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EXPERIMENTAL STUDY ON NOISE SOURCE IDENTIFICATION OF SPLIT UNIT AIR CONDITIONER SYSTEM

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Abstract

This paper presents the procedures and the results of noise source at the split unit air conditioner system. Noise in split unit air conditioning system is a frequent problem for the air conditioner manufactures. Split unit air conditioners have an indoor unit and an outdoor unit connected by communication pipes. Noise can reduce the efficiency and performance of the air conditioner. In order to identify and analysis of noise at air conditioner system, experimental have been done using sound intensity mapping method. The investigation was carried out by varying the parameter which is the fan speed and temperature at air conditioner. In order to identify where the noise source comes from, a grid rig had been build to get the noise location and their rating by located the microphone at the rig point. The signal from the probe will be analyze by using Pulse LabShop software. The results from the noise were showed in noise mapping with different color which indicates the different level of noises from different location. The highest noise sound levels occur at the front side of air conditioner which is at the fan that is about 74.784dB. The second highest noise sound level is occur at the right side which is at the compressor about 72.115dB. It can be concluded that sound power level will increase as higher as fan speed at the lowest temperature of the air conditioner.

Keywords: Sound Intensity Mapping, Noise Source, Fan Speed, Temperature, Pulse LabShop

Introduction

Air conditioners are typically categorized into split-type and multi-type air conditioners. Split-type air conditioners have an indoor unit and an outdoor unit connected by communication pipes. Multi-type air conditioners have plural indoor units connected to an outdoor unit. Air conditioners may also be categorized into ones that air conditioners operate a refrigerant cycle in one direction to only supply a room with cool air, and ones that selectively operate a refrigerant cycle in two directions to supply a room with hot or cool air. Now days, mostly every home has their own air conditioner system is to provide comfort during hot days and nights. A frequent problem for the air conditioner manufacture is the noise comes from the air conditioner. Noise is considered undesirable and the cause of the noise may in some cases even limit the heating or cooling efficiency of the air conditioner.

The noise produced by air conditioning unit probably caused by several mechanical and aerodynamics sources such vibration of the compressor shell, electric motor vibration and fan noise [1]. Any mechanical coupling of such source as the fans, the compressor or the electric motor will cause the cabinet panel to vibrate and radiate acoustics energy. The most annoying source of noise at some air-conditioning units appears to be due to the vibration of the electric motors at 120 Hz and harmonics [1,2]. Actually this vibration is due to fluctuations in the magnetic forces [2]. There are some studies on the fan noise have found that it is involved experiment with minor geometry changes of fan to reduce noise. Morinushi [3] have reported that minor changes in the location can have minimal effects on fan performance. This is parallel with Graham [4] stated that fan performance and efficiency are normally negatively affected by such changes. Field survey of the disturbance caused by the noise of outdoors residential air conditioner units [5]. Leventhall and Wise [6] reviewed the design specifications especially for low frequency noise and discussed the dominants factors in noise complaints. Noise mapping from air conditioned noise in classroom have been discussed by Lilly [7]. Research on the basic acoustical measurement methods based on sound pressure measurement to determine the sound power radiated from fans [8]. Basically, prediction of dominant noise source is very important in machinery noise control problem [9]. There are several standards for sound intensity measurements completed or under progress. ISO 9614 governs sound power determinations based on sound intensity [10-12]. This standard divided into two parts, one use for point measurements (ISO 9614-1) and another one makes use for scanned measurements (ISO 9614-2). However ISO 9614-2 is the most popular method and can be used for engineering and survey grade determination of sound power. Furthermore, ISO 9614 has been extended to allow scanned measurements to be for precision grade determination of sound power (ISO 9614-3).

In this research, noise source identification of split unit air-conditioner system was determined by experimental approach. Simple test rig have been fabricated to ensure the noise location by doing the experiments.

Fabrication of Test Rig

The fabrication of the rig is very important part before run the experiment because the rig is use for mapping the noise that comes from the air conditioner sources. The measurement will focus on the cross section in z-direction. The rig is design by using Solidwork and the dimension of the rig is 90cm x 70cm as shown in Figure 1. Each section of the cross section for the mapping is 10cm x 10cm. It was follow the International Standard ISO/DIS 9614-1 each section of the rectangular for the mapping is 10cm x 10cm. After complete the design and then it goes for the fabricating the rig and there are a few step to develop the rig. Metal Inert Gas (MIG) welder, cutter and hand grinder are used to assist in the fabrication. Figure 2 shows the fabricate rig with ties the wire at the holes to get the cross section 10cm x 10cm.

