NOISE REDUCTION DESIGN OF A VACUUM CLEANER

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2017

DECLARATION

I declare that this project report entitled "Noise Reduction Design Of A Vacuum Cleaner" is the result of my own work except as cited in the references

Signature :

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Date : 7 . 7 . 2017

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APPROVAL

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

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Date : 7/7/2017

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DEDICATION

To my beloved mother, father and fiancee

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ABSTRACT

High sound threshold emission can cause discomfort due to annoying high frequency noise radiation and can even lead to hearing losses for a long term period. This problem was detected in the noise generated by the former vacuum cleaner, which emits about 75db to 85db of sound. The high airborne noise of the vacuum cleaner comes from two sources, which are the electric motor and the vibrating part of the vacuum. Therefore, this project was carried out to reduce noise contribution in former dry vacuum cleaner and propose design for dry vacuum cleaner that emits lower noise ganeration. This project starts with identify the possible vacuum part that produce so much sound and find the way to overcome the problem of noise. It was found that the electric motor is the source of the airborne noise and there is not much sound produce by the vibrating parts. Measurement of the sound using sound pressure level shows the reading of the noise produce by the dry vacuum cleaner is about 78db. Measurement for the heat rejection by the motor also recoded by using thermocouple to make sure that the vacuum cleaner is not getting overheat when isolating the vacuum with damper. From the measured sound pressure level, the solution chosen is using damper to isolate the motor and the exhaust of the vacuum. Two type of damper use that is from cellular type and fibrous type of damper to isolate the electric motor hence, reduce the sound generated by the vacuum cleaner.

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ABSTRAK

Penghasilan bunyi yang tinggi boleh menyebabkan ketidaselesaan disebabkan oleh frekuensi bunyi yang menjengkelkan dan juga boleh membawa kepada hilang pendengaran dalam jangka masa panjang. Masalah ini telah dikesan dalam penghasilan bunyi yang dihasilkan oleh pembersih vakum yg lama iaitu menghasilkan bunyi anggaran dalam 75db ke 85db bunyi. Bunyi bawaan udara yang tinggi dari pembersih vakum datang daripada dua sumber, iaitu motor elektrik vakum itu dan bahagian vakum yg mengalami getaran. Oleh itu, projek ini telah dijalankan untuk mengurangkan penghasilan bunyi dari pembersih vakum kering yg lama dan mencadangkan reka bentuk baru untuk pembersih vakum kering yang mengeluarkan bunyi yang rendah. Projek ini dimulai dengan mengenalpasti bahagian vakum yang berpotensi menghasilkan bunyi yang kuat dan mencari jalan penyelesaian untuk mengatasi masalah bunyi tersebut. Ia telah dijumpai bahawa motor elektrik adalah sumber utama bunyi bawaan udara dan bunyi yang dihasilkan oleh getaran bahagian vakum adalah kurang. Pengukuran bunyi yang dijalankan menggunakan meter tahap tekanan bunyi menunjukkan bacaan bunyi yang dihasilkan oleh vakum pembersih adalah 78db. Pengukuran penolakan haba yg dihasilkan oleh motor elektrik direkodkan menggunakan 'thermocouple' untuk memastikan pembersih vakum tidak mengalami masalah lebihan haba apabila pengasingan motor elektrik dilakukan menggunakan peredam bunyi. Dari tahap tekanan bunyi yang diukur, penyelesaian yang telah dipilih adalah menggunakan peredam bunyi untuk mengasingkan motor elektrik and juga ekzos pembersih vakum. Dua peredam bunyi yang digunakan ialah dari jenis selular dan juga peredam jenis berserabut bagi mengasingkan motor supaya dapat mengurangkan penghasilan bunyi pembersih vakum.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Prof Dr. Md Razali Bin Ayob for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank the assistance engineer from Fakulti Teknologi kejuruteraan named Encik Khairul Fitri for spending his time to guide me and let me use the laboratory equipment. They would share his knowledge in the field of acoustic sound with me and guide me to do experiment.

I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank my family for their support.

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CONTENT

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LIST OF FIGURES

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LIST OF ABBEREVATIONS

SPL	Sound Pressure Level
db	Decibal
Pa	Pressure in Pascal
cm	Centimeter

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LIST OF SYMBOL

Lp	=	Sound pressure
P	=	Pressure per meter area
P_0	=	Reference sound pressure level

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CHAPTER 1

INTRODUCTION

1.1 Background

Most of the time, designer have been spent on a study of a acceptable noise level in industry and environment generally, little consideration has been given to the noise of individual household appliances. For average living rooms and kitchens were designed specifically for appliance noise measurement to give a comfortable house to live in. Among all the household appliances, vacuum cleaner is the highest source of noise after kettles and food mixers. The built-in suction unit which consisting of electric motor and centrifugal blower represent the source of noisy noise for the vacuum cleaner. (G. M. Jackson and H. G. leventhall 1974)

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The contribution of noise generation to the noise level depends on the geometry of the suction unit and the operation condition. During operation of the operating unit, the dust particle gather in the dust bag causing a flow resistance and shifting the operating point to lower flow rates and to higher pressure rise. The suction unit built into a vacuum cleaner operates thus from free delivery to a stall or surge and zero flow rate. At partial flow rate and lower amount of the cooling air, the temperature of the electric motor starts to increase rapidly and a longer operation of suction unit under this condition is not recommended. (M. Cudina and J. Prezelj 2007)

There are variety of technologies, design and configuration of vacuum cleaner was produced by engineer from the beginning until now such as upright vacuum cleaner, canister, drum, wet or dry, backpack, hand-held and robotic. Two major issues in the development of a new vacuum are high suction performance and low noise emission. The former was designed vacuum cleaner performance depends on the degree of vacuum pressure and it is improved mainly by the development of high performance motor with large capacity to offer suction power. (I-S. Park et al. 2010)

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1.2 Problem Statement

For a former vacuum cleaner that have been produced, the system is contribute highly noise emission within 70db to 90db or maybe above than that. The noise pollution produced in the house sometimes distracting the family privacy and can cause damage to the hearing for a long term. Noise generated in vacuum cleaners is considered flow-induced noise and the main sources of the noise are classified into a high-speed rotation of a fan in the electric motor and flow resistance in a suction nozzle.

