



CERTIFICATION OF APPROVAL

Designing Air Intake System for Engine Performance and Efficiency Optimisation

by

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Tronoh, Perak
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMED FAIZ B MOHAMED AMIN

ABSTRACT

Continuous improvements are being achieved in adsorption process for wastewater treatment where alternative adsorbents that are better and cheaper are always needed to improve the efficiency of the adsorption process. This study is aimed to study the feasibility of using fish scale as the adsorbent to remove heavy metal from its aqueous solution. The adsorption nature of three types of metals namely Copper (Cu), Nickel (Ni) and Lead (Pb) on fish scale are studied independently, in a binary metal environment, where another competitive metal is also present during the adsorption process and finally in a continuous adsorption process.

These objectives were achieved via batch equilibrium experiments and also the continuous equilibrium experiment. Atomic Absorption Spectrometry (A.A.S) and Inductively Coupled Plasma (I.C.P) were used to determine the concentration of identified metal in the particular solution. Apart from A.A.S and I.C.P, other experimental apparatus were also used to achieve the study's objectives.

From the experiments done, it could be seen that fish scales could indeed be used to adsorb heavy metals, comparable to the performance of other adsorbents that are more famous. It is seen that the Lead ions are the most favorable ion between the three being tested, followed by Copper ions and lastly Nickel. In the binary metal adsorption, it is seen that the adsorption of Lead and Nickel ions were affected by the Copper ions when they change from being the majority to the minority element in the solution. Copper in the other hand would be affected by the competing ion in all molar ratios.

In the continuous adsorption experiment, it is found that fish scales are also able to adsorb in a continuous process, with a maximum saturation loading of 2.55 mg Cu adsorbed / g fish scale. More studies are strongly recommended to fully utilize the great potential of fish scales as the heavy metal adsorbent in the future.

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ABBREVIATIONS AND NOMENCLATURES

ISO	= International Organisation of Standardised
VLIM	= Variable Length Intake Manifold
VVT	= Variable Valve Timing
VRIS	= variable Resonance Induction System
DOHC	= Double Over Head Cam
OEM	= Original Equipment Manufactured
SAE	= Society of Automotive Engineering
SCFM	= Standard Cubic Feet per Minute [ft^3/m]
CC	= Centimetre cubic [cm^3]

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The primary function of an air filter is to deliver both high airflow and superior dirt protection. The design of air filters suppose to provide minimum restriction for allowing high airflow into an engine. In the vast majority of cases increased airflow will increase engine performance measured by horsepower and throttle response (torque). The performance benefits of maximum airflow are clear, compelling and well documented. Most of the professional racers are willing to run expensive vehicles with no air filter, as opposed to installing a disposable air filter. Those racers are seeking the additional horsepower and throttle response which needed to win the race. Besides, some of the normal car owners also do the same thing with the reason of easier to overtake. The ability of an air filter to protect your engine is generally measured in accordance with testing procedure ISO 5011. Because no two air filters are alike, the specific airflow and overall filtration efficiency will vary depending on the filter in question. Both air flow and dirt protection are critical to engine performance. For this reason a consumer should always evaluate an air filter based on both its filtration efficiency and air flow capabilities. The variable runner length intake air manifold is operative to optimize the performance of an internal combustion engine over a wide range of engine speeds. The manifold includes a housing formed of upper and lower halves fixedly attached via conventional fastening means. The upper and lower halves define a plurality of runners having constant cross-sectional areas but different cross-sectional shapes. A tapered drum is disposed within the housing and includes one open end and a plurality of openings formed in the outer surfaces that communicate with corresponding runners of the housing. The tapered drum is rotatable mounted within the housing such that the

effective runner length or airflow path of the manifold is made adjustable by varying the angular position of the tapered drum disposed within the housing.

Variable intake manifold is employed to boost low to medium speed torque without any drawback in fuel consumption or high speed power, thus improve flexibility of the engine. An ordinary fixed intake manifold has its geometry optimized for high speed power, or low speed torque, or a compromise between them. Variable intake manifolds introduce one or two more stages to deal with different engine speeds. The result sounds like variable valve timing, but a variable intake manifold benefits more low-speed torque than high-end power. Therefore it is very useful for saloons which are heavier and heavier these days with better drivability, there are also increasingly more sports cars featuring variable intake manifold alongside VVT, these including Ferrari 360 M and 550M. Compared with VVT, variable intake manifold is cheaper. What it needs are just some cast manifolds and a few electric-operated valves. In contrast, VVT need some elegant and precise hydraulic actuators, or even some special cam followers and camshafts. There are two kinds of variable intake manifolds: variable length intake manifolds and resonance intake. Both of them make use of the geometry of intake manifolds to reach the same goal. In this report, writer designing and simulating an engine with air intake which combined high flow air intake and variable length intake manifold.

1.2 Problem Statement

1.2.1 Problem Identification

The primary function of an air filter is to deliver both high airflow and superior dirt protection. The standard air filter provided from car manufacturer is having a high restriction for air to flow into the engine. The reason is they tried to design the engine compartment with good packaging and spacing. Anyhow, the design of the air filter and the air box has affected the volumetric air flow into the engine. The function of air box is to avoid the intake system from taking the hot air produce by the engine. Hot air has less dense and cause less power for engine combustion. Other than that, most of the car has fixed geometry of the air intake while the engine is running in varies speed. Different engine speed will need different quantity of air to

combust. With a right volume of air for different speed will create a stoichiometric combustion. If the intake manifold has fix geometry, the area of air flow will be too small when the engine is run at high speed and too big when the engine is in idle condition. This will cause less fuel efficiency and lack of power. Instead of changing to new car with this technology, a new design needs to be done which applicable to most existing car. This will help car owner having the same benefits of latest engine technology without spend higher.

1.3 Objectives and Scope of Study

1.3.1 Objectives

The objectives of this project are as follow.

1. To relate the relationship between variable length air intake system (VLM) with engine horsepower and torque.
2. To design a high volumetric air flow air filter.
3. To design a variable geometry intake manifold.
4. To simulate the variable length of intake manifold and air filter.

1.3.2 Scope of Study

1. Variable Length Intake Manifold Testing

Engineering performs the air flow testing on a single cylinder test bed engine. The single cylinder test bed engine capable of measuring velocity of air & temperature, RPM, torque, and output temperature.

2. Design and High Air Flow Air Filter

Creating a new design which have high volumetric air flow air filter which has a high filtration and breathe from cool / low temperature air.

3. Simulate Air Flow of the Air Filter

Using Ansys software to study and simulate the characteristics of the air flow inside the air filter.

4. Power & Torque Testing

The horsepower/torque testing is performed by using software analysis. From the software, the output of the engine characteristic could be determined before applying fabrication process. The power and torque curves will be compared with the standard one to measure the improvement.

5. Engineering Air Flow Testing

Engineering performs the air flow testing on a air flow bench. The air flow bench capable of measuring airflow rates by cubic feet per minute (SCFM).

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Theory

2.1.1 Helmholtz theory and application

In this study, three heavy metals have been identified as the adsorbent for the adsorption process. These metals have been selected due to their identification as heavy metals and also priority pollutants. Furthermore, these materials are also available abundantly in a typical industrial effluent. In this section, the general information about Helmholtz theory and its application are discussed briefly (Simon, 2001).

A tuned intake path can have a light pressurizing effect similar to a low-pressure supercharger due to Helmholtz resonance. However, this effect occurs only over a narrow engine speed band. A variable intake can create two or more pressurized "hot spots", increasing engine output. When the intake air speed is higher, the dynamic pressure pushing the air (and/or mixture) inside the engine is increased. The dynamic pressure is proportional to the square of the inlet air speed, so by making the passage

narrower or longer the speed/dynamic pressure is increased. Many automobile manufacturers use similar technology with different names. Another common term for this technology is Variable Resonance Induction System (VRIS).

