NORHAFIS BIN SAMAT BACHELOR OF MECHANICAL ENGINEERING (STRUCTURE AND MATERIALS) 2015

THE DESIGN AND FABRICATION OF AN OIL VACUUM CLEANER FOR INDUSTRIAL USE

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This thesis is submitted as a part of the fulfillment for the bestowal of Bachelor in Mechanical Engineering (Structure and Materials) with honours.

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ABSTRAK

Vakum Pembersih Minyak (OVC) adalah alat yang selalu digunakan dalam sektor industri di negara serta digunakan secara meluas di luar rantau ini. Semasa menjalani latihan industri, vakum pembersih minyak yang digunakan tidak dapat menahan suhu panas minyak kotor yang hendak dibersihkan. Oleh itu, projek ini dihasilkan sebagai salah satu kaedah penyelesaian bagi masalah tersebut. Vakum yang dihasilkan ini menggunakan konsep vakum konvensional tanpa kehadiran tenaga elektrik namun menggunakan angin sebagai sumber kuasa. Maka, dengan menggunakan udara yang mampat dan juga menggunakan bahan kitar semula, vakum perbersih kos rendah yang berupaya menahan suhu tinggi dapat dihasilkan. Dalam projek ini, penyelidik menekankan kepada reka bentuk dan fabrikasi bahan kitar semula yang boleh menampung suhu yang tinggi dan juga dihasilkan daripada bahan kos yang rendah. Vakum pembersih minyak yang dihasilkan menggunakan tenaga daripada proses pengeluaran bagi menjalankan operasi.

ABSTRACT

Oil Vacuum Cleaner (OVC) is a common device used within industry sector in our country and widely applied outside of this region. It applied the concept of conventional vacuum without present of electrical energy but use the wind as the power source. During industrial training, a conventional oil vacuum cleaner was used only in short time due to not withstand the high temperature of oil waste present in the machine. Thus this project is one of the solutions to face the problem through industrial training. This vacuum cleaner use the conventional vacuum concept without use the electric power supply but use the wind as the source of energy. With the use of compressed air and recycled material, a low cost industrial vacuum cleaner which can withstand to high temperature was invented. In this project, the researcher emphasizes on the design and fabrication of recycled material that can cope with the high temperature and made of low cost material. It also uses the available energy from production process to operate.

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CAD	Computer Aided Design
CAE	Computer Aided Engineering
FYP	Final Year Project
AOV	Apez Oil Vacuum
DTY	Draw Texturizing Yarn
PVC	Polyvinylchloride
RM	Malaysia Ringgit
P_1	Pressure at point 1(Initial)
P_2	Pressure at point 2(Final)
Q	Flow rate
m^3	Cubic meter
ρ_{Air}	Density of air
$\rho_{coning\ oil}$	Density of coning oil
A	Area
V	Velocity

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND:

A vacuum cleaner is an electrical household appliance that is used to clean floors, carpets, furniture and some time in our car. A vacuum cleaner sucks up dusts and dirt by creating a partial vacuum using an electrical air pump. The air is forced to flow through a filter where the dust and dirt are captured. Vacuum cleaners are also used in industries to clean all sorts of waste such as oil spill, hazardous dust and machining waste. Although both domestic and industrial vacuum cleaners work based on the same principle, the industrial vacuum cleaners are specially designed to suit the intended application environments such as factories, construction sites or machining workshops.

This final year project (FYP) is about designing and fabricating a low cost industrial vacuum cleaner. This project was inspired when the author undergone industrial training at Recron (M) Sdn Bhd. Recron is a multinational company that produces various types of textile products for local and export market. One of the author's responsibilities was to maintain the machines used in Draw Texturizing Yarn (DTY) production line. Cleaning oil spill coming out of the machines is part of the routine works and sometimes it has to be done immediately without stopping the machine. At Recron, a general purpose industrial vacuum cleaner is used to clean the

oil spill. The detail specifications of the current vacuum cleaner will be discussed in the next chapter.

