



Aeroacoustic Sound Generation of Square Cylinder with Detached Flat Plate in Semi-Anechoic Chamber

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Abstract: Airfoil self-noise is produced when unsteady flow interacts with an airfoil surface. Trailing edge noise is one of many types of airfoil self-noise and is considered to be a major noise generation mechanism in many applications that use airfoil shapes including aircraft, submarines and wind turbines. Experimental measurements were taken in the semi anechoic wind tunnel using integrated sound level meter located at four different position: first, second, third and fourth position. Sound level meter were recorded at this different position. Experimental data of this kind would provide further insight into the trailing edge noise mechanism and could be used to validate theoretical noise predictions calculated using computational aeroacoustics techniques.

Keywords: Airfoil, Unsteady Flow, Semi Anechoic Chamber

1. Introduction

Anechoic is defined as free from echoes or reverberation. For an ideal chamber, there is no reflection from its walls, ceiling, or floor and an acoustical free-field condition would exist. Special designed absorption lining can absorb almost 99% of sound waves [1]. The background sound pressure level inside the chamber should be very low in order to increase the measurement accuracy. The anechoic chamber also must be insulated from external noises which symbolize excellent walls; floor, ceiling and absorption lining design due to fulfil the background sound pressure limit [2]. This practical anechoic chamber is expected not only to provide an acoustical free field, but also an environment which meets other requirements, including the control of temperature, pressure, humidity and ambient sound pressure level. Beside well-designed and executed anechoic chamber it is possible to make precise acoustical measurements of the sound output and frequency content of source and its directivity pattern [3].

Acoustic anechoic chambers are environments with a high acoustic insulation from the nearby environment, used to measure system under close to free-space. Anechoic chambers tend to be considerable size, in order to achieve an acceptable response due to requirements of these measurement. However, if an anechoic chamber is meant for a selected set of applications, many of these limitations will be overcome. Airfoil self-noise is made once unsteady flow interacts with an airfoil surface. Trailing edge noise is one in all many varieties

of device self-noise and is considered to be a major noise generation mechanism in several applications that use airfoil shapes including aircraft, submarine and wind turbines. Designing quiet airfoils to scale back the noise emission from these applications needs a radical understanding of the edge noise mechanism and corrects methods of predicting the edge noise radiated into the far-field [6, 7].

Many of the experimental studies conducted in the past used the actual size of wind tunnel for an aeroacoustics experimental work. Hence, the aims of this study is to develop a small size of semi anechoic chamber. The semi anechoic chamber will be used to investigate a characteristic of trailing edge noise by using far-field acoustic data obtained from the flow over a bluff body in the anechoic chamber. An evaluation of the bluff body effect to the sound propagation for the flow past a square cylinders also be examine.

2. Sound Wave Propagation

The sound waves basically spreading directly from the source to the receiver in the free field conditions [8]. Unimpeded sound is not subject to many influences such as reflection, absorptions, deflections, diffraction, refraction, diffusion and it is not subjected to resonance effect. Only anechoic chamber an approximate free field can be exist and is also known as a direct field, as in Fig. 1.

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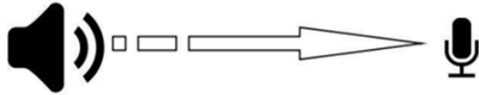


Fig. 1 - Free field (Direct Field)

The sound pressure is often converted into sound pressure level in practice. The Fig. 2 shows the sound power level and the distance from the source relationship can be written as an equation 1.

$$L_2 = L_1 - 20 \log \frac{r_2}{r_1} \quad (1)$$

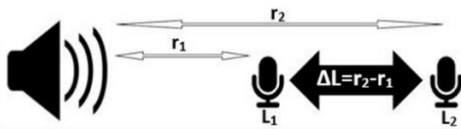


Fig. 2 - Sound power level and the distance from the source relationship

In chamber dimensions and shape there are no unique conditions or boundaries. Just requirement is governed by the ISO 3745 standard that endorses the largest amount of protest that can be estimated in the chamber, which by equation 2 is 5% of the net amount of the chamber [6, 9].

$$V_{object} \leq 0.05 \cdot V_{chamber} \quad (2)$$

The measurements of the chamber are then based on the papers suggested for estimation in the chamber [4]. With the ultimate objective of keeping away from conceivable room modes that can disturb free field circumstances, structuring the chamber's unpredictable state is smarter [10].

