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NOISE SOURCE IDENTIFICATION OF VACUUM CLEANER USING SOUND PRESSURE-VELOCITY (PU) PROBE

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Abstract- Noise is unwanted sound that is loud or unpleasant or that causes disturbance. It is well known that the noise produced by vacuum cleaner is very loud and it is a common problem which needs to be address since it can disrupt individual's comfortable hearing and concentration and while carrying out daily activities. In this paper, a series of measurement techniques was applied to diagnose the location of noise source. Sound Pressure Level and Sound Pressure-Velocity (PU) Probe equipment are used in the experiment to diagnose the location of noise source at the back, front, left, and right view of the vacuum cleaner.The technique is more efficient, making the noise identification process easier to facilitate the elimination of noise since it is easier to diagnose and locate the source of noise of vacuum cleaner. The 1/3 octave band data of the back, front, left, and right side view of vacuum cleaner are computed. Thenintensity measurement is presented in the form of noise mapping for each view. Based on the experimental results, the frequency and the dominant noise source of each view is identified.

Keywords- Pressure-Velocity, PU, Noise Source, Vacuum Cleaner, Sound Pressure Level, Scan and Paint.

I. INTRODUCTION

One of the three pillars of the sustainability is the environment auspice and noise is one of the factors to be considered in order to achieve environmental sustainability. Noise is unwanted sound that is loud or unpleasant or that causes disturbance. Noise emanating from vacuum cleaner is a common problem which needs to be address since it can disrupt individual's quality of sleep and interfere with their concentration while carrying out daily activities. Also, vacuum cleaner's noise can affect an individual's health significantly once it reaches certain level. Arnold P. G. Peterson in his study has explained about the effect of excessive noise exposure to the human hearing. One will be permanently lose hearing when exposed cumulatively to the excessive noise over extended periods. Almost every expert agree that the acceptable noise exposure is at an A-weighted sound level of 70dB, or less is not likely to cause significant hearing damage. However, as a practical compromise a limit of A-weighted sound levels of 85dB or more over 8 hours exposure or longer will gradually lose their hearing over time. [1]

Vacuum cleaner noise is a general issue in Malaysia that requires attention from various parties, such as manufacturers, consumers and government. The lack of environmental awareness among all side is one of the factors which manufacturers are not concerned to produce vacuum cleaner that has a low noise level. The assurance that users get an optimal comfort is very subjective because the term comfort is not only comfortable regarding temperature but also regarding sound. The existence of Malaysia environmental policies in noise control is insufficient to encourage manufacturers to produce vacuum cleaner that is environmental-friendly in noise control aspect. Hence, consumers need to play a vital role to drive this change since consumers are one of the major forces that can control the quality of goods or products.

In this study, VELO Scan & PaintMICROFLOWN software used to locate the noise source. It is a newfast tool to visualize stationary sound fields in a broad frequency range. The system is a superb engineering tool for troubleshooting or benchmarking all type of object on the spot. In practice, there are many cases where anechoic conditions are not applicable. Sound Pressure-Velocity (PU) probe are not highly affected by background noise or reflections and are suitable in situations with a high sound pressure over sound intensity ratio. PU probe allow direct measurement of sound pressure, particle velocity, sound intensity, sound power and the acoustic impedance. The Scan & Paint method is very simple; the surface is scanned with one PU probe while a camera is positioned toward the surface to film the scanning. The recorded video and audio data are automatically synchronized by the software and the measurement is directly ready to be processed. In the post-processing for each frame of the video the position of the probe is extracted. The auto-tracking function in the software enables to automatically recognize the probe and its position by the colour. At each measurement point the particle velocity, sound intensity and sound pressure are calculated from the relative time block of the audio data. A high resolution sound colour map is produced as result. A reference sensor can be added to have the relative phase correlation of the surface velocities. [2]The objective of this study is to diagnose the location of noise source at the back, front, left, and right view of the vacuum cleaner and to generate contour maps using the data measured bySound Pressure-Velocity (PU) Probe.

