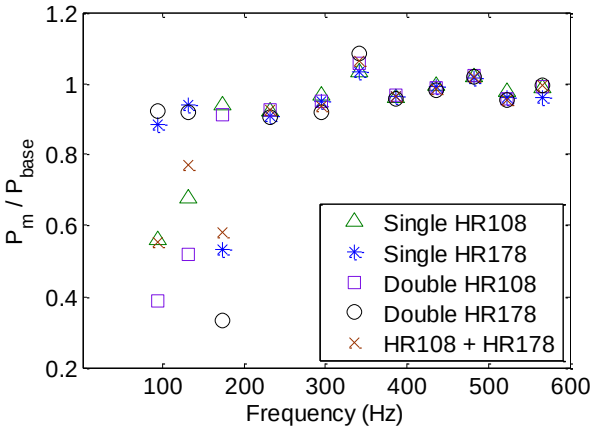


Figure 2: Normalized pressure response of acoustic modes with Helmholtz resonator(s) attached at one third the tube length from speaker. (2nd mode: 90 Hz, 3rd mode: 132 Hz, 4th mode: 168 Hz)

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3.2 Numerical Simulation

To investigate the effect of changing the resonators location along the piping system on its acoustic response, numerical simulations for the apparatus response by DELTAEC are performed for the system without and with attaching Helmholtz resonators and quarter wave side-branches**.** Figure 3 shows that the closest acoustic modes, 4th and 5th modes, are highly attenuated when the side branch and Helmholtz resonators are attached at the acoustic pressure antinodes where x/λ ratio is a multiples of 0.5, and can cause an adverse effect if each of them is attached at the pressure nodes. However, the effect of attaching a side branch on the system response is stronger than a Helmholtz resonator for both suppression and enhancement of acoustic pressure. This behavior agrees with the normalized pressure response obtained from the experimental results at the middle and the one-third pipe locations. The same conclusion can be drawn from Figure 4, which represents the effect of the location that these control devices have on modes shifting.

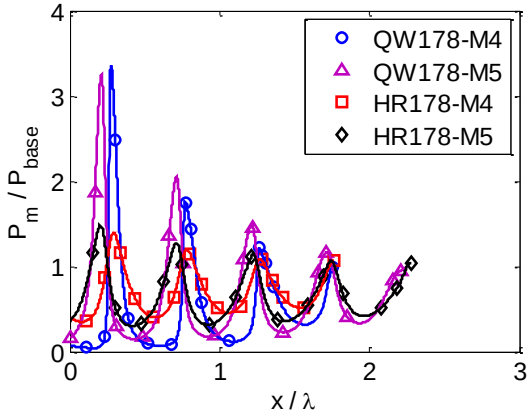


Figure 3 : The effect of normalized position of the HR178 resonator and the QW178 quarter wave side-branch on the normalized pressure amplitude relative to no attachment case for the 4th mode (M4: 168 Hz) and 5th mode (M5: 212 Hz).

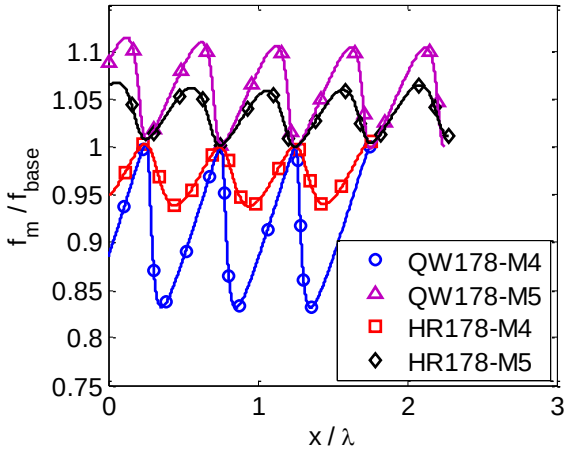


Figure 4 : The effect of normalized position of the HR178 resonator and the QW178 quarter wave side-branch on the normalized frequency relative to no attachment case for the 4th mode (M4: 168 Hz) and 5th mode (M5: 212 Hz).

It is noticed that the attachment of these control devices shifts the frequencies of the modes *away* from the resonance frequency of the passive control devices themselves, and the closest modes to the device frequency are the most to experience shifting. The same analysis was performed for attaching HR108 and QW108, and it shows the same behavior for all modes' pressure amplitudes and frequency shifting.

4 Discussion

It has been noticed from an analysis done similar to what is shown in Figure 3 for higher modes that if the resonator or side branch is placed at a position where x/λ > 2.125 from the excitation source, a slight increase in the mode's acoustic pressure occurs. This is also proven from the experiments as shown in Figure 2. Attenuation for modes higher than 590 Hz is found to be less than 5% when the resonators are attached at one-third tube length location, this corresponds to x/λ = 2.115. Moreover, for the case of attaching two resonators of the same size, the overall change, reduction or increase, of normalized pressure along the various acoustic modes can be related to the change done by a single resonator from the following empirical relation obtained from Figure 2:

$$\Delta P\%|_{two\ HR} = \Delta P\%|_{single\ HR} \times (1 + 0.416) \qquad (1)$$

5 Conclusion

The effect of attaching several Helmholtz resonators and quarter wave side-branches, as acoustic passive control devices, is investigated numerically for both and experimentally for the Helmholtz resonators. The study found that quarter wave side branches have higher ability to suppress targeted acoustical modes than Helmholtz resonators, and the amount of suppression is highly dependent on devices locations relative to the acoustic pressure nodes and antinodes, which can cause an adverse effect if placed near the pressure nodes.

Acknowledgments

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