1.2 PROBLEM STATEMENT

A general purpose industrial vacuum cleaner is normally used at Recron to clean the oil spill. However, it was observed that the use of this vacuum cleaner was not suitable if the oil temperature was high especially when the machine was operating. Although the existing vacuum cleaner is marketed as industrial use product, from the design aspect the material selection process was made mainly to reduce costs and therefore many of the main components are made of plastics. Even though engineering plastics are known for its durability however the main drawback is that the low melting temperature of these plastic materials causes some of the components to melt when it is used at high temperatures. Common issues when dealing with hot oil are leaking bin or tank; and melted hoses. There are special types of industrial vacuum cleaners that are suitable for high temperature applications however the unit price is very high. The cost of replacing or repairing a malfunction vacuum cleaner could be costly and time consuming. Therefore, a new innovative and low cost design of an industrial vacuum cleaner that can be operated at high temperature is needed.

1.3 THE OBJECTIVE AND HYPOTHESIS

The objective of this project is to design, fabricate and test of a new low cost oil vacuum cleaner system that is suitable for use in industrial environment. The hypothesis is that if the readily available sources such as compressed air and recycled material are used, a low cost vacuum cleaner that suitable for high temperature can be produced.

1.4 RESEARCH SCOPE

1) To identify the design requirements for a low cost industrial vacuum cleaner. Several concepts will be list out and comparing each of their best criteria. The engineering design tools for specified the requirement will be applied.

2) To use Computer Aided Design (CAD) and Computer Aided Engineering (CAE) in the design and analysis process. It will be design software such as Solidwork and material selection such as CES Edupack.

3) To fabricate a working prototype of a low cost oil vacuum cleaner. To obtain the low cost prototype, most of the main material used will be recycled material with some improvement to achieving the objective. Before fabricated it, some material selection will be conduct to support the suggesting material.

4) To conduct prototype testing under actual working conditions. After fabricating it, testing and refinement will be carried out. The testing area will be around the actual working condition with supervised from skillful technician. There will be refinement step if error or malfunction occur during testing process for directly troubleshoot problems.

1.5 PROJECT OVERVIEW

Chapter 1 will explained briefly about the purpose of this project and how this project is chosen. It will include background of the project, problem statement, objectives and research scope. Basically, the project generated while undergone industrial training. The problem arises when one of the vacuum cleaner was broken down due to high temperature.

Starting from problem that is, the broken down of an oil vacuum cleaner due to high temperature. Through time, with several advices and research from professional and project supervisor, a solution is achieved to resolve the problems.

The purpose is to suggest material which best to withstand high temperature and produce in low cost.

Chapter 2 will includes history of vacuum and how it evolved, principles of vacuum that is the main concept in this project, and comparison of product that mainly produced by other region beside Malaysia. The history helps in understand how this vacuum concept is applied for better used. Meanwhile for the comparison, many manufactures are not from Malaysia, so, the cost is quite high with shipping and the product cost itself.

Chapter 3 including Quality function development, engineering design process, house of quality, product design specifications, physical description, Pugh concept, morphological chart and configuration design. Several materials will be choosing to compared and be select as the best material. From that, other features will be added to help in making better design. All that features will also be compared with the advantage and disadvantage. Finally, one model will be selected which is the best from other model to fulfilled the purposed of this project and will undergoing testing and refinement after done in fabricating it.

Chapter 4 emphasize on result and discussion. This can be divided into three categories which are selection of material, fabrication process and testing the prototype. With selected design and material, the fabricated process and testing process is conducted in actual working condition. The testing is conducted two times for ensuring its function in the first test and second is for operate in working station. Sample calculation also constructed to check on flow rate that exist in the project.