The total noise level of a suction unit is generated partially by the blower and partially by the electric motor and involves aerodynamic, mechanical and electromagnet noise origins. The contribution of the particular noise generating mechanism to the total noise level depends on the design of the suction unit (size and form) and on the operations condition (speed and load).

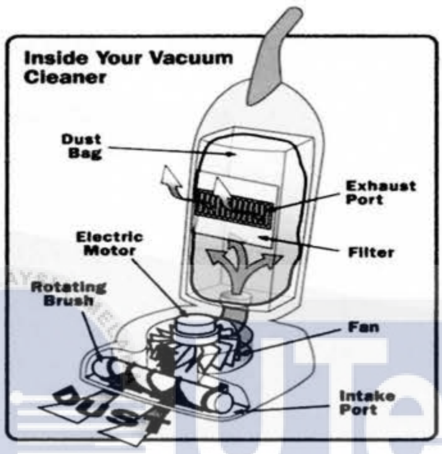

Figure 1.1: Upright vacuum cleaner

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1.3 Objective

There are two objectives of this project which are to reduce noise contribution in any type of former vacuum cleaner and propose design for vacuum cleaner which emits lower noise ganeration. The objectives are made based on the noise ganerate from the conventional vacuum cleaner which is higher and could effect to human hearing losses.

1.4 Scope of Project

The scopes of this project is only results of noise reduction are presented in this report because the result of the project are only noise level produce from the vacuum cleaner.

The second scope of projects is only wet or dry vacuum cleaner is simulate due to lack of time for doing experiment. There is also limitation on the budget to buy the vacuum cleaner which high in price.

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CHAPTER 2

LITERATURE REVIEW

2.1 Noise Transmission Through Vacuum cleaner

The sounds that are produce by vacuum cleaner mostly caused by the pressure drop behind the fan. The pressure level in the area behind the fan drops below the pressure level outside the vacuum cleaner (the ambient air pressure). This creates suction, a partial vacuum, inside the vacuum cleaner. The ambient air pushes itself into the vacuum cleaner through the intake port because the air pressure inside the vacuum cleaner is lower than the pressure outside. Steady thrust and drag forces that are induced on the blades as they move through the air and by impulsive interaction of the rotor blades with the inflow distortion and nearby stationary obstacles, such as the diffuser vanes and return passages cause the rotational noise of aerodynamic origin in the blower. (J.Preselj, 2007)

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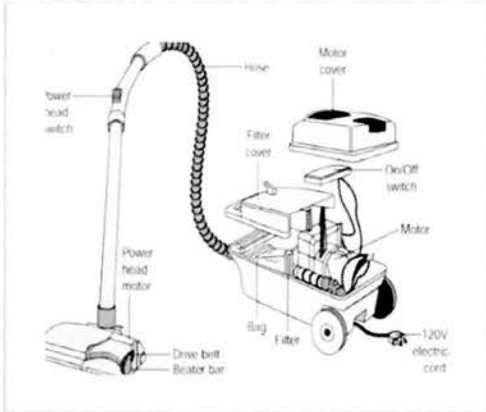

Figure 2.1: Inside dry vacuum cleaner

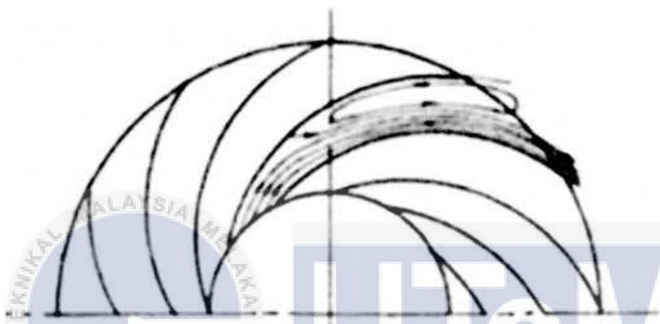

Figure 2.2: Sector of centrifugal blower with flow separations

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2.2 Noise Auditing

All noise measurements should be made from a standard test setup, at a constant distance from the noise source. There should be sufficient distance between the micrometer and the test equipment as even a slight variation in the testing distance will lead to higher variations in the readings of sound pressure levels. After establishing the test set up to adequately define the noise problem and to set a good basics for the control strategy, the following factors must be considered:

- The type of noise
- Noise levels and temporal patterns
- Frequency distribution

- Noise source (location, power, directivity)
- Noise propagation pathways, through air or through structure
- Noise rank order – in terms of contributions to excessive noise

Centrifugal blowers used in vacuum cleaners work with adverse pressure gradients along their flow path. An adverse pressure gradient occurs when the static pressure increases in the direction of the flow. This is important for boundary layer flows where increasing fluid pressure is akin to increasing the potential energy of the fluid, thereby leading to a reduced kinetic energy and a deceleration of the fluid. Since the fluid in the boundary layer is relatively slower, it is more greatly affected by an increasing pressure gradient. When flow reversal occurs, the flow was said to be separate from the surface. This has very significant consequences in aerodynamics. The flow reversal near the surface is the cause of vortex formation, creating oscillatory flows and a region of chaos. Thus, adverse pressure gradient and flow separation take a greater role in airborne noise generation.