Demeter, Olga, Geoff and Willy (2007) assessed Helmholtz resonance is the phenomenon of air resonance in a cavity. When air is forced into a cavity, the pressure inside will increase. Once the external force that forces the air into the cavity disappears, the higher-pressure air inside will flow out. However, this surge of air flowing out will tend to over-compensate, due to the inertia of the air in the neck, and the cavity will be left at a pressure slightly lower than the outside, causing air to be drawn back in. This process repeats with the magnitude of the pressure changes decreasing each time. The air in the port is the mass. Since it is in motion, it possesses some momentum. A longer port would make for a larger mass, and vice-versa. The diameter of the port is related to the mass of air and the volume of the chamber. A port that is too small in area for the chamber volume will choke the flow while one that is too large in area for the chamber volume tends to reduce the momentum of the air in the port.

2.1.2 Principles of Air Flow

In air flow, it has been identified that there are generally three types of principles that involve in air flow. They are interception, impaction and diffusion. Nyberg (2004) has explained these principles in greater details.

There are scientific principles that determine how an air filter removes dirt particles from the air stream. The first of these principles is known as interception, which applies to dirt particles traveling with the air stream. Air flow will always take the shortest path and as the air is forced to flow around the filter's fibers some of the particles will contact the sides of the fibers and be captured. These particles are then held in place by the oil or tacking agent in the fiber.

Another principle is known as impaction, which mostly affects larger or heavier dirt particles. Impaction occurs when the inertia or momentum of the particle causes it to deviate from the flow path. In other words the heavy particles do not follow the air

stream around the filter's fibers but instead they run straight into the fibers and are captured.

The most important principle for our use is diffusion, which deals with the laws of physics that govern the motion of very small dirt particles. Small particles are highly affected by the forces in the air stream. Forces such as velocity changes, pressure changes, turbulence caused by other particles and interaction with the air molecules cause these very small particles to become random and chaotic. As a result, these particles do not follow the air stream and their erratic motion causes them to collide with the filter's fibers. This phenomenon enables an air filter to capture dirt particles that are much smaller than the openings.

2.2 Literature Reviews

There were many literatures found about the principle of fluid mechanics and techniques in improving internal engine combustion. A lot of the examples are air ram charging effect, supercharger and turbocharger. As no literatures could be found about previous studies that have used air filter integrated with variable length intake manifold, these literatures would be able to help in explaining the results that are obtained by using air filter integrated with variable length intake manifold.

Nyberg (2004) the primary function of an air filter is to deliver both high airflow and superior dirt protection. The design of air filters should provide minimum restriction allowing high airflow into an engine. In the vast majority of cases increased airflow will increase engine performance measured by horsepower and throttle response (torque). The performance benefits of maximum airflow are clear, compelling and well documented. That is why so many professional racers are willing to run expensive vehicles with no air filter, as opposed to installing a disposable air filter. They are seeking the additional horsepower and throttle response needed to win the race.

Thomas (2004) have examined the ability of an air filter to protect the engine is generally measured in accordance with testing procedure ISO 5011. This test procedure using Coarse Test Dust, which includes particles ranging in size from less

than 5.5 microns to 176 microns. At its most basic level, an engine is an air pump. More air entering the engine increases the efficiency of the combustion process creating more horsepower and torque. Maintaining optimal, unrestricted air flow becomes a problem when it must pass through a filtering medium. The level of air resistance varies depending on the size, surface area and physical attributes of the filtering medium. Studies have shown most engine wear is caused by particles 10 to 20 microns in size.

In 2000, Variable Length Intake Manifold (VLIM) is an automobile engine manifold technology. As the name implies, VLIM can vary the length of the intake tract in order to optimize power and torque, as well as provide better fuel efficiency. There are two main effects of variable intake geometry which are swirl effect and pressurization.

Mahle (2007) have examined variable geometry can create a beneficial air swirl pattern in the combustion chamber. The swirls help distribute the fuel and form a homogeneous air-fuel mixture which ignites without engine knocking. At low rpm, the speed of the airflow is increased by directing the air through a longer path with limited capacity but the shorter and larger path opens when the load increases so that a greater amount of air can enter the chamber. In Double Over Head Cam (DOHC) designs, the air paths are often connected to separate intake valves so the shorter path can be excluded by de-activating the intake valve itself.

CHAPTER 3

METHODOLOGY

3.1 Methodology Flow Chart

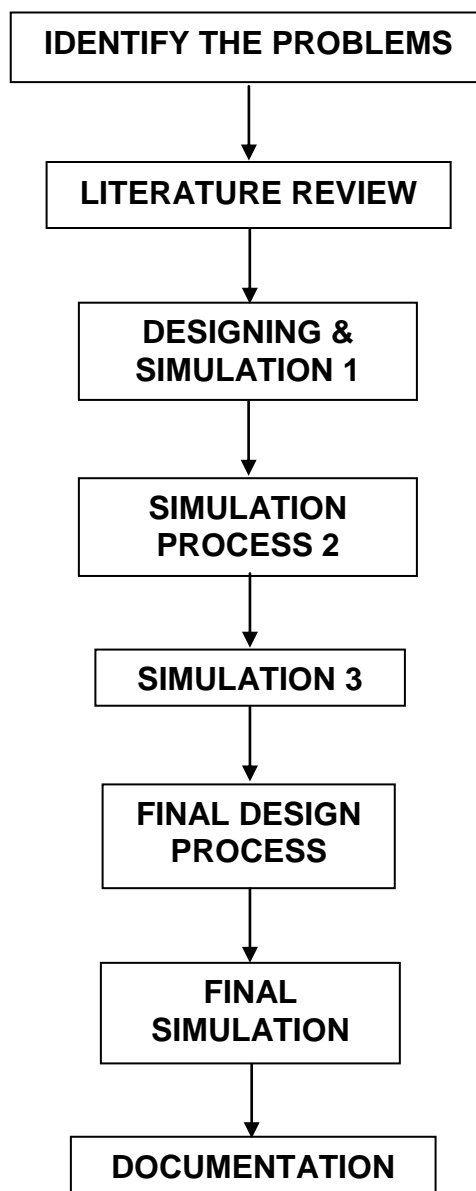


Figure 3.1 Methodology Flow Chart

3.1.1 Problem Identification

1. An online discussion was held with Mr. Martin b Treuhaft, Manager for Filtration and Fine Particle Technology, Vehicle Systems Research Department, South West Research Institute (SwRI). The discussion was discussed about the methods of air filter testing, equipments and also the testing procedure. From the discussion, the author had been informed about the International Society Organisation, ISO standard and also criteria that need to be considered in running air filter performance testing. The author also managed to get few 3rd party performance air filters testing result from SwRI which helps to determine the material and design selection.
2. A brief discussion was held with Mr. Azmi Othman, the person incharge for PETRONAS E-01powertrain from Petronas Research Centre (PRSS). From the discussion, the author was being informed about designing engine and the criteria that bring performance. Mr. Azmi also did inform the author how to apply simple variable length intake manifold testing to prove Helmholtz theory.
3. An interview had been made by the author with manager of Powerfil Auto Parts Sdn Bhd which located in Gombak, Selangor. Powerfil Auto Parts is a manufacturer for most local car manufacturer OEM air filter and oil filter. From the interview, the author had gained more knowledge in manufacturing process, quality and the problems to produce from the design process.
4. A few meetings also was held between the author and a few senior lecture from automotive department of Universiti Teknologi Petronas in determining the best way to improve air intake system for engine performance and optimise the efficiency.

3.1.2 Lab experiment of variable length intake manifold

One lab experiment was held to prove the Helmholtz theory in improving engine torque and power by designing variable length intake manifold. The test was done on engine test bed located at block 15, Universiti Teknologi Petronas. It was a single cylinder engine with capacity of 230CC and was run by using diesel fuel.