2.1 Calibration of the Anechoic Chamber

In order to calibrate the anechoic chamber and to verify a free field conditions, at least three different methods recommended to be used.

- i. The decrease in sound pressure - If there are no reflection inside the anechoic chamber, the intensity of the sound wave ought to decrease according to the inverse square law out to distances as great as the dimensions of the chamber will allow - the sound pressure decrease inversely with distance.
- ii. Using highly directional microphone - The anechoic chamber may be calibrated measuring the ratio of the sound, which travels directly to the microphone from the source, to the sound arrives at the microphone from all other directions. In case of reflections, the sound waves will arrive from directions other than that of the source and can be measured accordingly.
- iii. Impulse method - Measuring the echo of short impulse caused by reflection from the walls occurring at a later time.

3. Shape and Dimensions of the Chamber Design

Semi anechoic chamber is cubic in shape, approximately 1 m^3 in size and has walls that are acoustically treated with box wedges. This anechoic wind tunnel contains a contraction outlet that is rectangular in cross section and has dimensions of $50 \text{ mm} \times 500 \text{ mm}$. The maximum flow velocity at the contraction outlet is 40 m/s . The square cylinder that will use in the experimental work have dimension 50 mm in diameter.

Integrating Sound Level Meter (Model TES1353-H) were located in the anechoic wind tunnel in four different position. Fig. 3 below show the visualization of the semi anechoic chamber that developed.



Fig. 3 - Visualisation of the semi anechoic chamber

3.1 Wedge Structure and Design

The most important design element in the anechoic chamber is the wedge. The wedge have to be well designed in order to higher the absorption in low frequencies. Based the suitable wedge structure size in the small semi anechoic chamber, this will be produced more precise acoustical measurement of the sound. According to wedge structure comparison in section, the pyramidal and Harvard linear wedge structure is most suitable structure for wedge design [11, 13]. The Harvard linear wedge structure was chosen for wedge design in fact that it is commonly used wedge structure. Fig. 4 below show the designed wedge structure that will be develop.



Fig. 4 - Designed wedge structure

The most important parameter in the wedge design is its length [14, 15]. The wedge length is designed relating to the ratio from the actual anechoic chamber. The base dimensions were designed after taking a ratio. The change in base length does not affect the absorption so much. In the drawing below all parameters are fully dimensioned. Fig. 5 below shows the front view and side view of the wedge dimension. The total number of wedges was approximated to 320 pieces. The wedges are going to be installed in following pattern which has no acoustical substantiation. Fig. 6 shows the installation wedge pattern in the anechoic chamber.

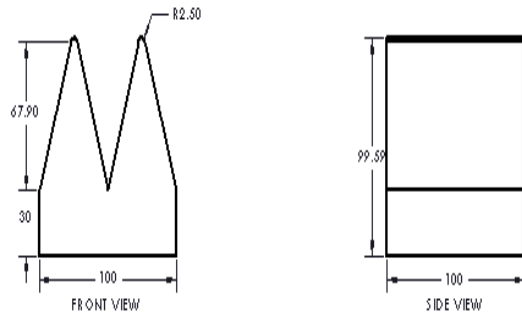


Fig. 5 - Designed wedge dimensions



Fig. 6 - Installation wedge pattern

3.2 Experimental Setup

There is a square cylinders that take place to evaluate an effect of detached flat plate to the sound propagation for the flow past a square cylinders with detached flat plate. Integrating sound level meter (Model TES-1353H) were located in the semi anechoic wind tunnel with different position. Fig. 7 below shows the arrangement of sound level meter in semi anechoic chamber.

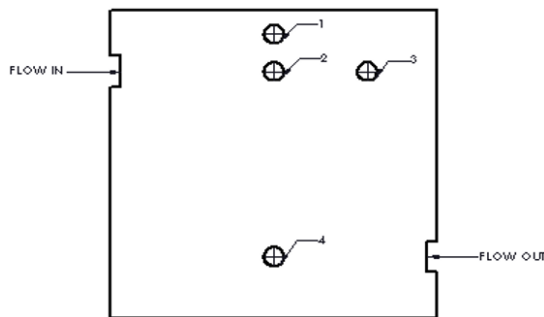


Fig. 7 - Location of integrating sound level meter in semi anechoic chamber

4. Results and Discussion

Sound level is normally characterized as Sound Pressure Level (SPL). SPL is actually a ratio of the absolute, Sound Pressure and a reference level. SPL is estimated in decibels (dB), as a result of the fantastically wide scope of forces that can be hear. Integrating sound level meter (Model TES-1353H) had been used to measure the sound pressure level which located different position in the semi anechoic chamber. Measurement of sound pressure level, dB of

acoustic test were record for 60 seconds for every different position in the semi anechoic wind tunnel. Test result of the experiment simplified in the graph.