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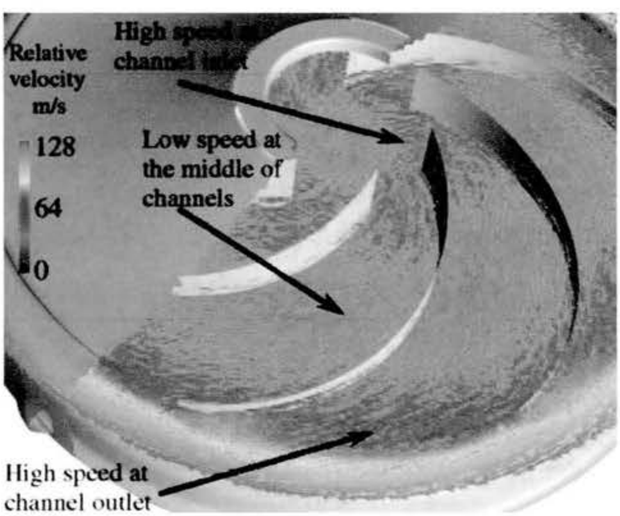

Figure 2.3: Flow in centrifugal blower by CFD

2.3 Characterization of the Structure-Borne Source

The noise generated within the suction unit is transmitted to the surrounding air partially through the airflow openings (mostly in the form of jets) representing sound bridges and partially through the vibrating structure (structure-borne noise). The excitation of the airborne noise in the surrounding air thus depends on the airflow velocity, geometry of the openings and on the vibration of the suction unit structure or the structure-borne noise. The structure-borne noise is a result of the common action of the aerodynamically, mechanically and electromagnetically excited forces, and depends on the design, mass, rigidity and damping of the suction unit elements. (J.Preselj, 2007)

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Figure 2.4: Result of a test to identify noise source for two different Frequencies (left 630 Hz : right 433 Hz)

The emitted noise of a suction unit is generated partially by the turbo blower and partially by the driving electric motor. The blower is the main source of aerodynamically generated noise, whereas the electric motor is the source of mechanical and electromagnetic noise origin causing most of the structure-borne noise. The structure-borne noise depends on the suction unit geometry; first of all, on the stator of the electric motor, or the metal shield if any, and the stator of the blower, or built-in vane diffuser, and on operating conditions (speed and load), primarily on appearing of the rotating stalls and surge.

2.4 Noise Control

In order to control of the noise during its propagation from the source to the receiver, some or all of the following actions need to be considered which is use of barriers, partial enclosures or full enclosure of the entire item of equipment and use of local enclosures for noisy components on a machine. Other than that, use of lined ducts or lined plenum chambers for air handling systems

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For the reverberation control, the addition of sound absorbing material to reverberant spaces is need to be considered to reduce reflected noise fields. Note that care should be taken when deciding upon this form of noise control, as direct sound arriving at the receiver will not be affected. Experience shows that it is extremely unusual to achieve noise reductions in excess of 3 or 4 dB(A) using this form of control which can be exorbitantly expensive when large spaces or factories are involved.

Lastly, for active noise control that involves suppression, reflection or absorption of the noise radiated by an existing sound source by use of one or more secondary or control sources should be considered.

2.4.1 Sound Absorption and Reflection

Sound absorption is the phenomenon by which sound is absorbed by transformation of acoustic energy into ultimately thermal energy. The friction produced between individual molecules of air moving within the restricted space of the pores has the ability to change some of the sound energy into heat. Alternatively, the vibration type absorbed will set the surface in motion by alternating air pressure. The friction between the molecules of the vibrating material creates heat (Parkin & Humphreys, 1958).

Sound absorbing materials are fibrous, lightweight and porous, possessing a cellular structure of intercommunicating spaces. The sound absorbing material is a dissipative structure that acts as a transducer to convert acoustic energy into thermal energy. The actual loss mechanisms in the energy transfer are viscous flow losses caused by wave propagation in the material and internal frictional losses caused by motion of the material's fibers.

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The absorption characteristics of a material are dependent upon its thickness, density, porosity, flow resistance and fiber orientation. Common porous absorption materials are made from vegetable, mineral or ceramic fibers which the latter for high temperature applications and elastomeric foams, and come in various forms. The materials may be prefabricated units, such as glass blankets, fiberboards, or lay-in tiles. When certain sound of energy is introduced because of the constant reflection of sound, the loudness is expected to be greater than if the same sound were made in a free field. Porous sound absorbers use the properties of interstices to alter the energy form of noise. Changes in flow direction, expansions, and contractions of the flow through irregular pores result in losses of momentum in the direction of wave propagation.

