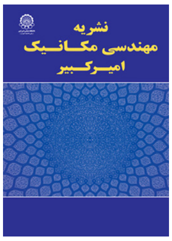

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Experimental Investigation of Flow Induced Noise Around Circular Cylinder by Measuring Unsteady Surface Pressures

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ABSTRACT: In the present study, noise emission from a circular cylinder model with 22 mm diameter and 500 mm length has been experimentally investigated. For this purpose, the surface pressure fluctuations have been measured both in spanwise and azimuthal directions by employing miniature condenser microphones, Pa-WM-61A. All the experiments are carried out in a subsonic wind tunnel with the turbulence intensity of 0.3% and maximum upstream velocity of 25 m/s. The results show that tonal noise for velocities of 10, 15 and 20 m/s takes place at vortex shedding frequencies of 98, 142 and 186 Hz respectively which correspond to typical Strouhal number of 0.2. Moreover, frequency of the first and second harmonic occurs at two and three times of the vortex shedding frequency respectively. In this study, the best collapses of the surface pressure spectra at low and middle frequencies can be obtained using the upstream flow scales whereas at high frequencies data are collapsed by employing downstream scales at vortex formation location. Furthermore, the longitudinal and lateral coherences can provide adequate information about the lifespan (or, inversely, the decay) of eddies and their physical size.

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1- Introduction

The aerodynamic sound generated from a bluff body structure in a stream has been a topic of interest in wind engineering research. Examples of aerodynamic sound can be found in the design of rotors for wind turbines, cables, towers, buildings, chimneys, distillation towers, parts of landing gear and so on. The magnitude of the sound generated from these structures is greatly amplified with increased wind velocity. Therefore, aerodynamic sound is becoming important into the design of structures located near high wind velocities.

Many components of bluff body structures can be characterized as circular cylinders of different diameter, aspect ratio, and alignment. Thus investigating the flow around a circular cylinder provides a good starting point for bluff body structures studies. Moreover, understanding of the acoustics nature of circular cylinder flows is beneficial in determination of noise sources of bluff body structures. Flow around circular cylinders is characterized by large region of flow separation leading to high drag and significant flow unsteadiness. This unsteadiness is manifested as fluctuating pressure on the surface of the body and in the wake region. Often the fluctuations may be periodic, leading to an Aeolian tone at the vortex shedding frequency [1].

Although Aeolian tones had long been associated with musical instruments and toys, the first quantitative measurements on sound produced by a cylinder in an airstream was reported in 1878 by Strouhal [2]. In 1879 Lord Rayleigh [3] confirmed Strouhal's general conclusions by observing the vibration and sound of a wire in a chimney draft. The observation of the staggered vortex street in the wake of a cylinder by Bernard in 1908 [4] and the theoretical demonstration of its stability by von Karmin in 1912 [5] led von Kruger and Lauth [6], Borne [7], and Rayleigh [8] to associate the tones and vibration with periodic vortex shedding.

In the present study, the characteristics of this noise are investigated by measuring surface pressure fluctuations acting on a circular cylinder model which equipped with several azimuthal and spanwise miniature condenser microphones, Pa-WM-61A. Moreover, pressure fluctuations are used to calculate different parameters such as power spectral density, azimuthal and spanwise coherences, spanwise length scale and convection velocity of eddies. These parameters are then used for exploring the flow physics around the model.

2- Wind Tunnel and Model

The experiments were carried out in an open subsonic wind tunnel of Yazd University with a test section size of 46×46×240 cm. At the maximum speed of 25 m/s the free stream turbulence intensity has been measured to be less than 0.3%. Due to contamination of the surface-pressure signals by background noise, the measurements of wall-pressure fluctuations are often carried out at free jet of wind tunnel. In the present wind tunnel, centrifugal fan is forward inclined blades type which creates nearly low to moderate broadband noise. However by covering the internal surfaces of the test section with an appropriate porous material (4 cm thickness) the background noise of the facility is reduced up to 15 dB.