1. Test bed engine was connected to dynamometer with power and torque indicator and the meter had being collaborated to 0 reading. A 5.2cm diameter of PVC piping was cut into few various lengths and an anemometer used to measure the air flow speed was prepared.
2. For each of the piping, a small 1cm hole was made at the center to put the air flow speed sensor. The piping lengths were 6cm, 10cm and 15cm accordingly.
3. The engine air inlet was tapped with masking tape to ensure the piping is fitted correctly.
4. The engine was started using 3 different length of piping started with 6cm until 15cm and different speed from 1000rpm to 3500rpm.
5. The torque and power reading were plotted against the engine speed.

3.1.3 Design Selection

Design comparison process was made to converge or minimise the design criteria based on the existing 3rd party performance air filter design and the OEM product. Because of the air flow testing workbench was not available in the university, the author managed to get help from South West Research Institute to get the result. The 3rd party air filter was using oil cotton while the OEM air filter was using paper as filter element. The test results were presents the air flow resistance, initial and cumulative efficiency, and dust capacity. Both tests were conducted in accordance with SAE ISO procedures with respect to the SAE J726 Jun93 air cleaner test code and ISO 5011:2000. The testing were conducted at 160scfm (101.3kPa, 20^oc) using PTI SAE ISO Fine Test Dust (Batch 5190F) at concentration of 1.0g/m³ air (0.028g/ft³) for 30 minutes. The results obtained were recorded in the table.

3.1.4 Simulation

In the simulation process, there are three types of software that being used. The first one is CATIA 3D modelling software and the second one is ANSYS and the last one is GT Power software.

1. CATIA software was used to develop three dimension modelling. A CATIA software version P3 V5R14 is used for the modelling process.
2. After finish modelling, the design was constructed into ANSYS simulation software and the air flow characteristic was studied. When the outcome of the design was not meet early assumption and specification, the process was return back to modelling before proceed to next step.
3. When the outcome met early assumption and specification, the design dimension was used to re-design in GT Power Software and simulations were done for a few times.
4. After getting result of torque and power curve, graph was analysed and comparisons were made.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and Discussions

After finish doing some research and knowledge sharing with a few expertises inside and outside the country, the author had gained more detail about the project and all the parameters that need to be considered. These include the volumetric efficiency, combustion efficiency and thermal efficiency. By considering the entire factor, the indicated mean effective pressure (imep) will increase; hence increase the engine performance and efficiency.

4.1.1 Mean Effective Pressure

MEP is stand for mean effective pressure. MEP is the work done per unit displacement volume. It scales out the effect of engine size. Two useful mean effective pressure parameters are imep and bmep. The indicated mean effective pressure (imep) is the net work per unit displacement volume done by the gas during compression and expansion. The pressure in the cylinder initially increases during

the expansion stroke due to the heat addition from the fuel and then decreases due to the volume increase. The brake mean effective pressure (bmep) is the external shaft work per unit volume done by the engine. Friction mean effective pressure (fmep) is work done by overcome engine friction to drive the engine.

$$\text{imep} = \text{imep} - \text{fmep}$$

$$\text{imep (net)} = \text{imep (gross)} - \text{fmep}$$

4.1.2 Designing Air Intake

In designing the air intake system, the author aim is to archive higher indicated mean effective pressure compare to standard air intake. Increase the oxygen that be burned with the fuel inside the engine chamber will help increase the pressure. After doing a research, the author had found that oxygen or air inside the engine cylinder can be increased by

- Increase the volumetric efficiency
- Use oxygenated fuel
- Use nitrous oxide
- Increase the thermal efficiency
- Increase the combustion efficiency

4.1.3 Volumetric & Combustion Efficiency Factor

High volumetric efficiency enables more air to be inducted in the cylinder. The more air goes inside the cylinder, the more fuel could be burned. Therefore, more power could be generated. When the engine run in high rpm, the engine need more air to be inducted but it is not 100% air could be filled inside the cylinder chamber. This is due to hydro-dynamics effect. This problem could be solved by using turbocharger, supercharger or intake manifold air ram charging. Turbocharger and supercharger are using turbine to pull the air inside go the engine while the air ram charging is using variable length of intake manifold (VLIM). Therefore, the author had decided to optimize the current concept of VLIM so that is will works in production car. The

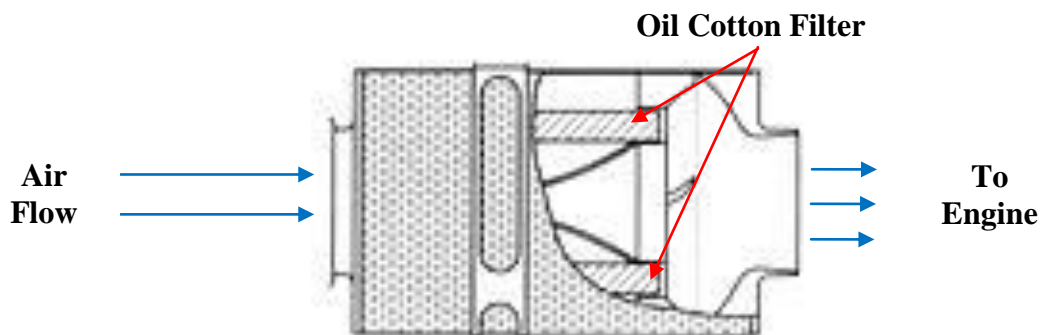
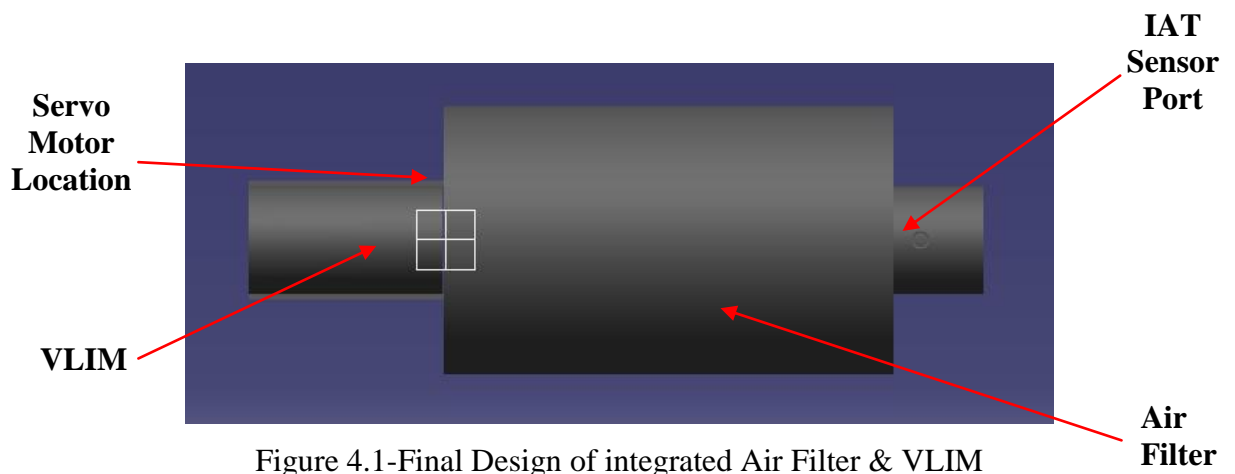
VLIM is used to shift the torque peak to the higher end. When higher volumetric efficiency is achieved, thermal efficiency also could be achieved.

Combustion efficiency is a calculated measurement (in percent) of how well the heating equipment is converting a specific fuel into useable heat energy at a specific period of time in the operation of a heating system. Thermodynamics shows that higher power output could be achieved by having large temperature gradient ($T_1 - T_0$). From there, the air intake will be designed facing outside of the engine compartment and tilted to the ground. This is to ensure the air that goes in is cold and not affected by heat from the engine.