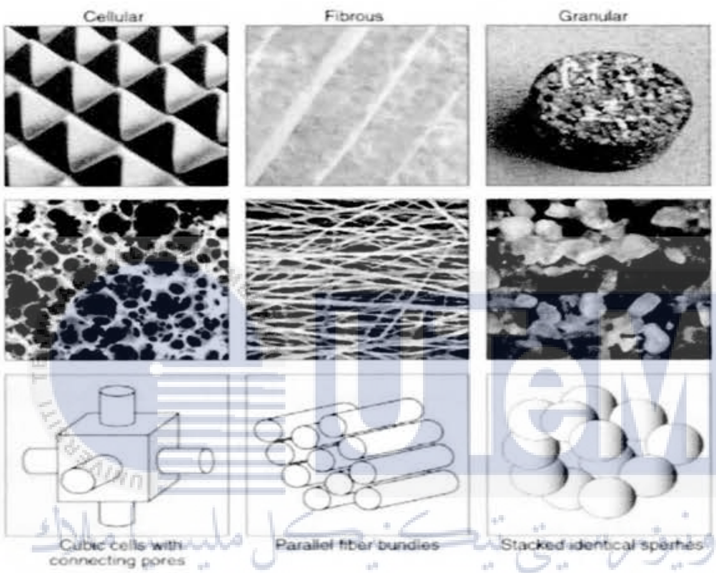

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Figure 2.5: The three main types of porous absorbing materials.

(Jorge P.Arenas, 2010)

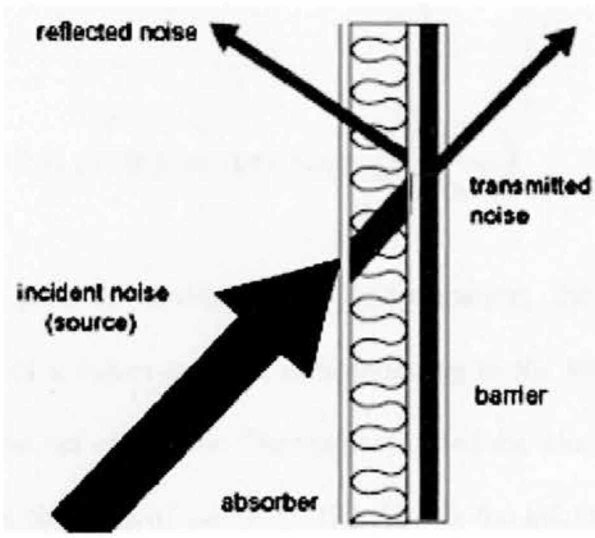

Figure 2.6: Impact of sound on the absorber

2.5 Sound Pressure Level (SPL)

One of the indices used to describe a sound-absorbing material is the Noise-Reduction Coefficient (NRC). The range of sound pressures that can be heard by the human ear is very large. The minimum acoustic pressure audible to the young human ear judged to be in good health, and unsullied by too much exposure to excessively loud music, is approximately 20 x 10^{-6} Pa, or 2 x 10^{-10} atmospheres (since 1 atmosphere equals 101.3 x 10^{3} Pa).

For the normal human ear, pain is experienced at sound pressures of the order of 60 Pa or 6 x 10^{-4} atmospheres. Evidently, acoustic pressures ordinarily are quite small fluctuations about the mean. To avoid a scale, which is too compressed over the sensitivity range of the ear, a factor of 10 is introduced, giving rise to the decibel. The level of sound pressure is then said to be decibels (dB) greater or less than a reference sound pressure according to the following equation:

$$SPL\ (dB) = 10\ log_{10}\left(\frac{p^2}{{p_o}^2}\right)$$

For the purpose of absolute level determination, the sound pressure is expressed in terms of a datum pressure corresponding to the lowest sound pressure that the young normal ear can detect. The result is called the sound pressure level, Lp (or SPL), which has the units of decibels (dB). This is the quantity that is measured with a sound level meter.

Sources at 1 m	Sound Pressure	Lp re 20 μPa *
Rifle	200 Pa	140 dB
Threshold of pain	20 Pa	120 dB
Pneumatic hammer	2 Pa	100 dB
6 dB = double the Pa	1 Pa	94 dB
Street traffic	0.2 Pa	80 dB
Talking	0.02 Pa	60 dB
Library	0.002 Pa	40 dB
TV Studio	0.0002 Pa	20 dB
Threshold of hearing	0.00002 Pa	0 dB

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Figure 2.7: Some typical sound level

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project to obtain data input for designing new vacuum cleaner with less noise. The flow chart of the project is shown in Figure 3.1. This project starts by studying the conventional vacuum cleaner and study the correct way to obtain noise source and valid measurement data. After suspected noise source in conventional vacuum cleaner, research of the noise reduction is performed before conducting sound level measurement. If the noise source shows a reduction result, a solution is proposed to resolve the noise problem. Otherwise a new suspected noise source is investigated, new noise reduction way is prepared and measurement is retaken for the new way to reduce the noise level of the vacuum cleaner.

