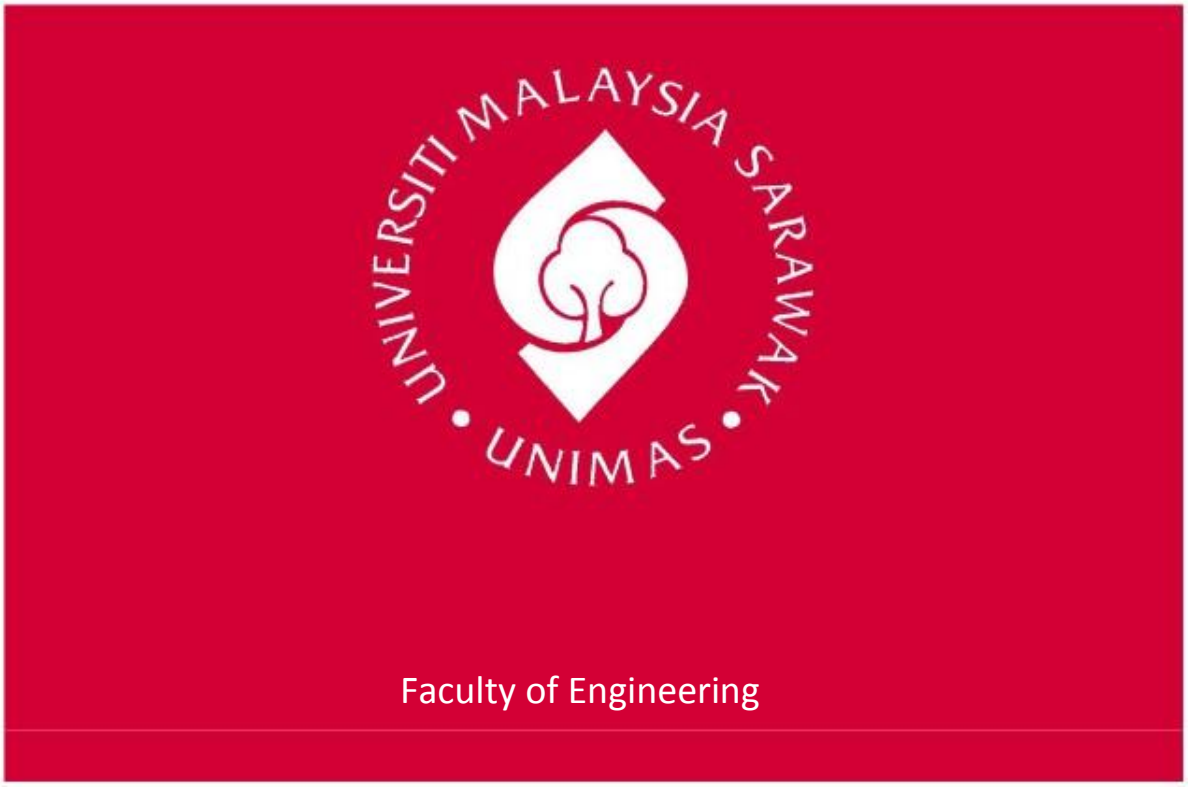


# DESIGN OPTIMIZATION OF AIR INTAKE FILTER SYSTEM FOR CAR'S APPLICATION

Firdhaus Bin Abdul Ghani

Bachelor of Engineering (Hons)

Mechanical and Manufacturing Engineering

2019

UNIVERSITI MALAYSIA SARAWAK

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Assoc. Prof. Dr. Syed Tarmizi Syed Shazali Date:

Project Supervisor

# DESIGN OPTIMIZATION OF AIR INTAKE FILTER SYSTEM FOR CAR'S APPLICATION

FIRDHAUS BIN ABDUL GHANI

A final year project report submitted in partial fulfilment of
the requirement for the degree of
Bachelor of Engineering (Hons) Mechanical and Manufacturing Engineering

Faculty of Engineering
Universiti Malaysia Sarawak

2019

Dedicated to my beloved family and friends.

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# ABSTRACT

Air intake and filter systems play a major role in getting air with good quality int o the vehicles. It helped to improve the efficiency for combustion and also reduces air pollution. The air intake system is work as to supply the engine with clean and correct amount of air ratio for the required air to burn in the manifold chamber. This paper focuses on modifying the geometry of the air filter cabin in to optimize the model thus, reduce the pressure drop. This research is to analyse the model and pressure drop of Perodua Axia air filter cabin on the intake system. In order to understand the flow behaviour through the air filter cabin, CFD analysis was carried out for an existing model. Based on the results of the existing CFD model, geometric changes such as guide vane placement in the inlet plenum are operated to improve the flow characteristics. The CFD analysis of the optimized and modified model was again carried out and the results showed good improvement in flow behaviour with considerable reduction in pressure drop and significant reduction in recirculation zones inside the air filter cabin. By using the CFD, optimize design of the air filter cabin is achieved with considerable reduction with an improvement of 29% of pressure drop reduction from the original model.