4.1.4 Design Outcome

4.1.4.1 Final Design Air Filter

A few simulations have been done by using GT Power Software, a right geometry specification for the air filter manage to be produced based on the standardized engine specification (as reference). The final design is as below;



4.1.4.2 Final Design VLIM

A few simulations have been done by using GT Power Software, a new design that meets our expectation performance manage to be produced by using the simulations. In GT Power Software, we have tried few designs and simulate it. Finally, the right design with right geometry manages to be produced. The movement of VLIM will be drove by servo motor and gears which is collaborated with engine speed. The design is as below;

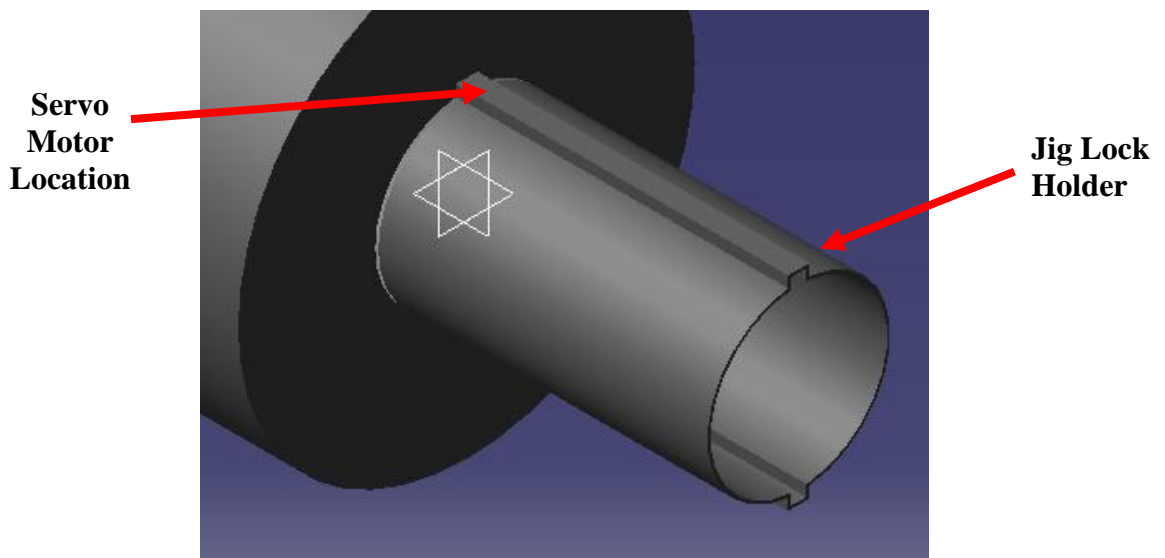


Figure 4.3-VLIM Snorkel Part A

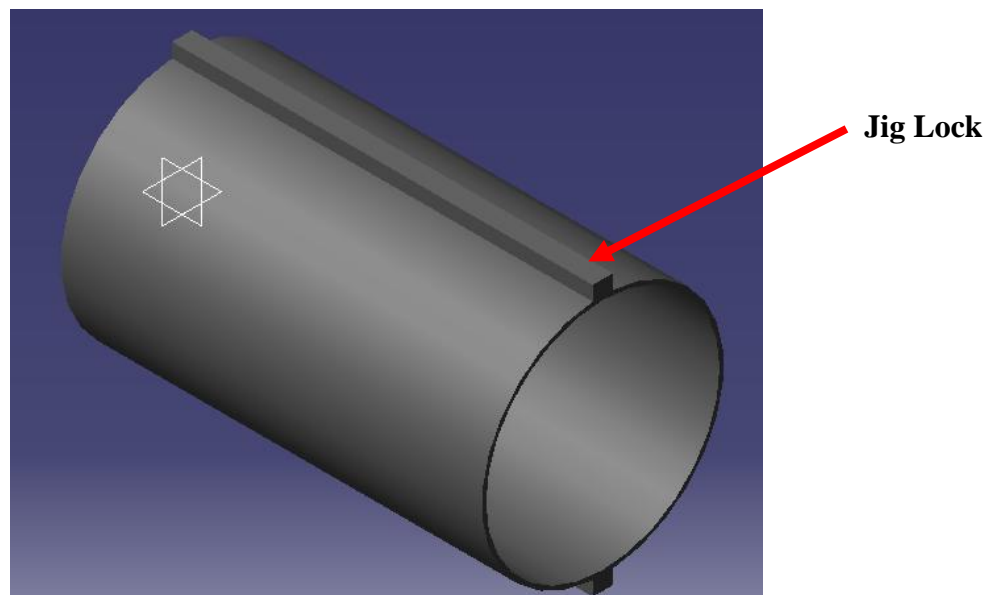


Figure 4.4-VLIM Snorkel Part B

4.1.4.2 Final Design Element Selection

From the comparison made from the results between 3rd party brand air filter and OEM product, the author had made spider web chart. The results as below;

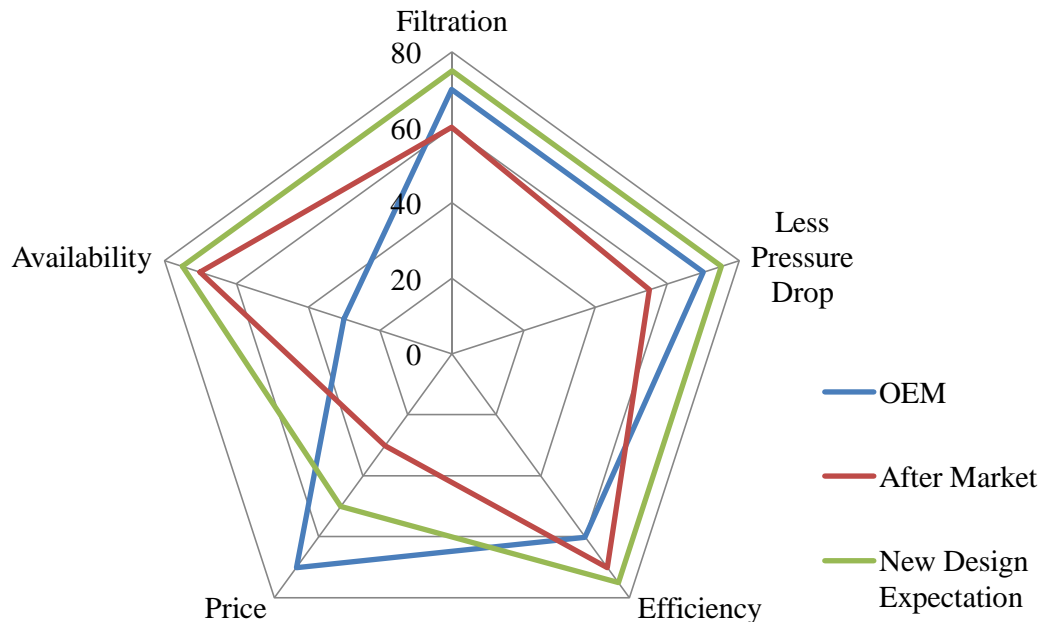


Figure 4.5-Comparison between OEM and 3rd Party Air Filter
(0: poor, 100: excellent)

*OEM= Original Equipment Manufactured

*After Market = K&N and AEM Cone Type (SwRI Project No. 03.10955.008)

*New Design = Expected Outcome

*Test Condition- (PTI ISO 12103-1), Air Flow: 160scfm, Pressure: 101.3 kPa,
Temperature: 20°C, Time: 30 min, Concentration: 0.028g/ft³

There are many differences between aftermarket product and OEM product. Aftermarket air filter is use oil cotton as the filtration element while the OEM air filter is using paper element. From the figure 4.8, it shows the difference between both product and also expected outcome of the new design in terms of filtration, less pressure drop, cumulative efficiency, price and its availability. In terms of filtration, less pressure drop and cumulative efficiency, the aftermarket air filter is better than

OEM air filter. This result is based on SwRI project report. Aftermarket products also available for various vehicle while OEM products only specific to certain vehicle. However, OEM product is cheaper due to no cost use for research and development. For the new design, the author try to hit the most excellent which suit to its expected performance and marketable.