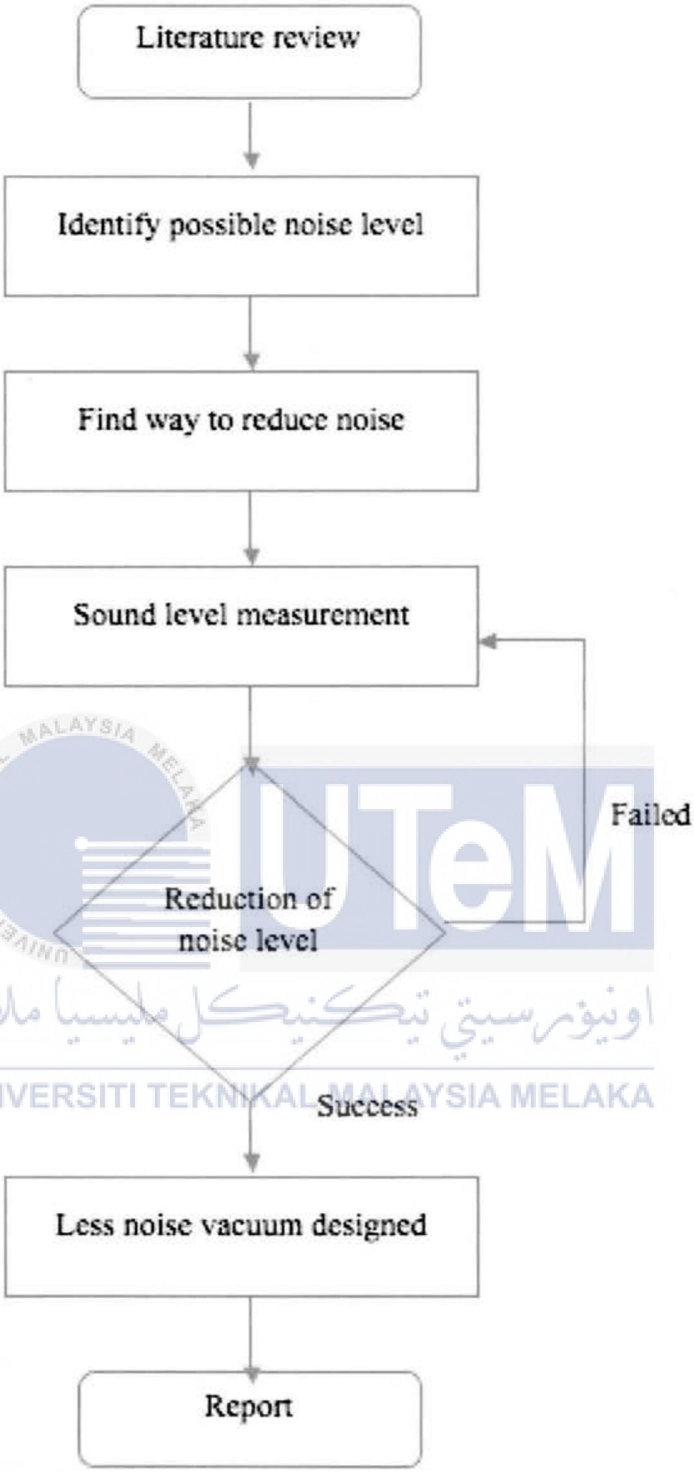

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Figure 3.1: Flow chart of the methodology.

3.2 General Experimental Setup

Figure 3.2 shows the general experimental setup for sound level measurement. Type 2 sound level meter and a computer were used to obtain data input for the noise reduction design of vacuum cleaner. The sound is then evaluated within the device and acoustic measurement values are displayed. The most common unit of acoustic measurement for sound is the decibel (dB). Measurement tests were carried out with various configurations, for example by rotating the vacuum cleaner unit in three directions and also measuring the sound levels by putting the sound damper around the vacuum motor to isolate it and test with different length towards the motor. There are three type of damper design that has been chosen to isolate the motor of the vacuum.

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Figue 3.2 (a): Sound level measurement experimental set up.

Figue 3.2 (b): Inside part of vacuum cleaner set up.

Figue 3.2 (c): Isolation motor of vacuum cleaner set up.

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Figue 3.2 (d): Exhaust port of vacuum cleaner set up

3.2.1 Sound Pressure Level (SPL) Measurement

In order to measure the sound pressure level of the vacuum cleaner, the sound meter level type 2 are use to measure noise generate from the vacuum cleaner. A type 2 sound levels meter has an accuracy of ±2 dBA as shown in figure 3.3. Type 2 sound level meter performs with the minimum level of precision required by OSHA for noise measurements. The sound level meter is placed in four points in 45-degree angle in circular as shown in figure 3.1 above so that it can collect and measure sound of the whole vacuum cleaner and take the average reading from those four.

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Figure 3.3: Sound level meter type 2 with wind screen

The sound level meter are setup 1 meter length and 1.5 meter hight from the vacuum cleaner as shown in figure 3.2. Before using it, the sound level meter should be calibrated and temperature-stabilized because of the surrounding environment at the test lab. The vacuum cleaner are switch on for a minute to get steady noise ganerated before taking the reading. The table is tabulated as table 3.1 below.

Test	Damper Placement	Sound Pressure Level (db)
1	Only isolate the motor	
2		
3		
1	Only at the exhaust of vacuum cleaner	
2		
3		
1	Combine isolate motor and exhaust of the vacuum	
2		
3		

Table 3.1: The SPL measurement table

3.2.2 Thermocouple Measurement

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. One is connected to the body whose temperature is to be measured; this is the hot or measuring junction. The other junction is connected to a body of known temperature; this is the cold or reference junction. Therefore the thermocouple measures unknown temperature of the body with reference to the known temperature of the other body. In this experiment, one junction is connecting to the electric motor and one to the body of the vacuum cleaner. The data of heat rejection by the electric motor will be tabulated as table 3.1 and the experiment runs three times each damper placement to get average result and minimize error. The thermocouple used in this experiment is Digital Industrial K-type Thermocouple Thermometer HVAC Stainless Steel Probe T3.