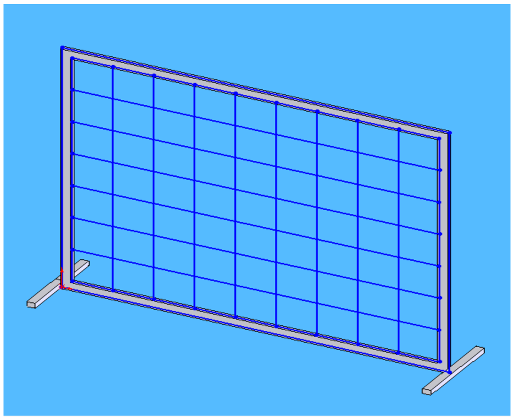

Figure 1: Design of test rig by solidworks

Figure 2: Final fabricated test rig

Experimental Setup

The research program involved studies on a commercial residential air conditioning split unit. The unit studied has an outdoor unit 84cm x 67cm of both sides. The measurement instrumentation included a probe, real time analyzer and a laptop with Pulse LabShop software. Digital signal analyzer, probe and microphone have been shown in Figure 3. The probe will detect the signal and then the frequency will be analyzed by the analyzer and transfer the signal into a laptop. The probe is consists of two one-half inch microphone with a 50mm spacer. For this research microphone type 4197 by Brüel & Kjær is selected. In order to run the software, the laptop with Pulse LabShop software will be connected to the real-time analyzer using LAN cable. From the real-time analyzer it will be connected to the probe with the suitable port. The port for a probe connection is determined using Front-End Setup that is in the Pulse LabShop software. For this experiment the microphone is connected to the port 3 and port 4 of analyzer. Figure 4 shows the outdoor unit of air conditioning systems. The air conditioning system is form York model YSL25B-AFAA with 1 horsepower (hp) using refrigerant R22 and 1.75kg of weight.

Figure 3: Digital signal analyzer, probe and microphone

Figure 4: The outdoor unit

Figure 5-8 shows the mapping at four sides which are front side, back sides, right side and left side of air conditioner system. The cross sections were made by the wire that tie to the test rig that has been design and fabricate for this mapping process.

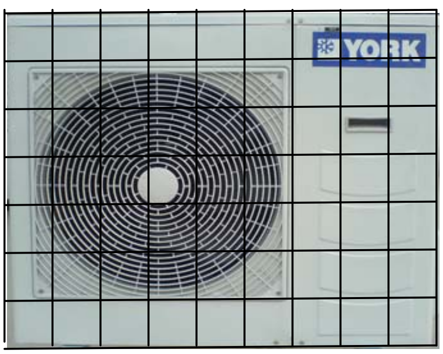

Figure 5: Front View Mapping

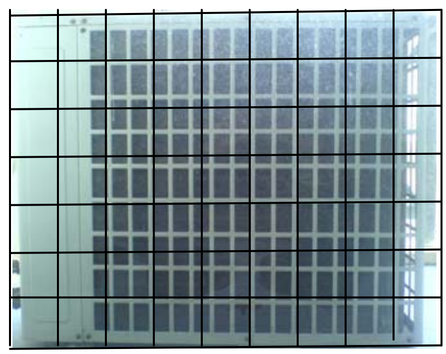

Figure 6: Back View Mapping

Figure 7: Left View Mapping

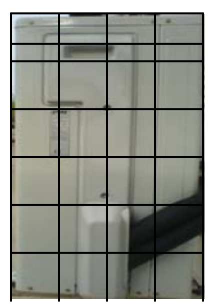

Figure 8: Right View Mapping

Result and Discussion

Noise generated from air conditioner systems was measured with a view to find out the noise contribution. Sound power is a measure of the amount of sound energy a sound source produces per unit time, independent of its surroundings. Sound power has a number of useful applications. It can be used to calculate the approximate sound pressure level at a given distance from a machine operating in a specified environment. It can be compare the noise radiated by machine of the same or different type. In this section, different temperature and fan speed were used to identify where the noise source of the air conditioner system always occurs. It easy to determine the source depends on the colour that obtain from the mapping process. The noise level indicator will present the value depends on the colour of the measurements. Table 1 shows that for high 20 °C give the highest value of sound power level at critical point foremost at all sides compare to the other different temperature. An even show that at the front side shows the increments of sound power level but for the other side it present that the highest value still at high 20 °C. The a-weighted one-third band sound power levels radiated by different parts of the units were determined from sound intensity measurements made on different parts of the air conditioner and for different temperatures and different speed of fan.