# ABSTRAK

Sistem pengambilan udara dan penapis memainkan peranan utama dalam mendapatkan udara yang berkualiti dan bersih ke dalam enjin kereta. Ia meningkatkan keefisienan pembakaran dan juga mengurangkan pencemaran udara. Sistem pengambilan udara berfungsi untuk membekalkan enjin dengan nisbah udara yang betul dan bersih untuk udara yang diperlukan bagi proses pembakaran dalam ruang manifold. Projek ini memberi tumpuan kepada mengoptimumkan geometri kabin penapis udara dalam industri automobil untuk mengurangkan penurunan tekanan dan meningkatkan kawasan penggunaan penapis. Kajian ini adalah untuk menganalisis model dan penurunan tekanan kabin penapis udara bagi kereta Perodua Axia. Analisis CFD dijalankan untuk model yang sedia ada untuk memahami kelakuan aliran melalui sistem pengambilan, geometri penapis udara dan media penapis. Keputusan yang diperoleh daripada analisis CFD model yang sedia ada menunjukkan hubungan yang baik dengan data eksperimen. Berdasarkan model CFD model yang sedia ada, perubahan geometri seperti pembelah angin yang diletakkan di bahagian dalam kabin penapis udara dilakukan, untuk meningkatkan ciri aliran. Analisis CFD bagi model yang dioptimumkan dan diubahsuai sekali lagi dijalankan dan hasilnya menunjukkan peningkatan yang baik dalam tingkah laku aliran dengan pengurangan penurunan tekanan yang ketara dan pengurangan dalam zon pengedaran di dalam kabin penapis udara. Dengan menggunakan analisis CFD 3D, reka bentuk optimum sistem pengambilan untuk enjin kereta dicapai dengan pengurangan yang besar dengan peningkatan 29% pengurangan penurunan tekanan dari model asal.

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# ABBREVIATIONS

| | |
|---|---|
| CFD | Computational Fluid Dynamic |
| 3D | Three-Dimensional |
| 2D | Two-Dimensional |
| cm | Centimeter |
| rpm | Revolutions Per Minute |
| Kg | Kilogram |
| s | Second |
| KPa | Kilo Pascal |

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

This thesis focuses on the air intake filter system for car application. Air is essential for the combustion process inside the engine. Clean atmospheric air is very much essential to burn the fuel inside the combustion chamber to produce useful power and undesired emission (Thorat & Kamble, 2011). To ensure the good quality of air into the engine, air intake system plays a major role. Air intake system also improve the combustion efficiency of the engine. Air will enter the filter via dirty pipe and inlet side plenum, which guides the flow through the filter media uniformly (Safwan, 2009).

Most vehicles are equipped with air filters for made from paper of felt. Air filter prevent dust from entering to the engine combustion chamber and protect against abrasive wear. The operation of an internal combustion engine without air filter would lead to ten time faster of engine wear (Herbert & Halderman, 1991). Fully utilization of the filter can significantly increase the lifespan of the filter, thus reduce the cost of filter replacement.

Particulate contaminant such as dust will significantly impact the engine and the car's performance. If the filter loses the capacity filtering the air, dust particle such as shard and debris can go through the filter and can lead to engine wear (Christian, 2017). Also, (Barris, 1995) specified that around 80% of the cases shows that the engines duration is limited by the consequences against wear. Moreover, if the process of contaminant continues, the whole engine may fail causing car break down.

## 1.2 Problem Statement

The flow efficiency of the intake system has a direct impact on the power the engine is able to deliver. This project is to analyse the pressure drop of the intake system. If the flow in the air intake determined to have less turbulent flow, there is less pressure drop across the intake system. Resulting in the increases of the efficiency for the combustion of air in the intake system. The CFD will be used for analysing the internal flow of the air filter cabin to get the initial result. From the analysis, the value of pressure drop in certain rpm of engine power can be determined. The difference speed of air flow based on the lower until maximum rpm of engine will be used.

In order to optimize the design, understanding on flows and pressure drop through the system is essential. CFD analysis is considered to be the most effective solution for analysis. This project will develop a modified and optimized design of the air filter cabin for Perodua Axia engine.

## 1.2 Objective

The objectives of this project include;

i. To develop a 3D model of an air filter cabin.
ii. To design the air filter cabin for the optimization.
iii. To reduce the pressure drop inside the air filter cabin.

## 1.3 Scope of Study

The scope of this project comprises the boundaries of project study. The pressure drop analyses of air intake system are wide range of study. Many components should be bound to achieve the goals of this project. First, the study using Bernoulli Equation to determine the pressure drop in calculation. This equation is very useful to identify the velocity, density and pressure of the air flow. Furthermore, this project study using the SolidWorks to design the air filter cabin model. The CFD will be used to analyse the air flow inside and get the result in difference speed of engine from minimum until maximum.