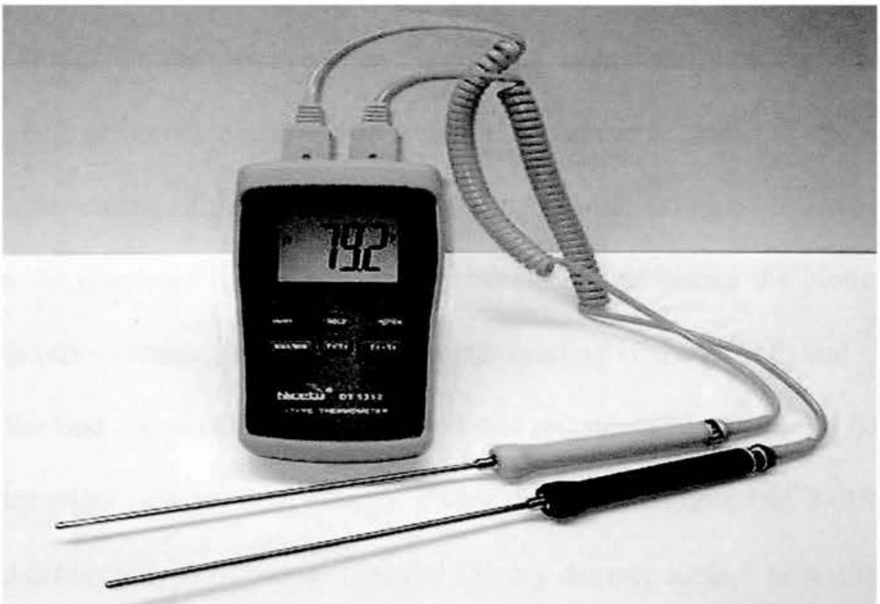

Figure 3.4: K-type Thermocouple Thermometer HVAC Stainless Steel Probe T3

Table 3.1: The heat rejection measurement table

Test	Damper Placement	Heat Rejection (joule)
1	Only isolate the motor	
2		
3		
1	Only at the exhaust of vacuum cleaner	
2		
3		
1	Combine isolate motor and exhaust of the vacuum	
2		
3		

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3.2.3 Design of Damper

Afew design of damper has been choosen to isolate the motor of vacuum cleaner that made of porous absorbing material. The damper is placed at the motor, exhaust and inner casing of the vacuum cleaner .The damper is placed to reflect and absorb the sound ganerated by the vacuum cleaner as well as isolate the motor. For the normal vacumm cleaner, the sound level meter reading is about 78db and in this experiment, the best damper design and method that reduce more sound will be take as propose design of new vacuum cleaner. Every design of damper has a different thickness and different type of porous material . Every damper surface give different degree of sound absorption and different reflection of sound that will help in reducing the sound ganerate from the vacuum cleaner.

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(a) (b)

Figure 3.5: (a) Design A damper (cellular type material)

(b) Design B damper (fibrous type material)

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

In this section, the results from series of experiment will be present and it is all will be discussed further later on. The data and results obtain during the experiment will be represented in a quantitative value and it is all are tabulated. The results will be in two parts:

1. The results of sound produced by vacuum cleaner with and without damper.
2. The results of heat rejected by the motor of vacuum cleaner with and without the damper.

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4.2 Result of Sound Vacuum Cleaner With and Without Damper

The first experiment conducted was testing the sound of vacuum cleaner without damper (original). This experiment objective was to get the initial sound produced by the vacuum cleaner to compare with vacuum cleaner that using damper. The experiment was repeated three times in fifteen minutes each season for three separated time that is days, afternoon and evening. The test was done in three-separated time in order to get known about the effect of temperature against the sound propagation.

Test	session	Sound pressure level (db)
1	Morning	78.5
2		78.4
3		78.4
4	Afternoon	78.1
5		78.3
6		78.3
7	Evening	79.7
8		79.8
9		79.8

Table 4.2: The sound data collected from the experiment without damper

4.2.1 Result of Sound by Vacuum Cleaner with Cellular Damper Type

In this part, the results of sound for the experiment involving the cellular damper type which attached to the vacuum cleaner. The details of the data from the experiment can be seen as the tables below:

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Test	Damper Placement	Sound Pressure Level (db)
1	Only isolate the motor	70.5
2		70.6
3		70.6
4	Only at the exhaust of vacuum cleaner	72.3
5		72.5
6		72.4
7	Combine isolate motor and exhaust of the vacuum	68.5
8		68.6
9		68.6

Table 4.2.1: The sound data collected with cellular damper type

4.2.2 Result of Sound by Vacuum Cleaner with Fibrous Damper Type

In this part, the results of sound for the experiment involving the fibrous damper type which attached to the vacuum cleaner. The details of the data from the experiment can be seen as the tables below:

Test	Damper Placement	Sound Pressure Level (db)
1	Only isolate the motor	71.4
2		71.4
3		71.5
4	Only at the exhaust of vacuum cleaner	72.8
5		72.9
6		72.9
7	Combine isolate motor and exhaust of the vacuum	69.7
8		69.8
9		69.8

Table 4.2.2: The sound data collected with fibrous damper type

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4.3 Result of Heat Rejection From The Motor with Cellular Damper Type

In this part, the results of heat rejection by the motor involving the cellular damper type, which attached to the vacuum cleaner was tabulated. The details of the data from the experiment can be seen as the tables below:

Test	Damper Placement	Heat Rejection (^{o}c)
1	Only isolate the motor	90.3
2		90.6
3		90.6
4	Only at the exhaust of vacuum cleaner	92.4
5		92.5
6		92.4
7	Combine isolate motor and exhaust of the vacuum	93.7
8		93.7
9		93.8

Table 4.3: The heat data collected with cellular damper type

4.3.1 Result of Heat Rejection From The Motor with Fibrous Damper Type

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In this part, the results of heat rejection by the motor involving the fibrous damper type, which attached to the vacuum cleaner was tabulated. The details of the data from the experiment can be seen as the tables below:

Test	Damper Placement	Heat Rejection (^{o}c)
1	Only isolate the motor	89.5
2		89.6
3		89.6
4	Only at the exhaust of vacuum cleaner	90.5
5		90.6
6		90.6
7	Combine isolate motor and exhaust of the vacuum	91.3
8		91.5
9		91.4

Table 4.3.1: The heat data collected with fibrous damper type

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4.4 Analysis of The Vacuum Cleaner with Cellular Damper Type

From the data obtained from the Table 4.2.1, we can see that the values of the difference sound pressure level due to different damper placement to the vacuum cleaner. From the chart below, we can see that the value highest sound value produce by the damper placement only at the exhaust of vacuum cleaner follow by the damper placement only at the motor. The most excellent damper placement that reduces much noise was placed on two parts that is at the motor and the exhaust of the vacuum cleaner.

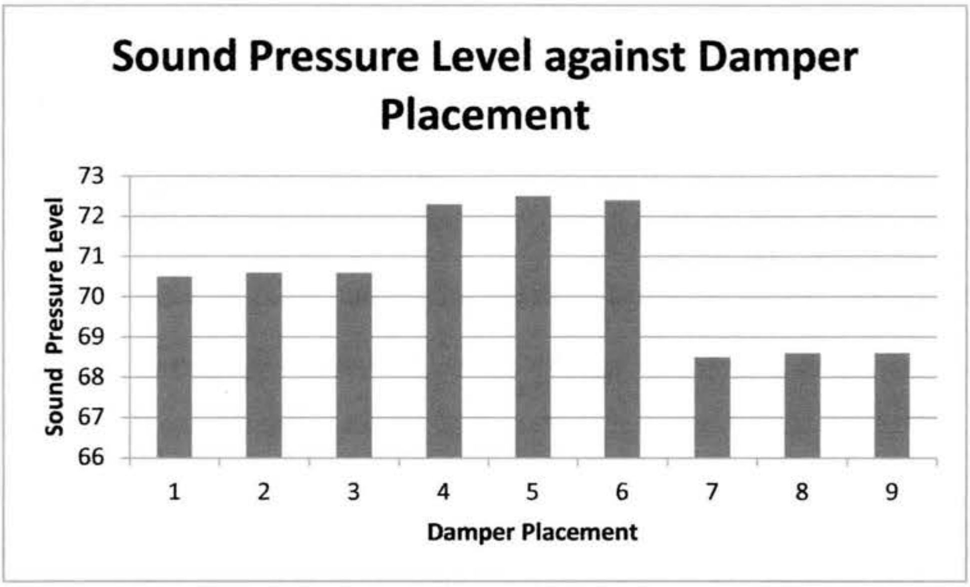

Chart 4.4: Graph sound pressure level (db) against damper placement

Other than collecting reduction from the vacuum cleaner, the data of heat rejection by the motor of vacuum cleaner also gathered. The data of heat rejection by the motor with cellular type damper placement has been tabulated as table 4.3 and a graph was drawn to show the relation between damper placement and the amount heat rejected by the motor.

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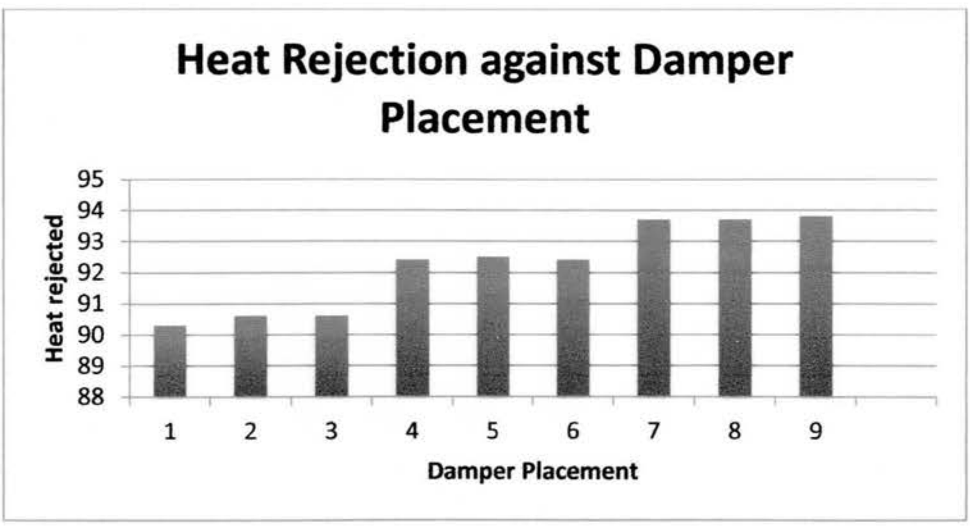

Chart 4.4.2: Graph heat rejection (^{o}c) against damper placement

From the chart above, we can see that the value highest heat rejected produce by the damper placement at on two parts that is at the motor and the exhaust of the vacuum cleaner due to blocking of heat flow in the exhaust part. Followed by the damper placement only at the motor and the most excellent damper placement that reject less heat was damper placed only at the exhaust part of the vacuum cleaner.

4.5 Analysis of The Vacuum Cleaner with Fibrous Damper Type

From the data obtained from the Table 4.2.2, we can see that the values of the difference sound pressure level due to different damper placement to the vacuum cleaner. From the chart below, we can see that the value highest sound value produce by the damper placement only at the exhaust of vacuum cleaner follow by the damper placement only at the motor. The most excellent damper placement that reduces much noise was placed on two parts that is at the motor and the exhaust of the vacuum cleaner.

