
# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## THE APPLICATION OF C- SHAPED CURVE IN AIR FILTER DESIGN: A CASE OF PERFORMANCE CAR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) with Honours.

By

**JULIA ANAK LUMING**
**B051110295**
**910410-13-5964**

FACULTY OF MANUFACTURING ENGINEERING
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TAJUK: **THE APPLICATION OF C-SHAPED CURVE IN AIR FILTER DESIGN : A CASE OF PERFORMANCE CAR**

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# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The member of the supervisory committee is as follow:

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# ABSTRAK

Secara teorinya, prestasi penapis udara adalah mengikut rekabentuk penapis udara, saiz penapis udara dan jenis bahan yang digunakan. Rekabentuk penapis udara dipilih sebagai kanta dalam kajian penyelidikan ini. Rekabentuk kon seperti Rezton dipilih sebagai rekabentuk yang sedia ada kerana prestasi dan rekabentuk yang sama jika dibandingkan dengan rekabentuk penambahbaikan. Prestasi penapis kon mengikut rekabentuk corong, sudut batang dan dimensi batang. Oleh itu, ciri-ciri ini diperlukan apabila merekabentuk penapis kon ini. Konsep berbentuk C peralihan keluk atau juga dikenali sebagai keluk berprofil tinggi kemudian dicadangkan untuk mengatasi masalah ini. SolidWorks adalah perisian yang digunakan dalam merekabentuk profil penapis udara sama ada secara sedia ada atau model rekabentuk penambahbaikan. Skim-skim struktur linear statik dan analisis "fatigue" digunakan untuk mengetahui kesesuaian struktur antara model dalam mod statik. Hasil ini menunjukkan bahawa apabila maksimum Von Mises tekanan dan anjakan adalah lebih rendah, justeru itu, nilai baik faktor keselamatan dapat dicapai. Selain itu, COMSOL Multiphysics 4.2a adalah pakej dinamik yang digunakan untuk menganalisis model-model dalam tujuan dinamik. Daripada hasil kajian ini, bagi input halaju yang sama iaitu $6\,ms^{-1}$, halaju, tekanan dan kelikatan untuk rekabentuk penambahbaikan adalah $82.152\,ms^{-1}$, 7848.8 Pa dan 3931.4 Pa.s manakala $79.794\,ms^{-1}$, 15366 Pa dan 691.73 Pa.s untuk rekabentuk sedia ada. Ia menunjukkan bahawa, rekabentuk penambahbaikan menghasilkan halaju dan kelikatan dengan nilai tertinggi dan oleh itu, tekanan rekabentuk penambahbaikan itu dapat dikurangkan. Oleh itu, rekabentuk yang berbentuk C memberi kesan yang baik dalam merekabentuk penapis udara yang berprofil tinggi yang kemudian sesuai untuk kereta prestasi.

# ABSTRACT

Theoretically, the performance air filter is in accordance to the shape design of air filter, the size of the air filter and the type of material used. The shape design of the air filter is selected as a lens on this research study. The conical design such as Rezton is chosen as an existing design due to its performance and similar design when compared to the improvement design. The performance of conical filter is mostly considered the design of the funnel, an angle of stem and the dimensions of stem. Thus, these characteristics are required when designing this conical filter. The concept of C-shaped transition curve or also known as high profile curve is then proposed to overcome this issue. SolidWorks is the software used in designing the air filter profile either in existing or in improvement design models. The structural schemes such as linear static and fatigue analyses are applied to find out the structural applicability amongst the models in static mode. The resulted showed that when the Maximum Von Mises Stress and displacement are lower, consequently, the good value of safety factor is achieved. Furthermore, the COMSOL Multiphysics 4.2a is the dynamic package that used to analyze the models in dynamic purposes. As the results, for the same input velocity where initial velocity is $6\,ms^{-1}$, the velocity, pressure and viscosity for improvement design are $82.152\,ms^{-1}$, 7848.8 Pa and 3931.4 Pa.s whereas $79.794\,ms^{-1}$, 15366 Pa and 691.73 Pa.s for the existing design. It shows that, the improvement design produced the highest values of velocity and viscosity and due to that, the pressure of the improvement design can be reduced. Therefore, the C-shaped design gives good impacts in designing the high profile air filter which then suitable for the performance car.