4.2 Design Simulation

4.2.1 Air Filter Design Simulation

From the 3D CATIA modeling, the 'Design 1' air filter has been simulated in ANSYS software application as below;

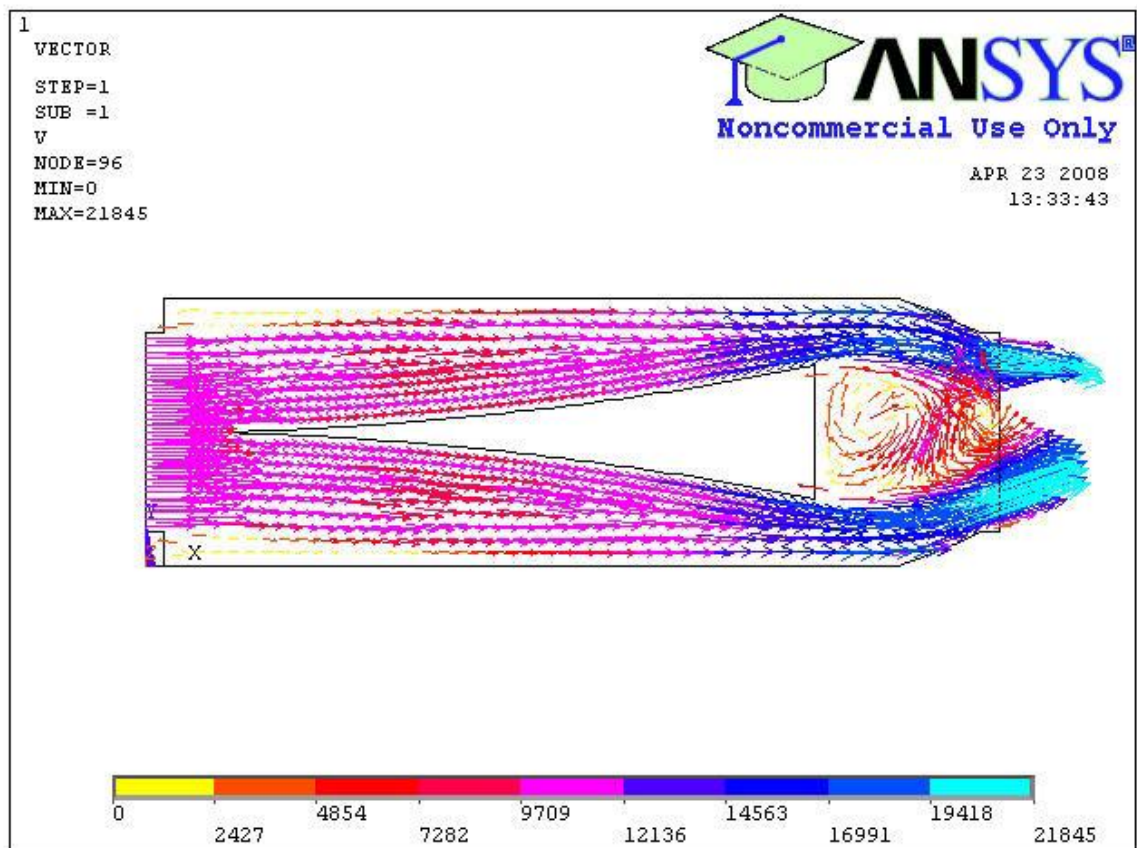


Figure 4.6 'Design 1; Air Flow Simulation

From the figure 4.6, the air flow speed increase tremendously which will bring more air into the engine inlet. However, the author did not satisfy with the design due to an air separation/weigh occur before reaching the air filter outlet.

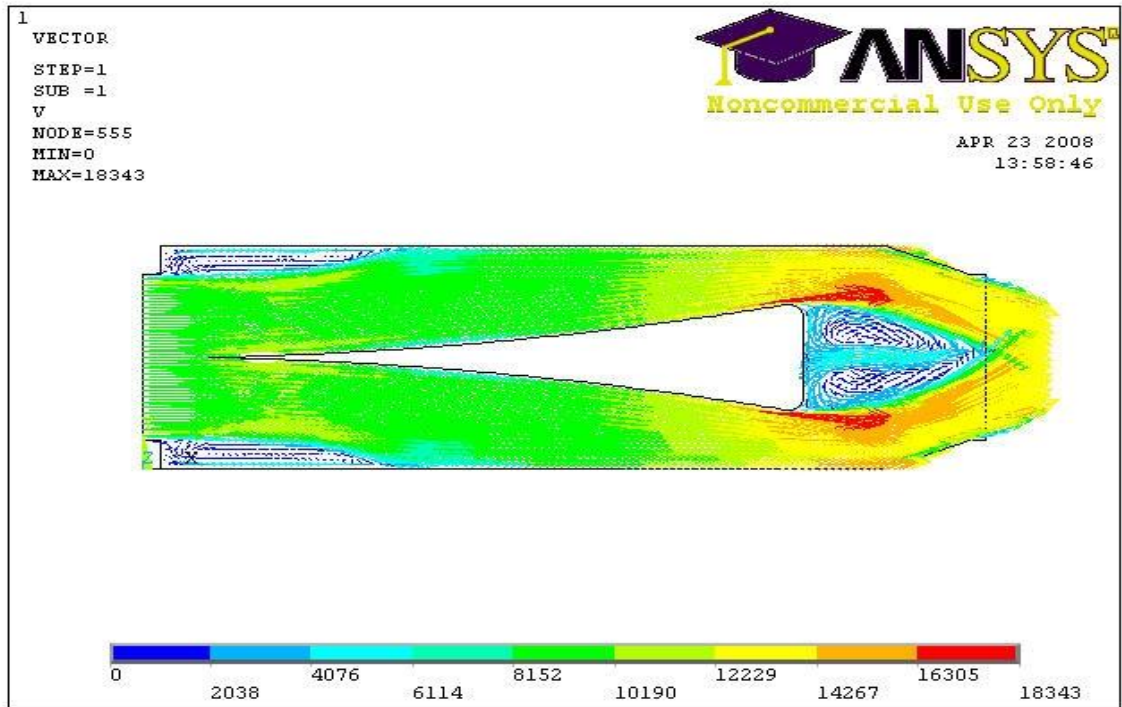


Figure 4.7 'Design 2' Air Flow Simulation

From the figure 4.7, some adjustment had been made in the centre fin where the sharp edge had been redesign with fillet curve. The simulation shows that the velocity of the air is faster, smooth air flow and more air was generated to the air filter outlet.

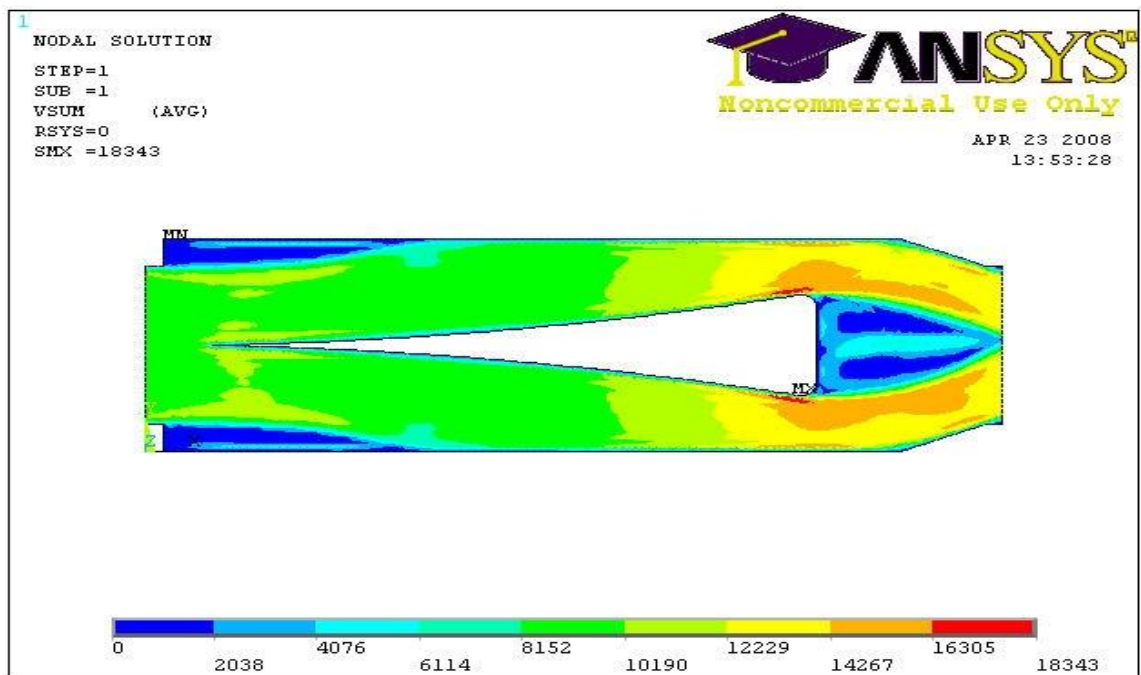


Figure 4.8 'Design 2' Air Flow Velocity Changes Area

4.2.2 VLIM Design Simulation

A few simulations have been done by using GT Power Software, a new design which that meets our expectation performance manage to be produced by using the simulations. In GT Power Software, engine specification that been used is as below;