Table 1: Sound Power Level at critical point for different temperature

Sides\Parameter	Sound Power Level (dB)		
	High at 20 °C	High at 22 °C	High at 24 °C
Front	74.7	75.682	75.683
Back	66.275	64.272	65.926
Right	72.115	67.617	70.345
Left	59.409	56.967	58.348

Figure 9 presents that the peak frequency occurred at 160Hz and the measurements will pick at this frequency. Figure 10 shown A-weighted one-third band sound power levels for the sound radiated form high speed of fan and temperature 20°C at a front side. Table 2 shows the details value of noise level at different location to determine where the highest sound signal radiated from the air conditioner. The sound power radiated of about 74.789 dB. The Figure 10 shows that the noise source at front air conditioning unit comes from the fan.

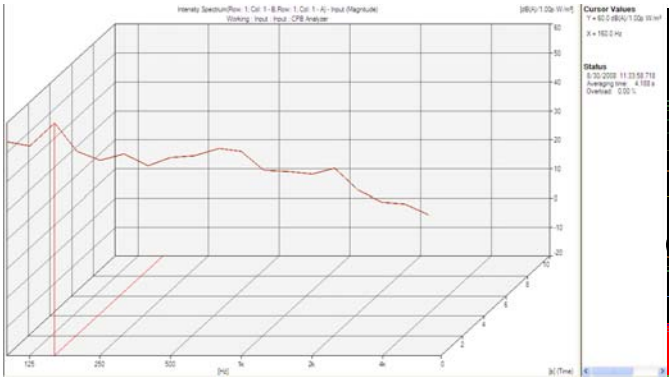

Figure 9: Frequency for front side is at 160Hz for 20°C

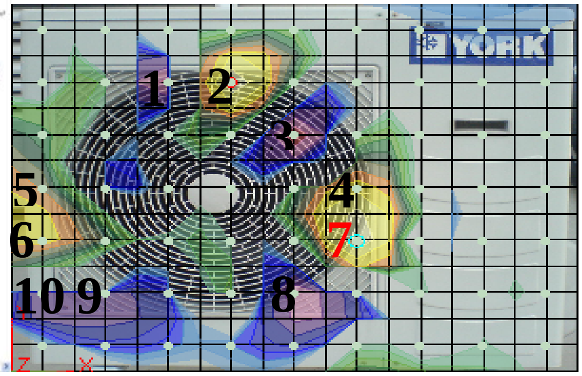

Figure 10: Noise sources for high speed fan at 20°C at the front side

Table 2: Sound power level at the critical point at the front side for 20°C

Location	Noise level, dB	Location	Noise level, dB
1	71.163	6	71.51
2	74.678	7	74.789
3	71.812	8	71.105
4	71.572	9	67.798
5	68.718	10	69.212

Figure 11 and 12 shows the peak frequency and a-weighted one-third band sound power levels result for the back side of the air conditioning unit. Table 3 shows the details value of noise level at different location to determine where the highest sound signal radiated from the air conditioner. The sound power level obtain is about 66.278dB at the highest peak of frequency is 630Hz. From the observation, the noise come forms the vibration of the housing of the air conditioner with the floor.