# DEDICATION

Specially dedicated to my father, Luming anak Giman and my mother. Sidot anak Andum who are very understanding, caring, patient and supporting for help me mentally. Also thanks to my dearest siblings, honorable lecturers and loyal friends for the guidance, patient and encouragement in my final year project.

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# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

PH - Pythagorean hodograph

$S_f$ - Safety Factor

DOE - Design of Efficiency

OEM - Original Equipment Manufacturer

CFD - Computational Fluid Dynamics

CAGD - Computer Aided Geometric Design

CAD - Computer-Aided Design

FEA - Finite Element Analysis

FEM - Finite Element Method

2D - Two Dimensional

3D - Three Dimensional

FEA - Finite Element Analysis

TET10 - Tetrahedral Elements

$\rho$ - Pressure

$\sigma_0$ - Von Mises Stress

$d$ - Displacement

$\eta$ - Viscosity

$v_0$ - Velocity

$v_i$ - Initial Velocity

# CHAPTER 1
# INTRODUCTION

The Chapter 1 focuses on the general ideas of the research study, which provided an overview of the air filter profile design using C shaped curve. In this chapter, it consists of the background of the project, problem statements, objectives and the scope of the research study.

## 1.1 Background of the Research Study

Air is not only vital in any life form on earth, but also the important mechanism in vehicles especially the performance of the car engine. Nonetheless, air is constantly contaminated with all sorts of pollutants such as fumes, dust, smoke and other atoms. For example, temperature and humidity, these particles are not always visible to the eye, but they are harmful to the engine. Chander et al. (2014) observes that these particles reduced the cleanliness of the air and can lead to severe damage of all engine components.

Basically, Julian (2011) stated that the air filter is an essential part of a car's intake system, as it is through the air filter that the engine "breathes". In addition, Julian (2011) also explained that the purpose of the air filter is to filter out dirt and other foreign particles in the air and improving the combustion efficiency. While an air filter is one of the essential components of engines as defined by Shukri et al. (2013).

Furthermore, Loud et al. (1991) noted that the important characteristic of an air filter is its efficiency. Bugli et al. (2004) explained that the factor that causes the efficiency of air filters are accordance to the shape design of air filter, the size of the air filter and type of

material used. Therefore, the shape design of air filter is selected as the lens for this research study.

In general, profiles define as the surface elevation along an alignment. Profile design is important in designing the air filter because the profile design will affect the efficiency of an air filter performance (Bugli et al., 2004). According to Michael et al. (2000), it is impossible to maintain good air quality with a poorly designed of an air filter. This statement also supported by Julian (2011) that the poor air quality will significantly impact the performance of a car engine.

Nowadays, there are several types of air filter such as panel filter, cylindrical filter and conical filter. In general, the method designing of panel air filter was using rectangular shape. Mathematically, the volume of a rectangle is increased in contrast to its density is low. Therefore, the pressure loss in the air filter is low due to low air density. Generally, the air filter panel was designed to have a high cleaning efficiency, but it shows that pressure drop is low (Farr, 1940). Figure 1.1 shows the panel of the air filter.

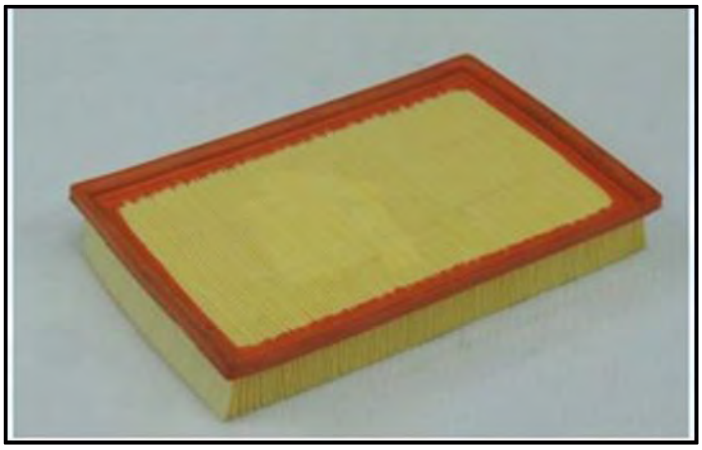

**Figure 1.1:** Panel air filter (Anonymous, 2014)

Besides, the type of cylindrical air filter was designed by using the cylinder method. Paul et al. (1996) said that a cylindrical air filter element consist of an inner liner and outer liner, a closed end and an open end. Paul et al. (1996) also said that the diameter of the opening is smaller than the outside diameter of that portion of the outlet of the end cap that extends into the housing. In cylindrical design, air is sucked radially in through the folded paper forming a thick cylinder wall and where the cleaned air is sucked out from

the filter axially through a central opening of the filter (Sundquist, 1998). Mathematically, the density of the cylinder is low due to its volume is high. Figure 1.2 represents the cylindrical of air the filter.

