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ABSTRACT

Air flow through corrugated pipes can produce high sound levels. This whistling phenomenon, can lead to serious structural and environmental problems. Previous study [1] showed that a row of identical T-joints, forming a multiple side branch system is a reasonable model for corrugated pipes at low whistling frequencies. The current research is carried out to investigate the effect of various geometrical parameters (e.g. cavity width to cavity depth ratio, pipe diameter to pitch ratio) and operational parameters (e.g. system pressure). In this context several experiments have been carried out with different side branch geometries to characterize the whistling behavior of the system. In this paper the discussion is kept limited to the effect of cavity depth and edge shape on whistling frequency and pulsation amplitude.

The T-joints that have been used have an internal diameter (D_P) of 33mm which is equal to the inner diameter (D_{sb}) and depth (L_{sb}) of the the side branch. The length of the main pipe (L_P) of each T-joint is 100mm and the side branch is located half way along this segment. Plugs with different heights were employed to vary the depth of the side branch segment. The multiple side branch system is connected to a high pressure air supply system. The acquisition system of the setup has been improved, compared to the one used earlier [1], by means of a trigger system which allows simultaneous measurement of the mean velocity from turbine flow meter and pressure from the piezo-electric pressure transducers placed at the end of the side branches.

Experiments performed with different number of T-joints showed that by increasing the number of side branches in the system a better representation of actual corrugated pipes can be achieved in the sense that even for high flow velocities the whistling frequencies corresponds to the longitudinal acoustic modes of the main pipe. The experiments presented in this study were performed with 19 side branches. A typical result that was obtained is shown in Figure 1 where the first 16^{th} longitudinal modes were detected.

To the authors' knowledge, the work of the Binnie [2] on corrugated pipes is the first study which highlight the importance of cavity depth on whistling. He reported an increase of Strouhal number from 0.4 to 0.7 when the ratio of pipe diameter to corrugation depth (D_p/L_{sb}) is decreased. Later Belfroid [3] observed a similar increase in Strouhal number when increasing relative corrugation volume which is defined as $V_{rc} = V_c/(V_c + V_p)$ where V_c and V_p stands

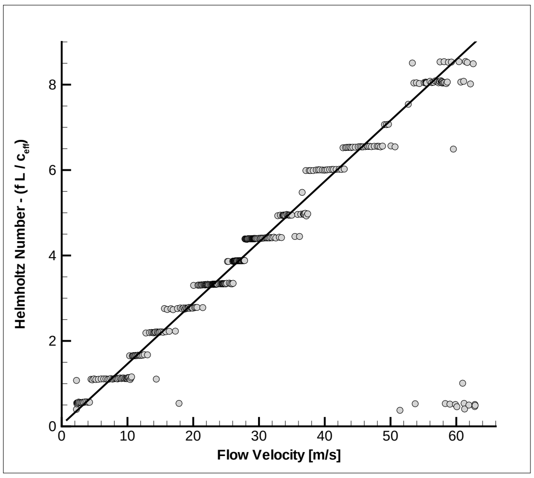

Figure 1: Measured Helmholtz number as a function of mean flow velocity with 19 side branches and 8mm cavity depth

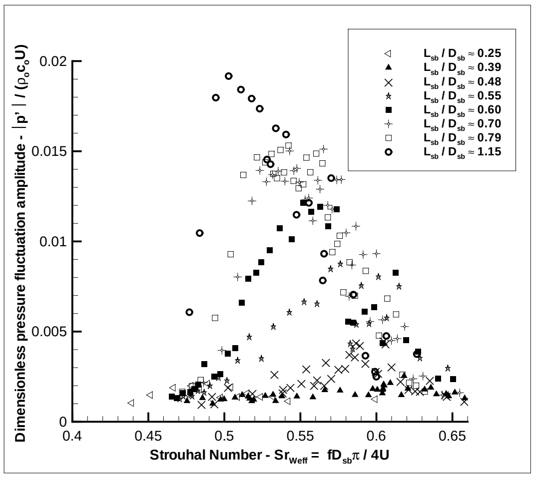

Figure 2: Measured dimensionless pressure fluctuation amplitude for the 2^{nd} acoustic mode as a function of Strouhal number

for corrugation and pipe volume, respectively. This effect is investigated for the multiple side branch system. Eight different side branch depths were considered ranging between 8mm and 38mm. The Strouhal number ($Sr_{Weff} = fD_{sb}\pi/4U$) and respective dimensionless pressure fluctuation amplitude ($|p'|/\rho_0 c_0 U$) for the 2^{nd} acoustic mode is given in Figure 2. It is seen that increasing cavity depth increases the amplitude of oscillations. A significant non-monotonous shift in Strouhal number is also observed with changing cavity depth. Between the depths of 8mm and 13mm, which corresponds to L_{sb}/D_{sb} ratio of approximately 0.25 and 0.39, an increase in Strouhal number is observed with increasing cavity depth. However, for deeper cavities (L_{sb}/D_{sb} from 0.39 to 1.15) a decrease in Strouhal number with increasing cavity depth is observed. So the phenomenon is more complex than expected on the basis of data from the literature [2,3]. The effect of the edge shape of cavities has also been studied. As expected from the vortex sound theory [4] a rounded upstream edge result in a higher amplitude than a sharp one.

References

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