Chapter 5 is conclusion and recommendation that involve on the outcome gained through one year by completing this project such as acquiring new knowledge and also gaining priceless experience. Other than that, some recommendation is add so that for future sake, better improvement can be employ.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF VACUUM CLEANER

A vacuum cleaner is an appliance that removes dry material (dust, fibre, threads) from the surface to be cleaned by an airflow created by a vacuum developed within the unit. The material thus removed is separated in the appliance and the cleaned suction air is returned. In 1900, vacuum cleaners were already been invented but operated totally by human (Ashby 2012). The housemaid standing firmly on the flat base while pumping the handle of the cleaner, thus compressing below it, via leather flap-valves for introduce one air-way flow, sucked air inside a metal that contain filter at a flow rate 1 L/s. The butler involved in manipulated the hose. Material that present in that time is quite conventional because it was obtained directly from natural sources such as wood, rubber, leather and canvas. Despite that, some metal was already pressing in the making such as for container filter (metal used is mild steel that are rolled to make a cylinder) as shown in Figure 2.1.

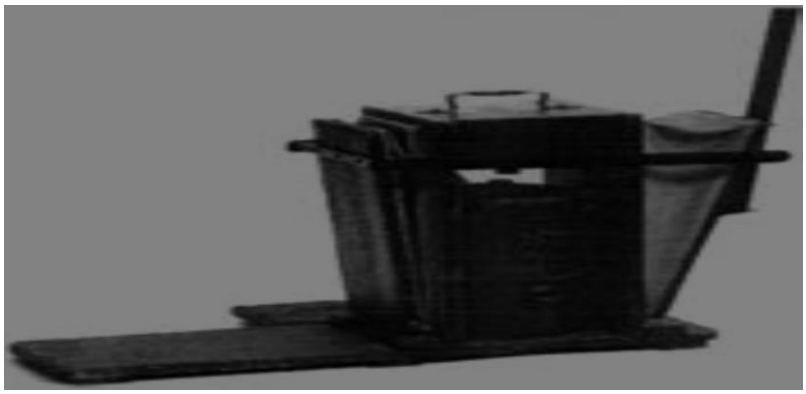

Figure 2.1: First generation of vacuum cleaner (Ashby, 2012).

Meanwhile, the electric vacuum cleaner was first appeared around 1908. During 1950, cylinder cleaner is formed shown in Figure 2.2 (flow rate about 10L/S). The principal for this design can be described as air flow is axial, electric fan will draw it through. The electric fan will occupied about half diameter of cylinder where the rest will holds the filter. Following that, advancing in design is achieved when electrically driven air pump is invented. The motor are thick and have flow power and can function properly without housemaid's elbow or tea breaks. It is totally made up of metal and include the tube that suck up dust are made up of mild steel which metals have entirely replaced all natural materials.

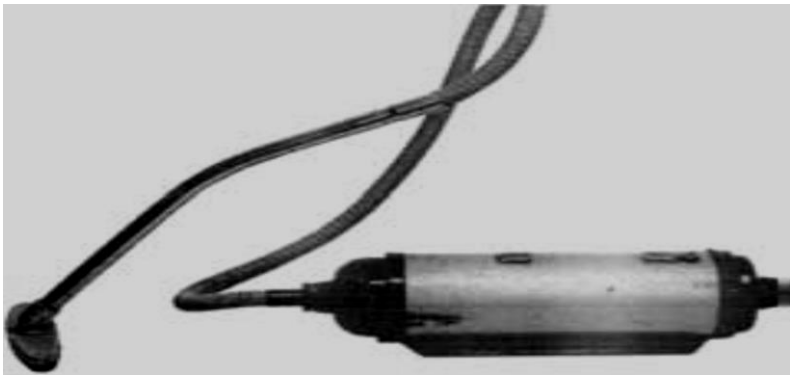

Figure 2.2: Second generation of vacuum cleaner (Ashby, 2012).

Since the development had been increased aggressively, together with tendency of using new material, comes out the 1985 vacuum cleaner as in Figure 2.3. Specifications that available are power around 16 housemaids working flat out

(800w) and double up the power (Ashby 2012). For the air flow is still longitudinal and dust removal by filtration technique. This is due to higher power density inside the motor that operate, induced better magnetic field, and higher operating temperature (bearings, insulations, heat resistant and windings). The outer part is totally polymer and another example of good design that involved plastics. The top part is single molding with some extra bits joint by snap fasteners molded into original component. Number of components had surprisingly reduced with casing had only 4 parts, held by 1 fastener contrary to previous 1950 cleaner that consists 11 parts and 28 fasteners.