1.1. The Scope of Study

The scope of study related to this research is focused on the specimen of Vacuum Cleaner with maximum power of 15000W and dimension of 425cmx290cmx317cm which is already on the market. The microphone use in this experimental study is Sound Pressure-Velocity (PU) Probe and the result are analysed using VELO Scan & Paint MICROFLOWN Technologies. The experimental study of this research, conducted at Acoustic Laboratory, Level 3, Malaysia-Japan International Institute of Technology (MJIIT) with room dimension of 836 cm x 683.5 cm and the Sound Pressure Level (SPL) of vacuum cleaner are calculated.The significant of this experiment is to give an informative knowledge and encourage manufacturer of vacuum cleaner to produce a better product with less noise and to encourage people to have sensitivity of environmental quality control especially in noise control at home.

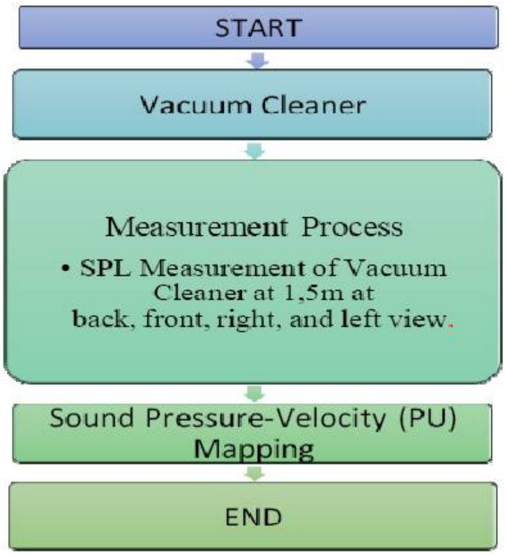

Figure 1. Flowchart of study

1.2. Theory

1.2.1. Definition of Sound Pressure Level Averaged Value

The average value of sound pressure level, L_p is about a given source required for determining directivity. The average value is obtained by dividing the sum by n, the number of such measurement.
Thus,

$$L_p = 10\log\left[\frac{1}{n}\sum_{i=1}^{n}(10)^{L_{pi}/10}\right] \text{ dB} \quad \text{(Equation 1)}$$

Let $L_{pi}(i = 1,2,3,\ldots n)$ be the n values of Sound Pressure Level (SPL) measured.

1.2.2. Sound Intensity of Pressure-Velocity (PU)

The instantaneous intensity I(t) of a sound wave is the instantaneous rate per unit are at which work is done by one element of fluid on an adjacent element. It can obtained by a product of pressure (p) and particle velocity (u) as

$$I(t) = pu \qquad \text{(Equation 2)}$$

Generally the intensity I is defined as a time average of $I(t)$, so the time averaged rate of energy transmission trough a unit area normal to the direction of wave propagation,

$$I(t) = pu = \frac{1}{T}\int_0^T pu\, dt. \quad \text{(Equation 3)}$$

In order to obtain the time-averaged intensity using a p-u probe, the general expression in Equation (3) can be implemented as,

$$I(\omega) = \mathrm{Re}\left(S_{pu}(\omega)\right) \qquad \text{(Equation 4)}$$

Where S_{pu} is the cross spectrum between the pressure and particle velocity signals acquired.

II. DETAILS EXPERIMENTAL

2.1. Experimental Setup

The dimension of vacuum cleaner is studied and frame guidelines are made using wood in order to proceed to the next step of experiment which is to measure intensity cross spectrum and to generate contour map. A specimen of Vacuum Cleaner is prepared with dimension of 425cm x290cm x317cm. The Sound Pressure Level is measured first using dosimeter on the back, front, left and right view of vacuum cleaner at a distance of 1.5m. Then, noise source is measured using Sound Pressure-Velocity (PU) probe. The measurement procedure to acquire the data is based upon the scanning technique “Scan & Paint”. [3] The acoustic signals of the sound field are acquired by manually moving a Pressure-Velocity (PU) intensity probe across a measurement plane while filming the experiment with a camera. In the post-processing stage, the probe position is extracted by applying automatic colour detection to each frame of the video. The recorded signals are then split into multiple segments using a spatial discretisation algorithm, assigning a spatial position depending on the tracking information. Therefore, each fragment of the signal will be linked to a discrete location of the measurement plane.