**Figure 1.2:** Cylindrical air filter (Anonymous, 2014)

Moreover, the cone air filter was designed by using the cone method. Beyer (1987) said that the conical design is created by cutting the top off a cone (with the cut made parallel to the base) that displayed in Figure 1.3.

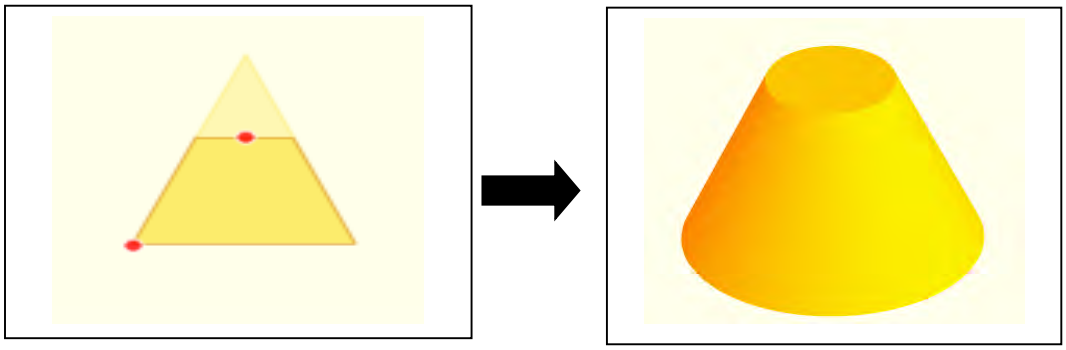

**Figure 1.3:** The slicing top off a cone (left) and final conical design (right) (Beyer, 1987)

In cone method, the suitable measurement of filtration through stainless steel folded in order to form a cone (Bogaty and Carson, 1944). Griffin and Parish (1922) have highlighted the performance of conical filter accordance to the design of the funnel, angle and the dimensions of the stem. Thus, when applying the cone method, the designer should consider these characteristics. The cone method is depicted in Figure 1.4.

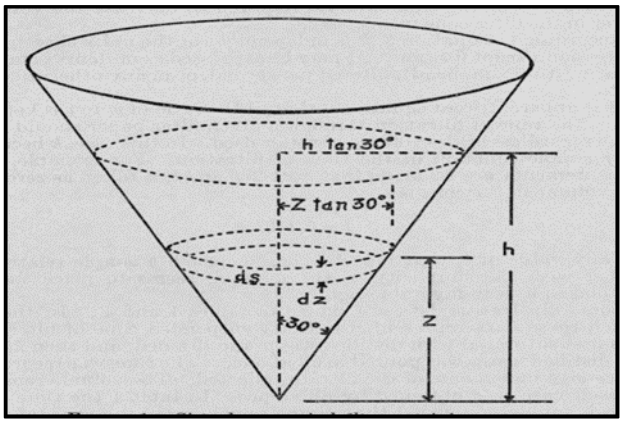


**Figure 1.4:** Cone and its application in conical filter (Bogaty and Carson, 1944)

The example of conical air filter such as Rezton's air filter. Rezton's air filter has applied cone as a basis model of designing it. According to Tadeusz et al. (2004), the pressure loss coefficient of the conical filter elements is higher than another type of the shape design while the air velocity is also increased. Figure 1.5 shows the Rezton's air filter.

**Figure 1.5:** Conical air filter (Anonymous, 2014)

These shapes of air filters have been compared in term of their functionalities. By referring Figure 1.6, it shows the relationship between the face velocity and dust capacity among the type of the shape design air filter. The 'dust capacity' of an air filter refers to the amount of dust the filter is capable of holding during its functional life. While, the 'face velocity' refers to the airflow divided by the total area of the air filter. Figure 1.6 also depicts the different relationship or curve exist based on the type of air filter and type of material used to create the filter. These curves are shown in the graph. From the graph,