Figure 2.3: Third generation of vacuum cleaner (Ashby, 2012).

Although the sources on polymer are quite limited during that time, cost saving and weight is greater as shown in Table 2.1 (Ashby 2012). Next for Figure 2.4, it shows a different concept which is inertial separation rather than filtration. To work this concept, rotation and power have to be higher than, product is larger and higher cost.

Figure 2.4: Fourth generation of vacuum cleaner (Ashby, 2012).

Table 2.1: Comparison of cost, power and weight of vacuum cleaners (Ashby, 2012)

Cleaner and date	Dominant materials	Power (W)	Weight (kg)	Approximate cost*
Hand powered, 1900	Wood, canvas, leather	50	10	£240–$380
Cylinder, 1950	Mild steel	300	6	£96–$150
Cylinder, 1985	Molded ABS and polypropylene	800	4	£60–$95
Dyson, 1995	Polypropylene, polycarbonate, ABS	1200	6.3	£190–$300

*Costs have been adjusted to 1998 values, allowing for inflation.

Thus, development design requires the innovation and creativity to use either new materials or recycled materials properties, both aesthetic and engineering. There are many manufacturers of vacuum cleaners cannot improvised rather innovate or create for better use in the future.

2.2 PRINCIPLE OF VACUUM ENERGY

The main concept in this project is manipulates the vacuum or air pressure that available in the production line. But first, vacuum concept needs to be expressed clearly. Vacuum is obtained from Latin word that is *vacua*, which is empty. Vacuum is just only half of empty space, whereas some of other gases and air have been removed from a gas containing volume (gas is defined from Greek word chaos = infinite, empty space). For simple word is, vacuum defined as any volume consists of less gas particles, atoms and molecules (a lower particle density and gas pressure) compared to surrounding outside atmosphere. Starting from well-known Greek philosophers, Demokritos (460-370 B.C) and his teacher Leukippos (5^{th} century B.C), where discussing the concept of vacuum and assuming there might exist an absolute empty space, contrary to matter of countless number of indivisible atoms forming the universe. Aristotle (384-322 B.C) claimed that nature is frightened by total emptiness and there is an insurmountable horror vacui. Thus, he rejected about these an absolute vacuum. He speculated that the idea of this empty space would introduce the principle of motion that not including resistance. Following that is an

experiment carried out by scientist and philosopher from French named Blaise Pascal (1623-1662), stated that horror vacui was proved wrong as in Fig 2.5. He also measured the altitude with the Hg barometer was invented by Torricelli, provide enough into the concept of vacuum physics and gives many vital knowledge in physics. Thus, unit for measure degree of vacuum by the International Standards Organization (ISO) of pressure was known as honor of Pascal (Neils Marquardt 1999):