Table 4.2.2(a)-Standard Engine Geometry (as reference)

Bore [mm]	93.0
Stroke [mm]	81.0
Connecting Rod Length [mm]	157.0
Piston Pin Offset [mm]	0.00
Displacement/Cylinder [liter]	0.550
Total Displacement [liter]	2.201
Number of Cylinders	4
Compression Ratio	8.90
Bore/Stroke	1.148
IVC [CA]	-110
EVO [CA]	134
IVO [CA]	357
EVC [CA]	376

From the above engine specification, an air filter with standard geometry has been attached to the engine GT Power simulation program as below;

Table 4.2.2(b) Standard Air Filter Geometry (as reference)

Diameter at Inlet End	mm	150
Diameter at Outlet End	mm	150
Length	mm	150
Discretization Length	mm	[dxi]
Surface Roughness	mm	0.025
Wall Temperature	K	300
Heat Conduction Object		ign

As a result, the simulation has come out with power and torque curve as below;

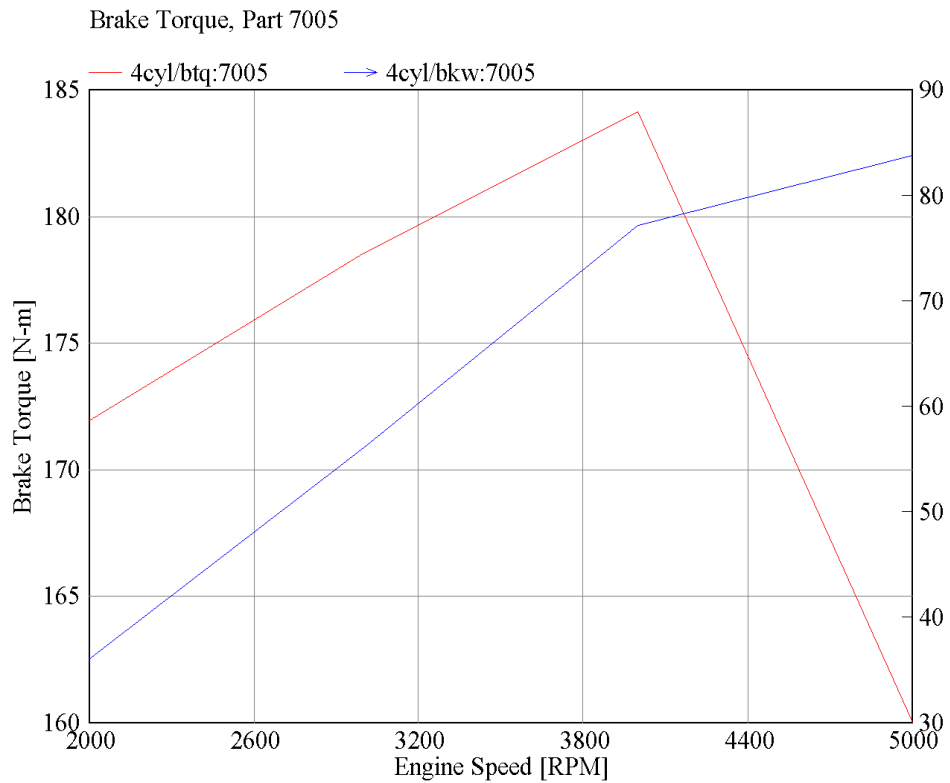


Figure 4.9-Result of Power and Torque curve (Simulation 1)

From the above graph, the torque curve is inclining slowly at the beginning of the engine speed and only achieves its pick at around 4000rpm with 184N-m while for power curve; it is only achieve 83kW at 5000rpm. From the graph, it shows that pressure drop at the idling engine speed is too high. Therefore, the air filter has been re-designed to get better output.

As a result, the simulation has come out with better power and torque curve as below;

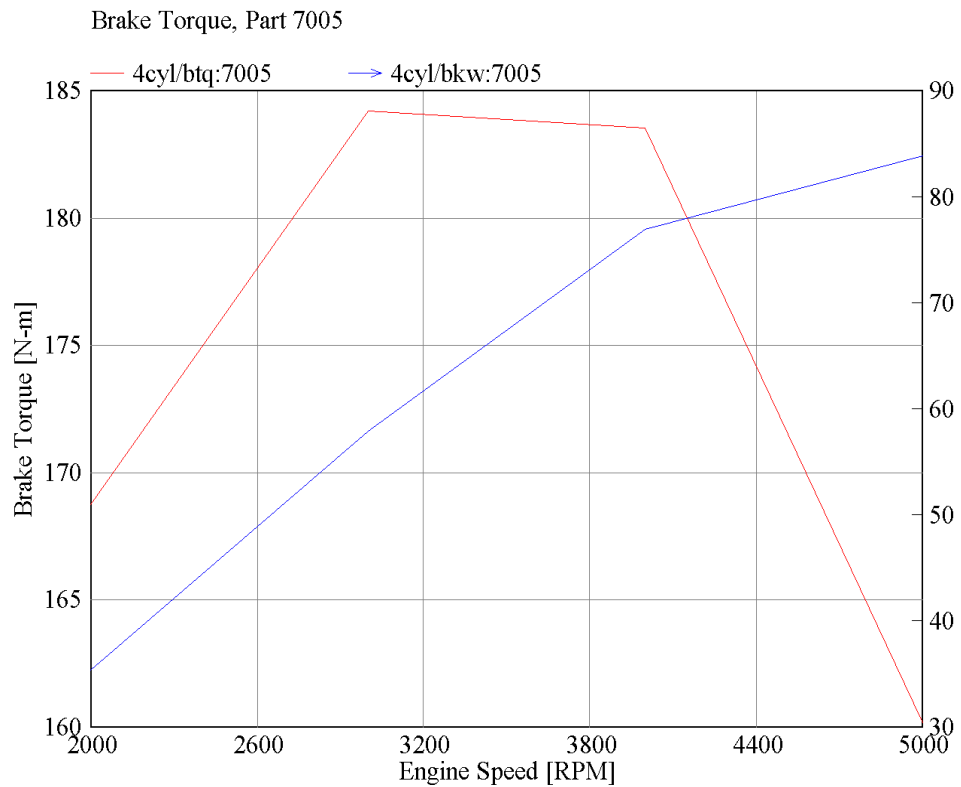


Figure 4.10-Result of Power and Torque curve (Simulation 2)

From the above graph, the torque curve is inclining drastically at the beginning of the engine speed and achieves its 2nd pick at around 4000rpm with 183N-m while for power curve; it manage to achieve 60kW in early stage at 3000rpm. From the graph, it shows that pressure drop at the idling engine speed is better. Therefore, the air intake system has been developed with variable length intake manifold (VLIM) to get the best output. The best power and torque curves occurred as figure 4.14;