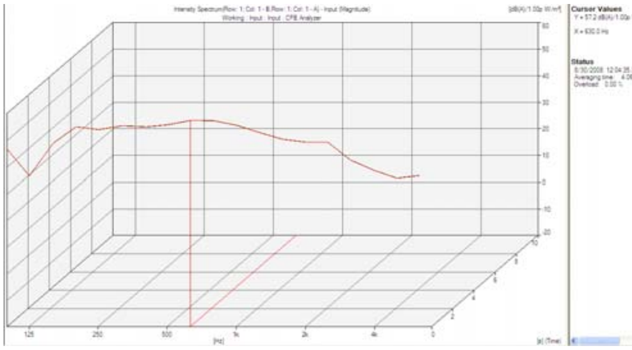

Figure 11: Frequency for back side is at 630Hz for 20^oC

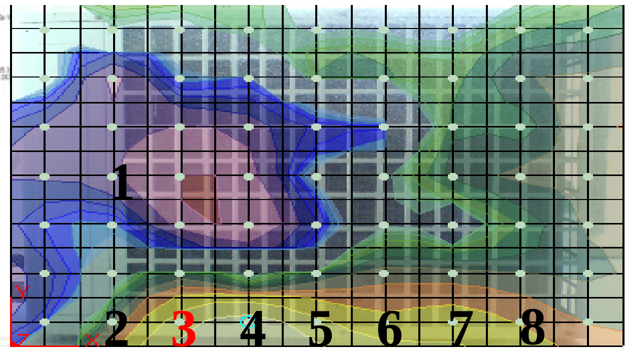

Figure 12: Noise sources for high speed fan at 20^oC at the back side

Table 3: Sound power level at the critical point at the back side 20^oC

Location	Noise level, dB	Location	Noise level, dB
1	62.51	5	62.947
2	64.87	6	62.375
3	66.278	7	62.339
4	64.37	8	62.225

The noise radiated at 160Hz for the right side of the air conditioner system as shown in figure 13. Figure 14 shows the A-weighted one-third band sound power levels radiated from right side where is behind the compressor and the total sound power levels is around 72.115dB. Table 4 shows the details value of noise level at different location to determine where the highest sound signal radiated from the air conditioner. The total sound power levels is increased is about 5dB from the back side. This shows that the noise at the compressor radiated more at the right side.

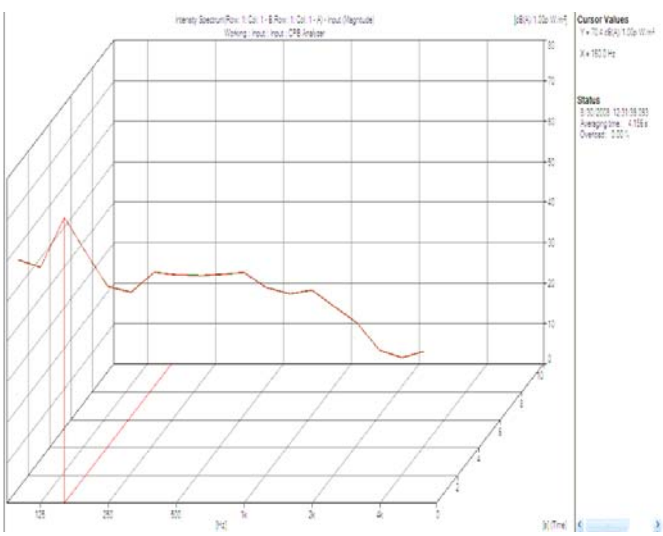

Figure 13: Frequency for right side is at 160Hz for 20^oC

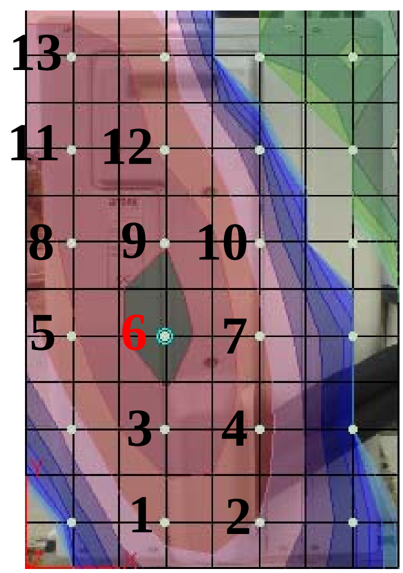

Figure 14: Noise sources for high speed fan at 20^oC at the right side

Table 4: Sound power level at the critical point at the right side for 20^oC

Location	Noise level, dB	Location	Noise level, dB	Location	Noise level, dB
1	69.226	5	69.817	9	70.284
2	68.448	6	72.115	10	71.048
3	69.198	7	68.741	11	69.698
4	70.876	8	71.448	12	70.385

The noise radiated at 160Hz for the left side of the air conditioner system as shown in figure 15. Figure 16 presents result for the a-weighted one-third band sound power levels from left side where is close to the fan. Table 5 shows the details value of noise level at different location to determine where the highest sound signal radiated from the air conditioner. Form the noise mapping it gives 59.409dB at 160Hz for the total sound power levels. The sound power levels are low compare to the front side because the noise from the fan radiated more from the front side.