1 Pa = 1 N/m2 = 7.501 x 10-3 Torr =10-2 mbar

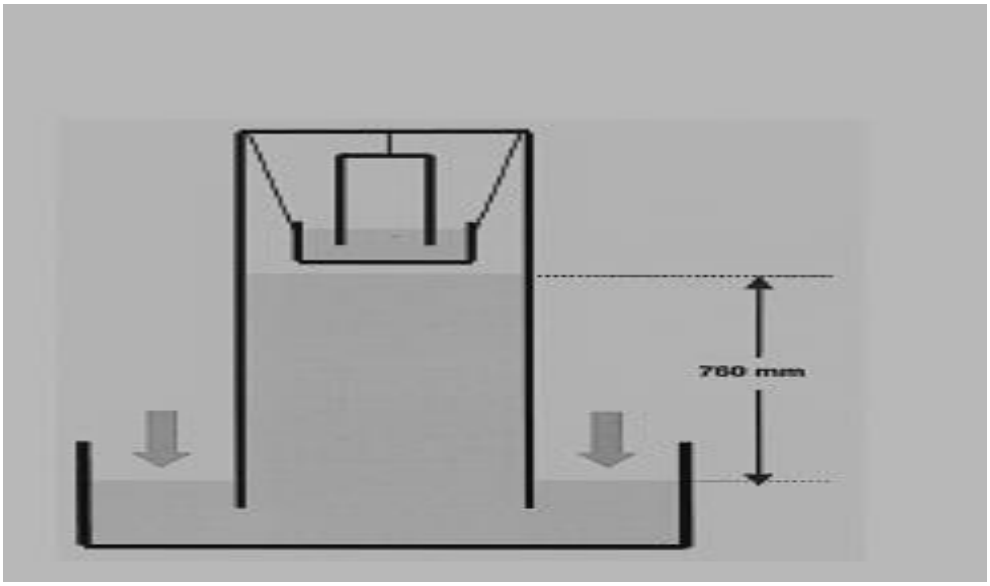

Figure 2.5: Experiment by Blaise Pascal proving the existing of atmospheric pressure with vacuum (Niels Marquardt, 1999).

Other significant discovery was through Robert Boyle (1627-1691) that built vacuum pump with Edme Mariotte in year 1627-1684 (Neils Marquardt 1999). They expressed that the law of Boyle-Mariotte, the fundamental equation of gas law that was valid for ideal gases in thermodynamically equilibrium, (p=pressure, V=volume and T=absolute temperature of gas)

Vacuum can be defined as particles in a volume with constant motion. It exerts a force on its surface area that called pressure. Pressure, force over unit area of vessel is measured by comparing it with atmospheric pressure.

Table 2.2: Conversion factors for pressure in various systems of units

	Pa ($N m^{-2}$)	mbar	Torr (mm Hg at 0 °C)	Technical Atmospheres (at)	Physical Atmospheres (atm)
Pa ($N m^{-2}$)	1	1.0×10^{-2}	7.5×10^{-3}	1.02×10^{-5}	9.87×10^{-6}
mbar	1.0×10^{2}	1	7.5×10^{-1}	1.02×10^{-3}	9.87×10^{-4}
Torr (mm Hg at 0 °C)	1.33×10^{2}	1.33	1	1.36×10^{-3}	1.32×10^{-3}
Technical Atmospheres (at)	9.80×10^{4}	9.80×10^{2}	7.36×10^{2}	1	9.68×10^{-1}
Physical Atm.(atm)	1.01×10^{5}	1.01×10^{2}	7.60×10^{2}	1.03	1

2.2.1 Composition of air

Atmospheric air contains a combination gases with over 78% nitrogen (refer Table 2.2), whereas lightest gas hydrogen is the rest of high and ultrahigh vacuum. This is because, hydrogen will easily diffuses into walls, take in by all surfaces enclosing the volume and is less adequately pumped than gases of vast active molecules.

Table 2.3: Composition of atmosphere (at sea level)

Gas	Percent by Volume (m^3)	Partial Pressure (mbar)
N_2	78.08	7.93×10^{2}
O_2	20.95	2.12×10^{2}
Ar	0.93	9.39
CO_2	33×10^{-3}	3.33×10^{-1}
Ne	1.8×10^{-3}	1.87×10^{-2}
He	5.24×10^{-4}	5.33×10^{-3}
Kr	11×10^{-4}	1.11×10^{-3}
H_2	5×10^{-5}	5.06×10^{-4}
Xe	8.7×10^{-6}	8.79×10^{-5}
H_2O	1.57	1.72×10
CH_4	2×10^{-4}	1.99×10^{-3}
O_3	7×10^{-6}	7.06×10^{-5}
N_2O	5×10^{-5}	5.06×10^{-4}

(Niels Marquardt, 1999)

2.2.2 Ideal gases

For the theoretical concept related with ideal gas is very applicable for characterization of vacuum-physics completion. There are several assumptions such as (a) molecules shape are small spheres (b) the density of the gas is approximately small, example is volume of molecules is miniature differ to volume of filled with gas (c) molecules that not applying forces to another, i.e. the temperature obtained for the gas is not quite low, (d) flow of molecules is continuous and irregular and (e) the contact between molecules is elastic. In this normal conditions, conversion from one state of a gas state, given by P_1 that is pressure, thermodynamic temperature denoted by T_1 in