Next, spectral variations across the space are computed by analysing the signal segments. The results are combined with a background picture of the measuredenvironment to obtain a visual representation which allows us to seethe sound.

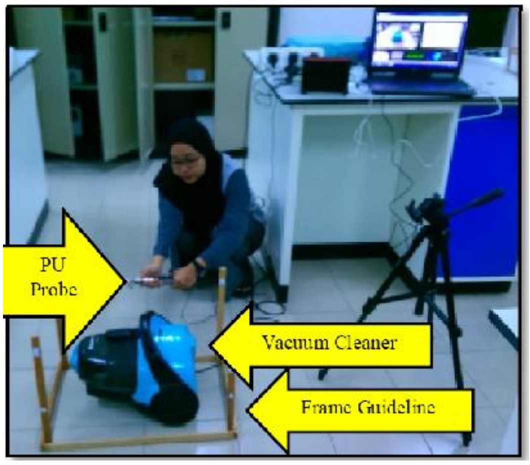

Figure 2. The Experimental Setup

III. RESULTS AND DISCUSSION

3.1.Result of Sound Pressure Level (SPL) Measurement

The experimental result of SPL measurement generated in sound spectrum graph where the sound spectrum shows complicated measured from 0 – 800Hz. For instance, the spectrum graph shows complicated frequencies cycle when it reached 50 cycles for every second. At this level, the result of spectrum graph was used to identify the highest peak point of manyfrequencies cycle. Here, the maximum frequencywas set up to 800Hz because the dominant noise frequency happens in those range is sufficiently to be identified. The sound spectrum shows the frequency of the highest peak of noise generated by the vacuum cleaner. As mentioned earlier, the exact frequency values of peak frequency are hard to identify in the sound spectrum because it is so complicated and cannot be shown in detail. Therefore, to ensure the exact frequency of noise can be easily identified, themeasurementof sound pressure was carried out, and the result was viewed in 1/3 octave band. In 1/3 octave band, the frequency value was detailed out to every peak of noise. By generating 1/3 octave band, the exact value of high peak could be identified. Figure 3,4,5and 6 shows 1/3 octave analysis of sound intensity at the back view, front view, rightside view, and left side view, respectively.

From these figures it was shows that the highest level of noise produced by vacuum cleaner is at frequency of 630Hz. The noise value at 630Hz frequency is more than 70dB which is higher than other noises in different frequencies at 1/3 octave band analysis. The next process of this experiment is to find the noise source in the vacuum cleaner at a frequency of 630Hz by using a sound pressure-velocity (PU)-mapping techniques.