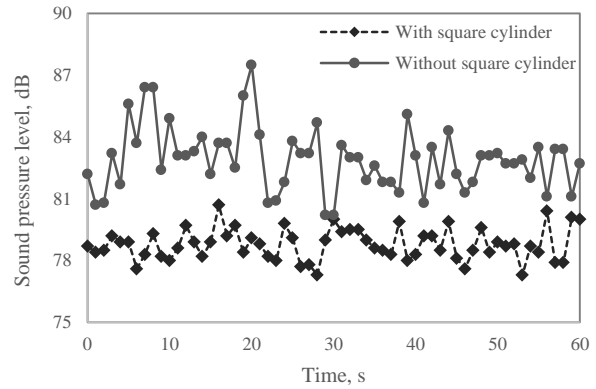


Fig. 8 - Sound pressure level vs time at the first position

At the first second, sound pressure level with square cylinder is 78.7 dB and at the 60 second, sound pressure level increase to 80 dB. The maximum sound pressure level with square cylinder is 80.7 dB at 17 seconds, while the minimum sound pressure level is 77.3 dB at 29 and 54 seconds. Meanwhile, sound pressure level without square cylinder at the first second is 82.2 dB and at the 60 second, sound pressure level increase to 82.7 dB. The maximum sound pressure level without square cylinder is 87.5 dB at 21 seconds, while the minimum sound pressure level is 80.2 dB at 30 and 31 seconds.

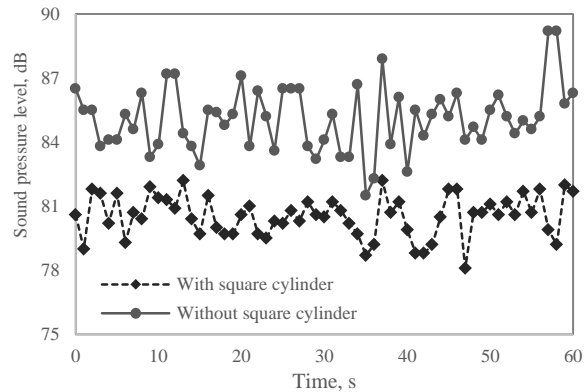


Fig. 9 - Sound pressure level vs time at the second position

At earlier second, sound pressure level with square cylinder is 80.6 dB and at the 60 second, sound pressure level increase to 81.7 dB. The maximum sound pressure level with square cylinder is 82.2 dB at 14 and 26 seconds, while the minimum sound pressure level is 78.1 dB at 48 seconds. Meanwhile, sound pressure level without square cylinder at the first second is 86.5 dB and at the 60 second, sound pressure level increase to 86.3 dB. The maximum sound pressure level without square cylinder is 89.2 dB at 58 and seconds, while the minimum sound pressure level is 81.5 dB at 36 seconds.

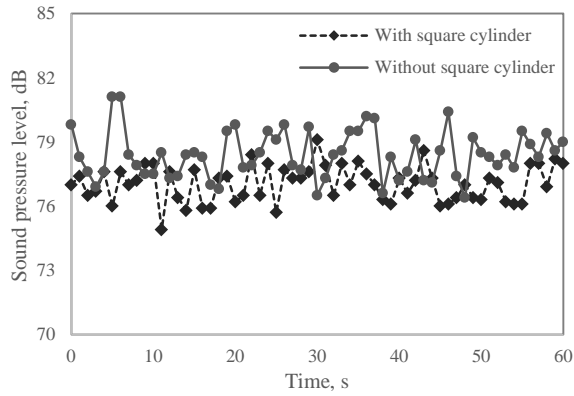


Fig. 10 - Sound pressure level vs time at the third position

At third position, sound pressure level with square cylinder is 77.0 dB and at the 60 second, sound pressure level increase to 78.0 dB. The maximum sound pressure level with square cylinder is 79.1 dB at 31 seconds, while the minimum sound pressure level is 74.9 dB at 12 seconds. Meanwhile, sound pressure level without square cylinder at the first second is 79.8 dB and at the 60 second, sound pressure level decrease to 79.0 dB. The maximum sound pressure level without square cylinder is 81.1 dB at 6 and 7 seconds, while the minimum sound pressure level is 76.4 dB at 49 seconds.