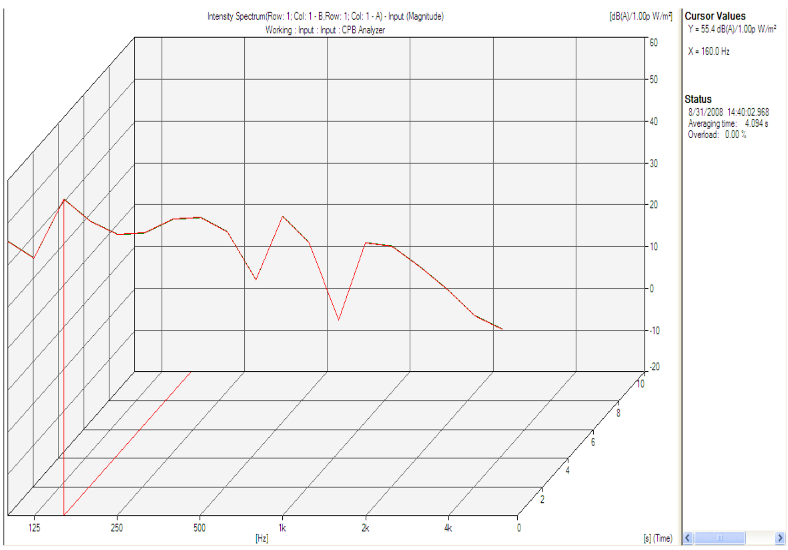

Figure 15: Frequency for left side is at 160Hz for 20^oC

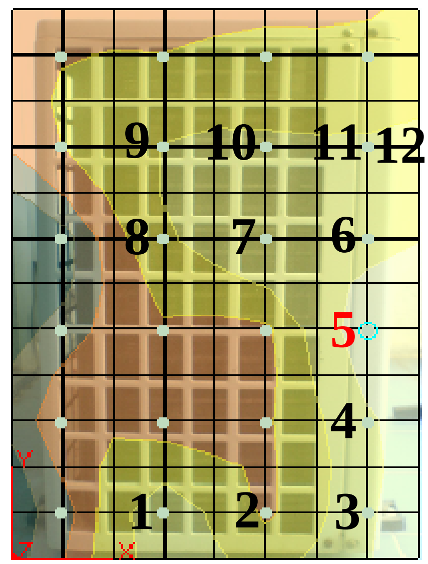

Figure 16: Noise sources for high speed fan at 20^oC at the left side

Table 5: Sound power level at the critical point at the left side for 20^oC

Location	Noise level, dB	Location	Noise level, dB	Location	Noise level, dB
1	57.902	5	59.409	9	57.051
2	55.204	6	57.848	10	57.24
3	58.341	7	57.193	11	57.178
4	58.28	8	56.762	12	57.075

Figure 17 shows the total sound power at different temperature and the fan speed is constant at high fan speed. It were measured at all average for each side to see that where the noise radiated more. Figure 18 shows the total sound power at different temperature and the fan speed is constant at medium fan speed. It were measured at all average for each side to see that where the noise radiated more. Figure 19 shows the total sound power at different temperature and the fan speed is constant at medium fan speed.

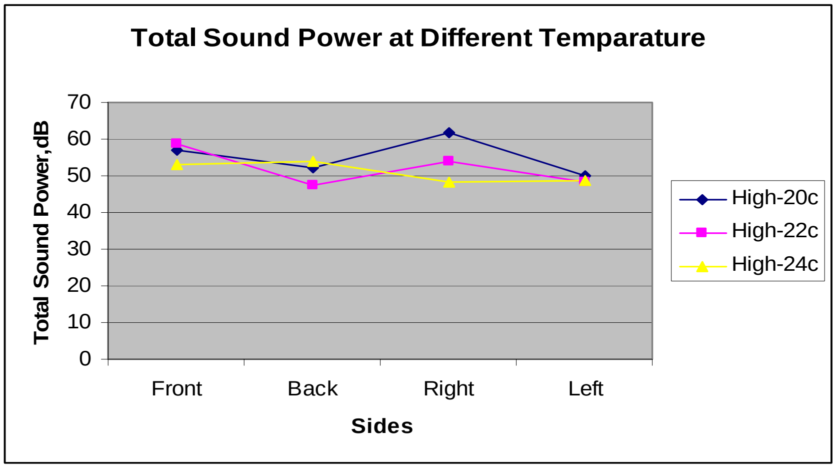

Figure 17: Graph of total sound power at different temperature for high fan speeds