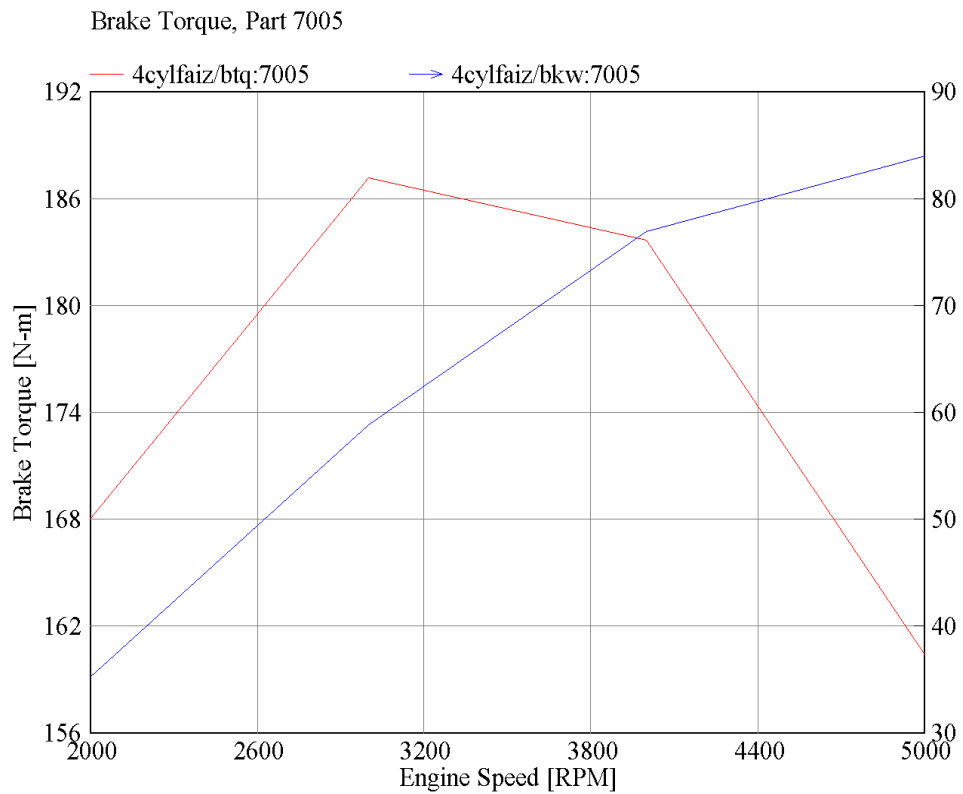


Figure 4.11-Result of Power and Torque curve (Simulation 3)

From the above graph, the torque curve is inclining tremendously at the beginning of the engine speed and achieves its 1st pick at 3000rpm with 187N-m and 2nd pick at 4000rpm with 184N-m while for power curve; it manage to achieve 60kW in early stage at 3000rpm and 78kW at 4000rpm. From the graph, it shows that the variable length intake manifold has helped the engine to achieve higher torque at lower rpm and produce more power at higher rpm.

Table 4.15 - Engine MEP, Torque and Power (SI Units)

	Indicated	Crankshaft	Friction	Attachments	Brake
MEP [bar]	11.0	11.0	-1.8	0.0	9.1
Torque [N-m]	192.1	192.1	-32.0	0.0	160.1
Power [kW]	100.6	100.6	-16.8	0.0	83.8

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

After the study has been conducted, the author is able to know all the information needs that vital in designing engine air intake. Researchers around the globe have developed variable length intake manifold for last few years, however putting it into production vehicle is still less. Besides, they are more towards developing new air filter design. The author has decided to develop both. Variable length intake manifold which integrated with air filter is something new and the studies could give more impact on engine performance and efficiency. In this report, the author shows that the design that has been developed is approved based on its simulation. The result shows that the new design has capability to give more torque during at the lower speed and bring more power at higher speed. The good thing is the design also applicable to most existing cars. Thus, it will give more economic value to users. However, a prototype needs to be implemented to ensure its capability in real engine.

CHAPTER 6

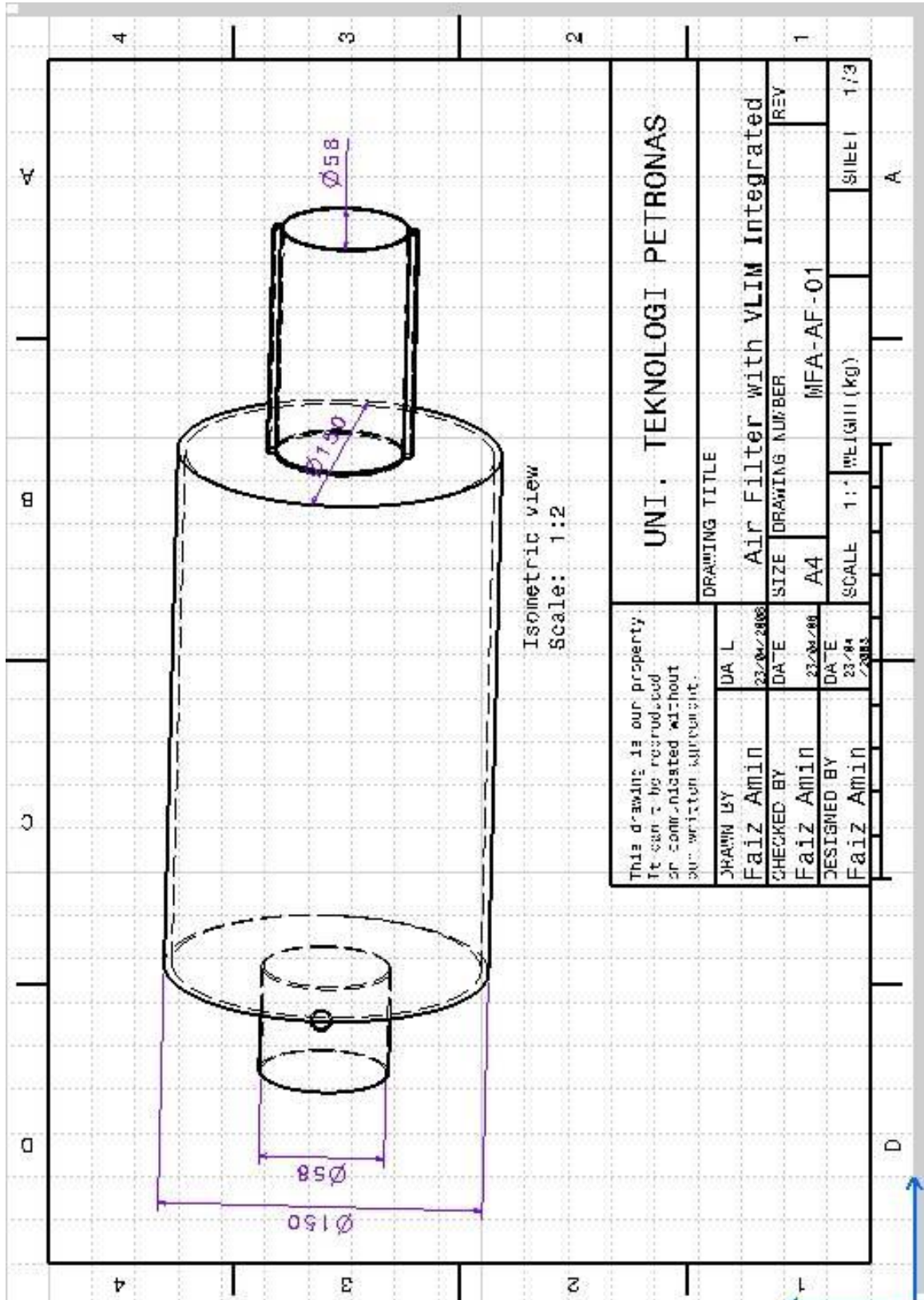
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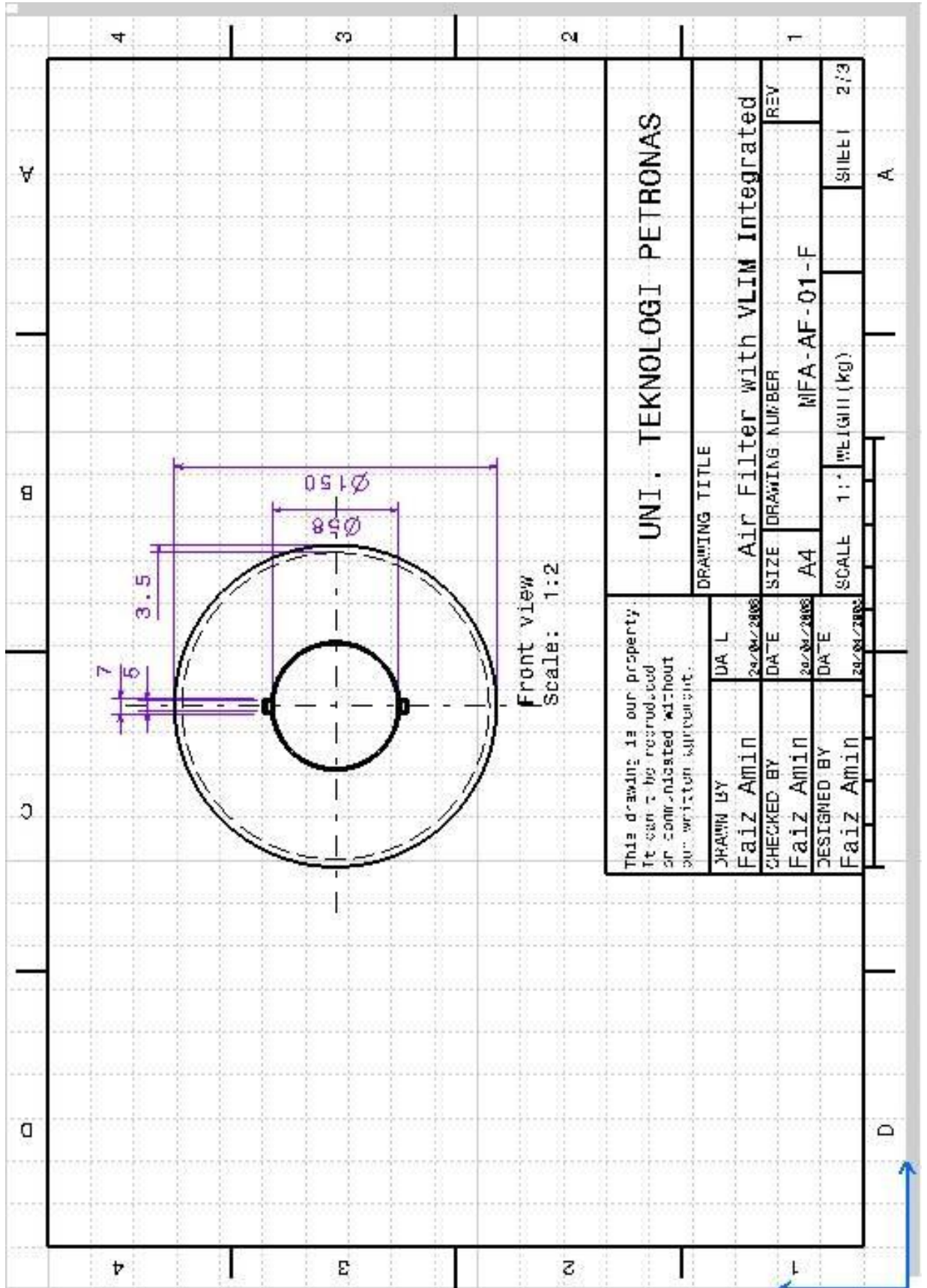
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APPENDICES