## 1.4 Summary of Thesis

Chapter 1 provide the reader with an overview of the project background whereby it briefs about the definition, function of air intake system and air filter of vehicle and factors that affecting the air filter. The problem statement, objectives and scope of study are also included in this chapter.

Chapter 2 consists of the literature review of the research. This include the previous and existing studies that implemented by other researchers which is related to the field of study.

Chapter 3 focuses on the methodology of this research. It consists of the work flow and process involved in the analysis and design optimization of the air filter.

Chapter 4 explain on the result obtained from the analysis and testing process. Also, discussion also included to justify the result. All the result obtained is visualised in the form of diagram and figures to ensure clarity and wide view for the reader.

Chapter 5 deducts this research with an appropriate conclusion and recommendation for further improvements in the future.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter present a review of literature of air intake system, component of air intake filter system, type of air filters used, past research and the aspect relating to the pressure drop analysis.

## 2.2 Air Intake System

The first air intake system was introduced in the 1980s where it consisted of moulded plastic tubes and a cone-shaped cotton gauze air filter. Intake systems have been extremely simple throughout much of the automobile's early history. The first cars that had the air intake systems was consisting literally of nothing, only a fresh air inlet into the carburettor.

Because air often contains particulate matter, especially in sandy and dusty environments, an unfiltered air allows contaminants to enter the carburettor, which can cause an issue to the engine. This led to the first air filters being developed, first in the agricultural industry and then in the automotive industry.

The basic function of the engine air intake system is to provide the engine as much as possible with a fresh air-fuel mixture for combustion in the combustion chamber. (Ceviz, 2010). A vehicle used daily cannot have the same system of intake as a racing vehicle. Engines specifically for racing require maximum volumetric efficiency to increase power and torque, thereby increasing the fuel consumption. Daily driving vehicles rarely use high end power, thus the economically and drivability at lower speeds is important (Makgata, 2005).

### 2.2.1 Component of Air Intake Filter System

Air intake systems usually consist of inlet pipe, air filter, air box, outlet pipe, intake manifold plenum, and intake manifold runner.

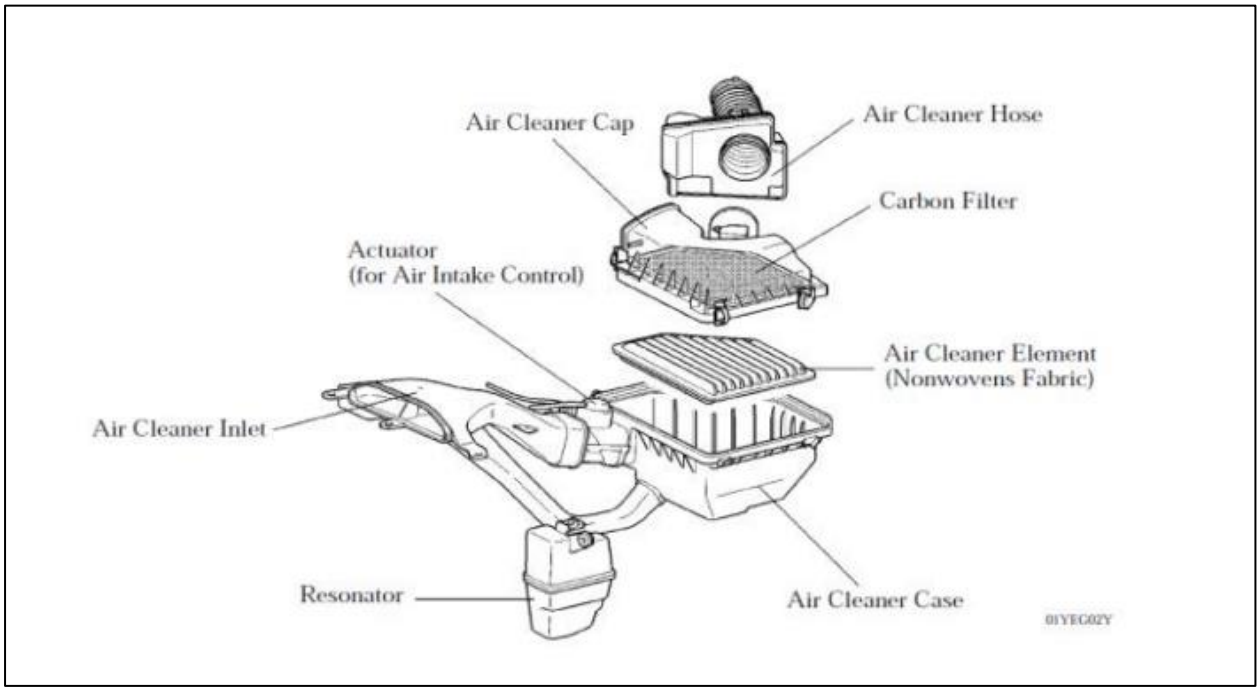


Figure 2.1: Air Intake Filter of Automobile (Abraham,2015)