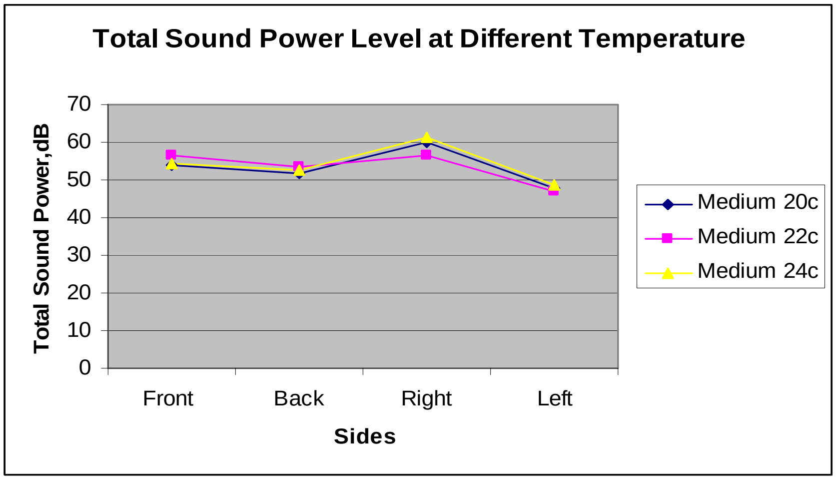

Figure 18: Graph of total sound power at different temperature for medium fan speeds

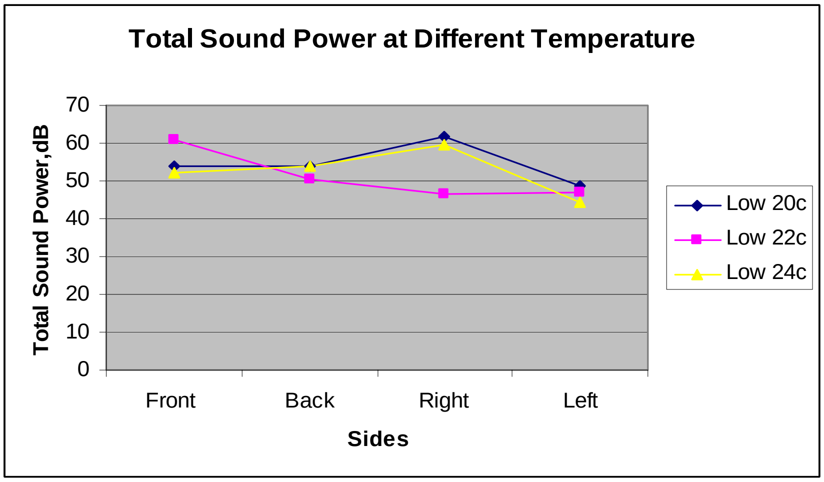

Figure 19: Graph of total sound power at different temperature for low fan speeds

For this section the analysis was done to find out the effect of fan speed at same temperature. Figure 20 shows the total sound power for different fan speeds at 20°C. It were measured at all average for each side to see that where the noise radiated more and the effect to sound power at different fan speed. Figure 21 shows the total sound power at different fan speeds at 22°C. Figure 22 shows the total sound power at different fan speeds at 24°C. It were measured at all average for each side to see that where the noise radiated more.