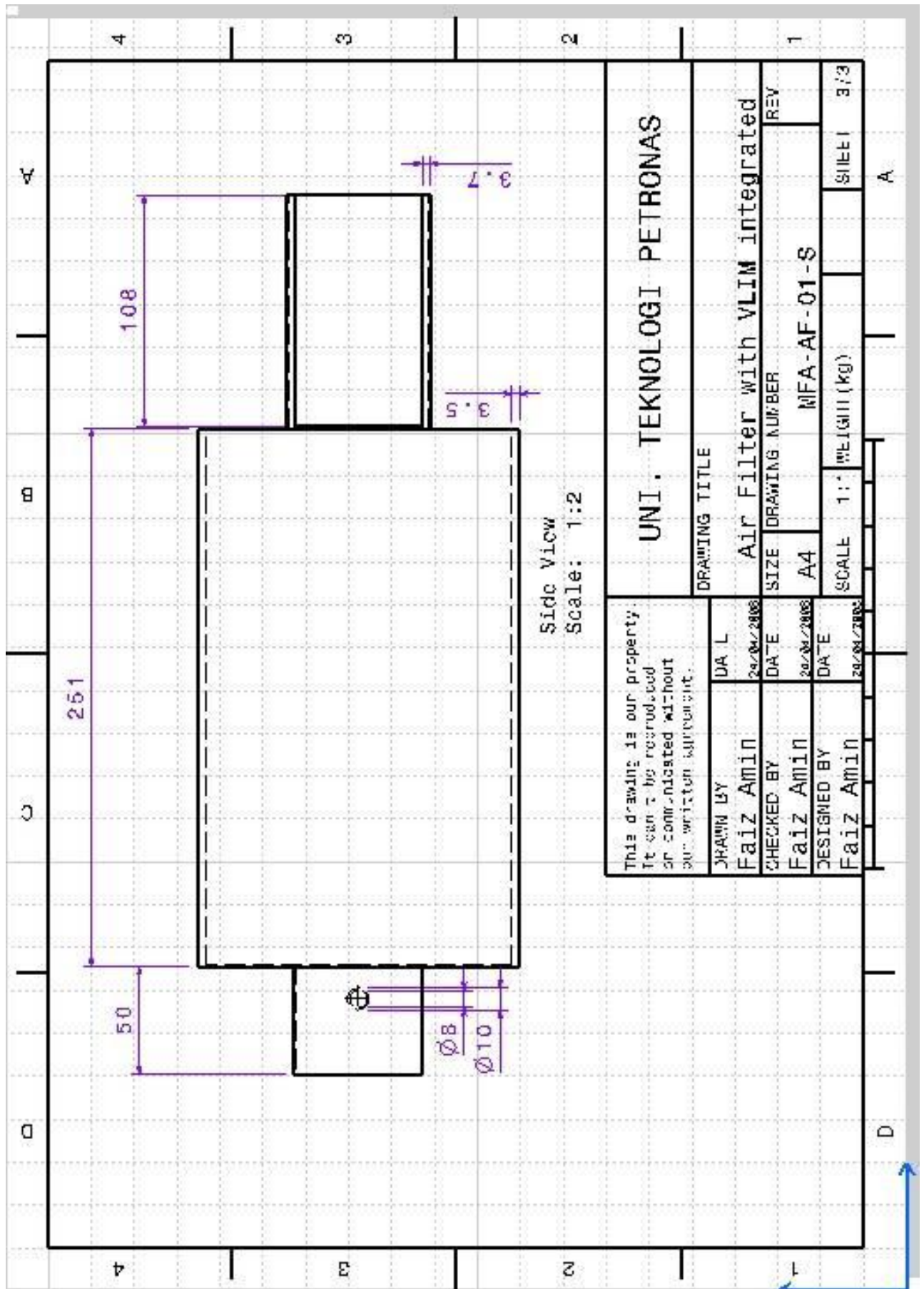
Appendix 1: Isometric View of Integrated Air Filter & VLIM



Appendix 2: Front View of Integrated Air Filter & VLIM



Appendix 3: Side View of Integrated Air Filter & VLIM





**Designing Air Intake System for Engine Performance and
Efficiency Optimisation**

By

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