The air through these air intake systems can face a major pressure drop challenge, thus establishing a major obstacle for the designed to minimize the pressure drop in the air intake system. Low air flow resistance and good air distribution are the important design criteria for developing the air intake systems (Ceviz, 2007). A positive pressure at the end of the frontal dirty pipe would help to overcome the drawback. Most car manufacturers designed the dirty pipe to be placed at the front of the vehicle to increase the engine's ability to consume more air. Also, getting the air from the vehicle's front can help reduce the internal noise contribution from the intake orifice (Rizalman, 2008).

### 2.2.2 Air Flow Through Air Intake System

For an engine that equipped with a carburettor, the air flow is straightforward. Air will be flows through air filter into the carburettor where the air is mixed with fuel. The air-fuel mixture then enters through the intake manifold chamber and is drawn into cylinder. Air temperature sensor is the most advanced part in this system. This sensor is used for measuring air temperature which can enable cool air to enter the heated pipe.

For Fuel-injected car, long plastic tube will guide the air to the air filter. After entering the air filter, the air goes through a flow meter, throttle body with an air valve, then to the air intake chamber, intake manifold and finally to the cylinder (Shahril,2012).

## 2.3 Type of Air Filter Used in Vehicles

In today's market, there are 4 main types of air filters used in vehicles. These include paper filters, foam filters, high performance filters and oil bath filters.

### 2.3.1 Paper Filters

Paper filter is the most common for automobile engine air cleaners, because they are efficient and cost-effective. The pulp can come from crops made from softwood, hardwood or fibre. Dissolving pulp or mercerized pulp is used for high-quality filters. The "paper" in these filters is pleated to increase the surface area. So, there is more space and area for the filter to filtered dust and particulate matter. The disadvantage of these filter is that the flow poor thus restrict the engine performance. In fact, as long the paper filter is sized appropriately for the airflow volumes, it will be encountered restriction to flow until the filter has become clogged with dirt and needed to replace with a new one. These filters are relatively cheap and easy to be replace but need to be done more often than any other type of filters. Figure 2.2 shows a paper filter.

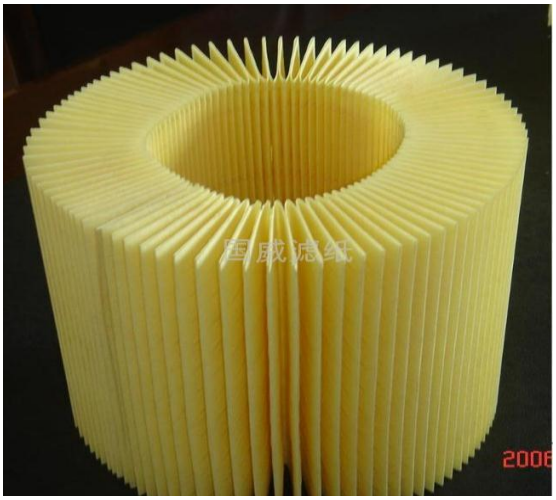

Figure 2.2: A paper filter (Clayton, pp 87)

### 2.3.2 Foam Filters

For dusty areas and in sports such as off-road and rally racing, foam filters are very popular. This is due the foam material which is a polyurethane that is soaked in oil. These types of filters come in different grades thickness of the foam. These factors contribute to the airflow resistance and the dirt filtration capacity. The particles are captured by Brownian motion and inertial impaction mechanisms. Shown in Figure 2.3 is a foam filter.

Figure 2.3: Foam filter (Clayton, pp 87)

### 2.3.3 High Performance Filters

High performance filter is typically made from cotton gauze as shown in Figure 2.4 which gives about 99% of the filtration efficiency. These types of filter usually used among competition vehicles where the increase in air intake and power of the engine is important. These filters can be a bit pricier than the others, especially if bought with a cold-air intake system. Filtration mechanisms due to impaction and interception are predominant in the capture of particles.

Figure 2.4: Cotton gauze filter (Clayton, pp 90)

### 2.3.4 Oil Bath Filters

Oil bath filter is one of the older versions of air filter. The general principle of an oil bath air cleaner is that incoming air is sucked downwards through the filter system towards the bowl containing a reservoir of oil as illustrated in Figure 2.5. The airflow will change abruptly in direction from traveling down to the oil pool before returning to the filter outlet. Any dirt that was carried in the air is unable to make the turn because if the inertia. Thus, it continues straight and trapped onto the oil.