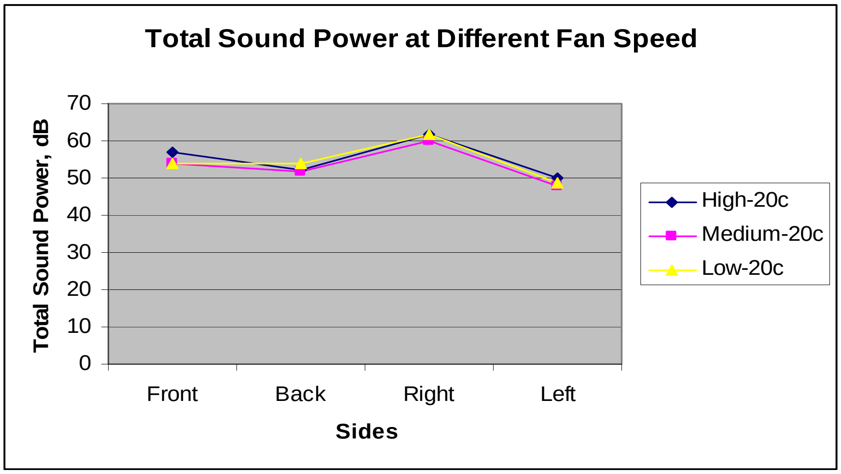

Figure 20: Graph of total sound power at different fan speeds at 20°C

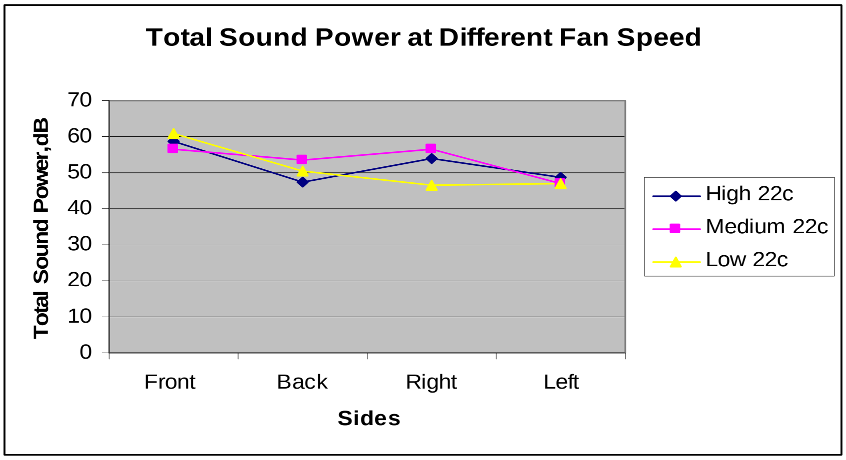

Figure 21: Graph of total sound power at different fan speeds at 22°C

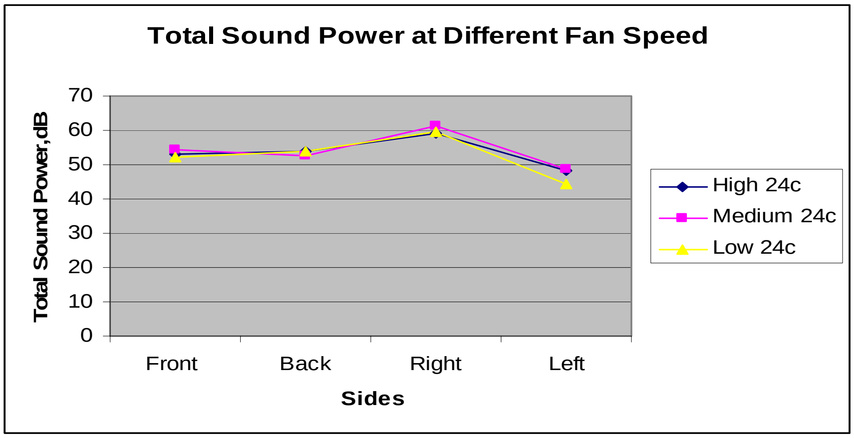

Figure 22: Graph of total sound power at different fan speeds at 24^oC

The result for same fan speed is use but for different temperature to determine the total sound power level at each side. The analysis wants to determine the effect of temperature of air conditioner at the same fan speed. Based on the Figure 17, Figure 18 and Figure 19 present that to achieve lowest temperature it will gives high total sound power. Although the result is not very accurate the increments when the temperature is at low temperature but at the some data it show very clear the increment of total sound power. The result for same temperature is use but for different fan speed to determine the total sound power level at each side. The analysis wants to shows the effect of high fan speed of air conditioner at the different temperature. Based on the Figure 20, Figure 21 and Figure 22 when higher fan speed it will also gives the higher total sound power level. Form the observation it is because the different of revolution per minute (rpm) of fan speed is not very much effect the total sound power level.

Conclusion

The result obtained from the sound intensity mapping process shows that for different temperature and different fan speed gives different effect on the noise signal as had been proved in this project. Sound power level will increase as higher fan speed and the lowest temperature of the air conditioner. From the analysis of the data it can be concluded that the highest noise sound levels occur at the front side which is at the fan that is about 74.784 dB. The second highest noise sound level is occur at the right side which is at the compressor is about 72.115 dB. The results that get from the analysis give the similar result with two papers that shows the noise generated from the air conditioner systems always occurred at the fan and compressor.

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