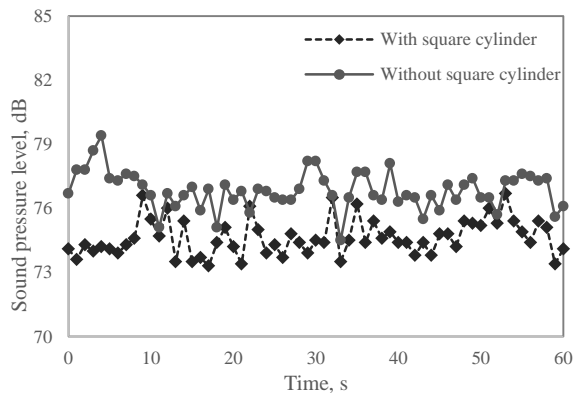


Fig. 11 - Sound pressure level vs time at the fourth position

Sound pressure level with square cylinder is 74.1 dB and at the 60 second, sound pressure level constant 74.1 dB at the starting time counter. The maximum sound pressure level with square cylinder is 76.7 dB at 54 seconds, while the minimum sound pressure level is 73.3 dB at 18 second. Meanwhile, sound pressure level without square cylinder at the first second is 76.7 dB and at the 60 second, sound pressure level decrease to 76.1 dB. The maximum sound pressure level without square cylinder is 79.4 dB at 5 seconds, while the minimum sound pressure level is 74.5 dB at 34 seconds.

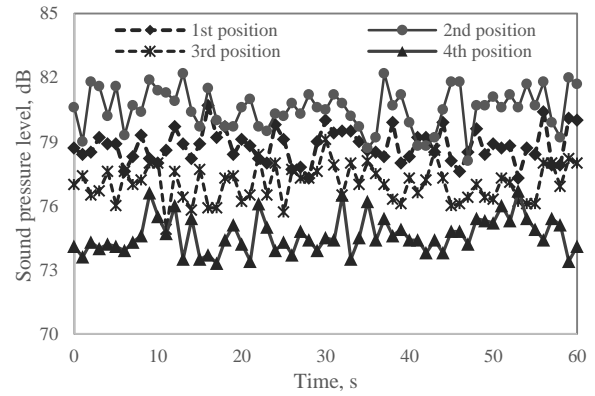


Figure 4.5: Graph of sound pressure level, dB versus time, s at different position with square cylinder

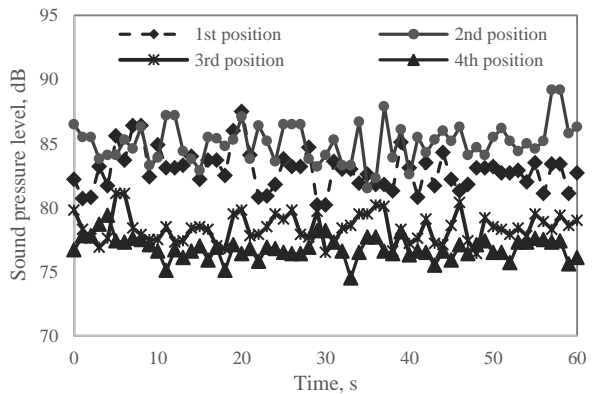


Figure 4.6: Graph of sound pressure level, dB versus time, s at different position without square cylinder

Acoustics test result show that at the second position, sound pressure level give the higher reading compared to first, third and fourth position because the integrating sound level meter directly face the wind from blower.

5. Conclusion and Recommendation

In order to perform the correct measurement of sound and vibration, the special acoustic conditions have to be fulfilled. The semi anechoic chamber has to be designed to meet the special requirements for sound and vibration correct measurement. The most important design parameter in anechoic chamber design is the acoustic free field condition. Consideration in semi anechoic chamber design is important due to acoustic free field condition. One of many design parameter should be considered is acoustic wedge design. Based on previous study, this is the most important parameter that they considered because from the wedge structure, it can affect the sound propagation in semi anechoic chamber.

From the overall result of acoustic test, a characteristic of trailing edge noise by using far-field acoustic data obtained in the anechoic wind tunnel have been investigate and an effect of detached flat plate to the sound propagation for the flow past a square cylinders with detached flat plate have been evaluate. From acoustic test, sound pressure level with square cylinder effect the sound propagation.

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