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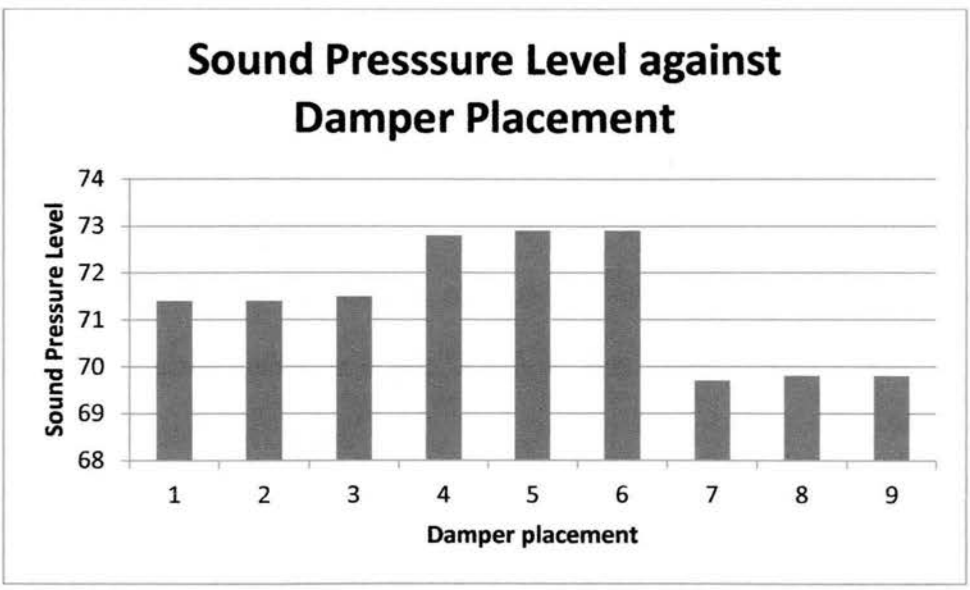

Chart 4.5.1: Graph sound pressure level (db) against damper placement

The data of heat rejection by the motor with fibrous type damper placement has been tabulated as table 4.3.1 and a graph was drawn to show the relation between damper placement and the amount heat rejected by the motor.

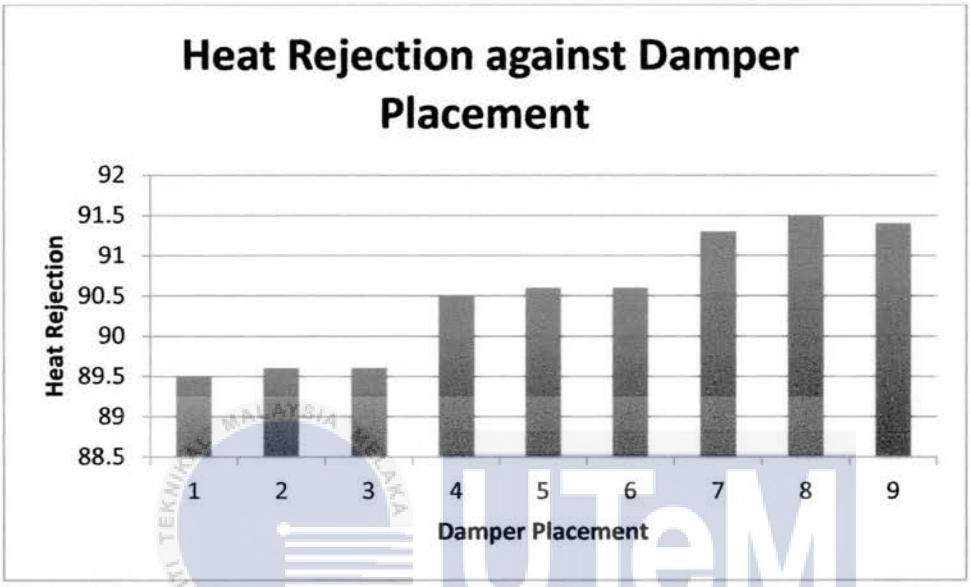

Chart 4.5.2: Graph heat rejection (^{0}C) against damper placement

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From the chart above, we can see that the value highest heat rejected produce by the damper placement at on two parts that is at the motor and the exhaust of the vacuum cleaner due to blocking of heat flow in the exhaust part. But there are slightly different in temperature of the best damper placement with cellular type about 2.3 ^{0}C. Followed by the damper placement only at the motor and the most excellent damper placement that reject less heat was damper placed only at the exhaust part of the vacuum cleaner

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In a nutshell, first objective which is to reduce sound of former vacuum cleaner was achieved by using damper with different material to isolate the source of noise. The new propose design of vacuum cleaner only emits 68db of sound pressure level which less than former vacumm noise(78db). Two type of damper were used to isolate the source of noise for the vacuum cleaner which is cellular type and fibrous type of material.

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Next, second objective is to propose new design of vacuum cleaner which emits lower noise also achieved. The best damper design is cellular type damper placed at the electric motor and the exhaust of the vacuum with reduction about 10db but increase the heat generated by the motor due to influent flow of air blocked by the damper.

5.2 Recommendation

For future works, a lot of improvement need to be done. The other reseacher should use other material and changing the blade maybe for better performance of vacuum cleaner. The method that I am doing is not recommended because the damper cause the motor to overheat due to blocking the air flow. It is recommended to change the blade of the motor to prevent turbulent flow happening and can reduce noise ganerated by the vacuum cleaner.

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