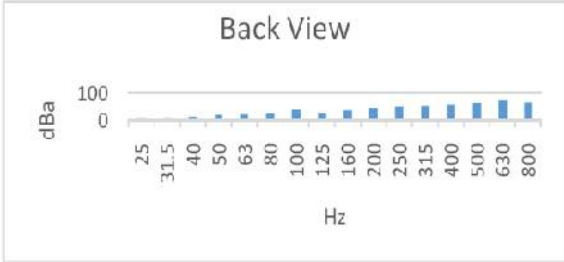

Figure 3. 1/3 octave analysis of SPL at back view

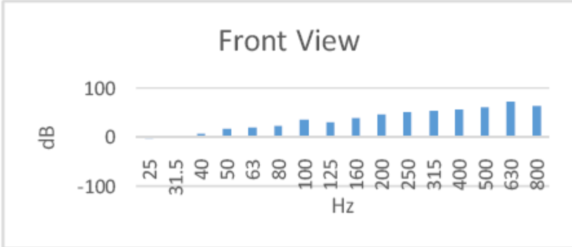

Figure 4. 1/3 octave analysis of SPL at front view

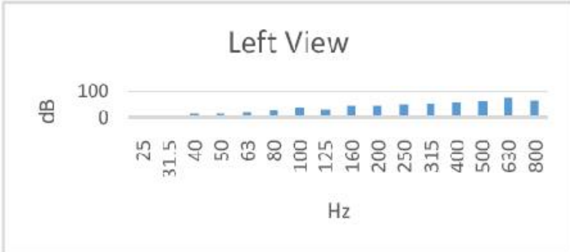

Figure 5. 1/3 octave analysis of SPL at right view

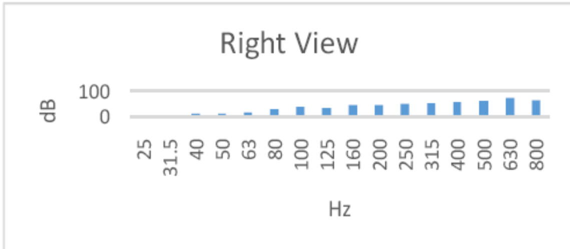

Figure 6. 1/3 octave analysis of SPL at left view

3.2.The Examination of Noise Source Using the Sound Pressure-Velocity (PU) Probe

The result of the sound pressure-velocity (PU) measurement after signal processing was carried out using VELO Scan & Paint MICROFLOWN software, are shown in Figure 7,8,9,and 10. Detailing out the pattern of the map from contour graph generated from the experiment process will help to determine the noise source. The identification of noise source could be performed easily with contour graph plotted. The low frequency and high frequency is differentiated by colour code as the dark blue colour is the lowest and dark red is the highest value. As shown in the figures, the dark red colour maps are the areas contributed to high noise. The larger area of dark red map at the lower side is found to be the exact source of noise because it is very dominant. Furthermore, the area of dark red colour from the contour graph can infer that mechanical parts such as fan and fan motor and the lower side of vacuum cleaner are some of the noise sources. Here, it was found that the noise of fan motor is emitting the dominant noise. Moreover, the blowers used in vacuums are the main source of airborne noise and blade wakes are unavoidable in vacuum system.Turbulences due to wake formation contribute significantly to blower noise. This noise is further carried along the flow path to the exhaust ports.

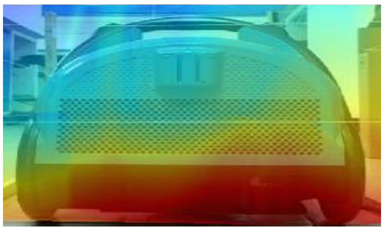

Figure 7. Contour map of sound pressure-velocity (PU) at 630Hz back view

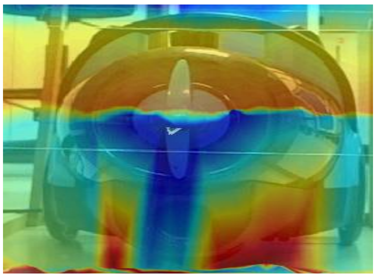

Figure 8. Contour map of sound pressure-velocity (PU) at 630Hz front view

Figure 9. Contour map of sound pressure-velocity (PU) at 630Hz right side view

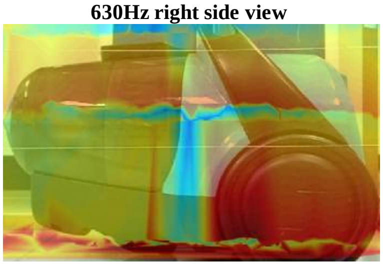

Figure 10. Contour map of sound pressure-velocity (PU) at 630Hz left side view

CONCLUSION

An experimental technique using sound pressure-velocity (PU) probe to identify a main source noise for vacuum cleaner had been studied. The conclusion from the study can be drawn as follows;
The noise source of vacuum cleaner can be identified and the contour map can be generated directly by using Sound Pressure-Velocity (PU) Probe.

The lower side of the vacuum cleaner is the mainly source of the noise and these noise was significantly contributed by the blower in the vacuum cleaner.

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