The circular cylinder used in the present work has a diameter of 22 mm with the span of 500 mm. The model is

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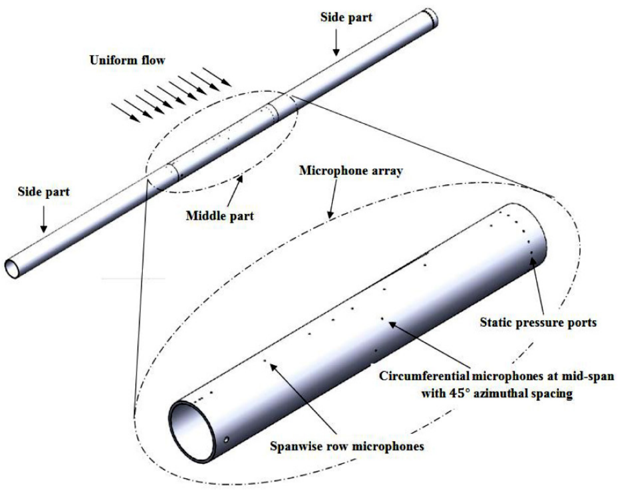

Fig. 1. Cylindrical model including array of microphones on the middle part

composed of a middle body and two similar side parts, which allow spanwise and azimuthal microphones to be installed inside the middle part. The two side parts are attached to the main body by two side bushes. All parts of the model were manufactured from steel to ensure having necessary strength and surface accuracy. The experiments are conducted at three different free stream velocities, 10, 15, and 20 m/s. The blockage ratio of the cylinder model is less than 5% for all the experiments and hence the wind tunnel walls effect on the measured quantities is negligible. CAD view of the circular cylinder model is shown in Fig. 1.

3- Results and Discussion

Fig. 2 shows the surface pressure power spectral density measured by microphone No. 1 at angle of 90° referenced to p_0=20 µPa. The microphone correction function is applied on all data. The wind tunnel background noise power spectral density is also shown in these figures for comparison. As may be seen, results in all frequency ranges are not contaminated with the background noise. This figure shows that tonal noises at velocities of 10, 15 and 20 m/s occur at vortex shedding frequencies of 98, 142, and 186 Hz which are corresponding to the typical Strouhal number of 0.2. In this case, the first and second harmonic peaks occur at two and three times the frequency of the vortex shedding frequency respectively as shown in Fig. 2.

Lateral coherence measured between spanwise microphones No. 1 to 8 at θ=90° and for different spanwise positions are depicted in Fig. 3. Results shows that the coherence at low frequency is bigger than high frequency and it can be concluded that eddies responsible for creating pressure fluctuations at low frequencies are bigger.

4- Conclusions

In the present study, tonal noise of flow around a circular cylinder model was measured by using several azimuthal and spanwise miniature condenser microphones, Pa-WM-61A, mounted beneath the model surface. All the experiments were carried out in a subsonic wind tunnel for three free-stream velocities of 10, 15 and 20 m/s. The results showed that tonal noise at vortex shedding frequencies is corresponding to typical Strouhal number of 0.2. Moreover, the first and second harmonic peaks occur at two and three times frequency of the vortex shedding frequency respectively. Moreover, the longitudinal and lateral coherences results showed that bigger eddies have high level energy and high lifespan compared to the small ones.

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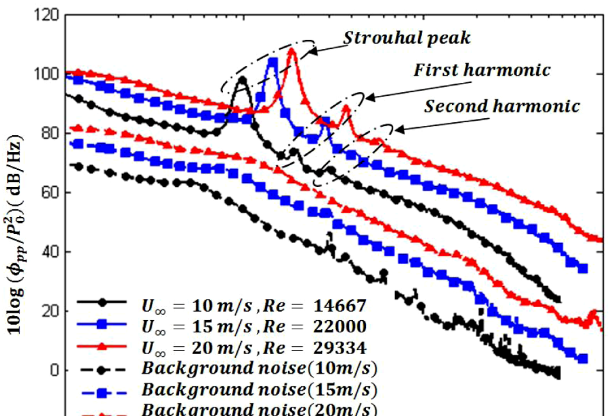

Fig. 2. Surface pressure spectra at *z*/*D*=0 and along with wind tunnel background noise

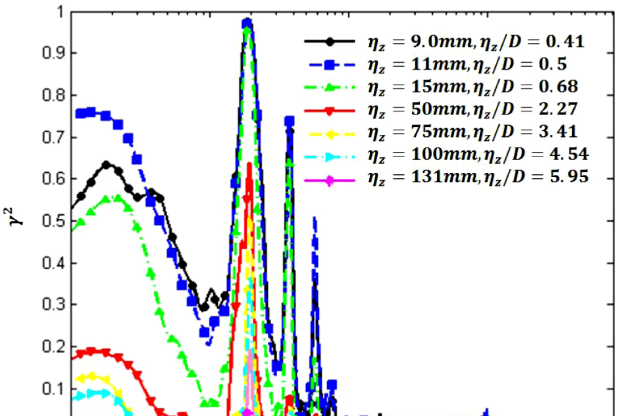

Fig. 3. Lateral coherence variations for various spanwise distances at 20 m/s

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