An Investigation on the Effects of an Intake Air-Swirl Device on Fuel Consumption of a Spark Ignition Engine

by

Mujtahid bin Mohd Abidin

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Ir. Dr. Shaharin Anwar Sulaiman)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

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.

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MUJTAHID BIN MOHD ABIDIN

ABSTRACT

At present, the use of cars as a mode of transportation has become a necessity for the public. The escalating fuel cost on present days has led to the search for alternative devices to reduce fuel consumption for cars. Due to this problem, a number of fuel saving products have been invented with the hope to improve the fuel consumption. These products include gas additives, fuel treatments, air filters, spark plugs, and aftermarket engine modifications. One of the products, which are known as Cyclone, is a non-moving device designed to enhance fuel economy by creating a swirling air motion, and thus resulting the air in the intake hose to move faster by continuously whirling around corners and bend. However, some of the products in the market may not increase mpg (miles per galloon) as claimed in their advertisements. Therefore this research project intends to investigate the effectiveness of Cyclone on fuel consumption of a spark ignition engine. In order to achieve the objectives, an experimental study to investigate the performance towards fuel consumption as a result of installing Cyclone is Multicylinder Test Bed Engine was done. The effect of the static blade angles in the Cyclone was also investigation by reproduction of two more units at different angles. In addition, a smoke test was performed to visualize the flow pattern of the air leaving the Cyclone, in order to relate its effect on fuel consumption.

ACKNOWLEDGEMENT

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

In internal combustion engine design, volumetric efficiency refers to the efficiency with which the engine can move the charge into and out of the cylinders. Volumetric efficiency is the ratio of volume of fuel and air actually enters the cylinder during induction to the actual capacity of the cylinder under static conditions. Therefore, those engines that can create higher induction manifold above the ambient pressure will have efficiencies greater than 100% (Don, 1988). Volumetric efficiencies can be improved in a number of ways, but most notably the size of the valve openings compared to the volume of the cylinder and streamlining the ports. Engines with higher volumetric efficiency will generally be able to run at higher RPM and produce more overall power due to less parasitic power loss moving air in and out of the engine.

The internal combustion engine is still today the predominant prime mover for many applications such has vehicle propulsion, marine propulsion and generator sets (Don, 1988). Two types of IC engine exist. The first where the combustion is initiated by a spark is termed 'Spark Ignition' (SI) and embodies petrol and gas engines. The second, where combustion is initiated spontaneously by virtue of rise in temperature during the compression process is termed 'compression Ignition' (CI), and embodies diesel engines.

Air swirling devices or simply known as Cyclone is one of the recent air enhancement systems which are available in the market (Michaud, 2005). The system uses a principle of vortex flow that creates swirling motion that believes improve fuel consumption.

Figure 1 shows a picture of a Cyclone, which is a mechanical, non moving device that has several blades around it circular shape. Specifically, the Cyclone is a non-moving vortex generator that fits inside the air intake hose of a car's engine. It creates a swirling cyclone of air within the combustion chamber (Nain and Will, 2005).

Figure 1.1: The picture of a Cyclone

If the stopper in a sink full of water is ever pulled and watched the water swirl down the drain, it can be seen one example of a vortex. Simply put, it is an energetic swirling mass. Another more extreme example of a vortex is the tornado, one of the most powerful forces in nature (John and Elly, 2000). One of the methods used to create and control vortices inside the car engine is the vortex generator. The Cyclone is the result of years of computer-aided and wind tunnel tested research into the beneficial effects of controlled vortices. It is believed to increase the fuel consumption within the range 3% to 5%. (Nain and Will, 2005).

1.2 Problem Statement

The recent price for crude oil almost reaches up to 90 dollar per barrel as shown in the Figure 1.2 (Willy, 2007). Moreover the price is keeping increasing and exceed 100 dollar per barrel nowadays. A year forecast shows that the price reach up to 115.30 per barrel (Bleviss, 2007). Crude oil behaves much as any other commodity with wide price swings in times of shortage or oversupply. The crude oil price cycle may extend over several years responding to changes in demand as well as OPEC and non-OPEC supply.

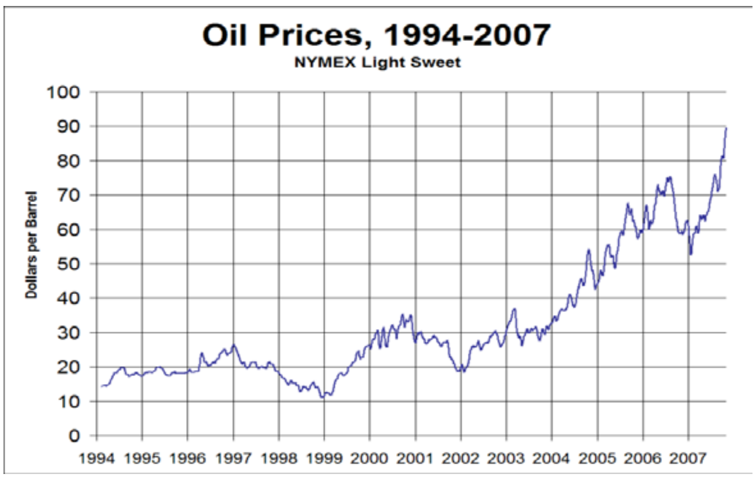

Figure 1.2: Year trend of oil price between 1994- 2007 (Willy, 2007)

Due to the increase of fuel price, vehicle owners demand devices that can lower their vehicle fuel consumption without compromising the performance of the engine. A lot of air enhancement systems are available in the market, but the practically of such systems are unknown. Some of the air enhancement systems deliver great performance but it generates bad effect on the environment and the engine itself (John and Elly, 2000). The lack of understanding on how a Cyclone works and its design help promotes fuel efficiency are known to be the main problem identified of this research project. Many car owners are still in doubt regarding this Cyclone that claims can improve the fuel consumption of their cars (Nain and Will, 2005). Cyclone is one of the methods that is claimed to provide better fuel consumption besides using the magnetic devices.

1.3 Significance of the Project

There are many companies that sell Cyclone but the consumers are least exposed of the Cyclone whether it was really works as claims by the manufacturers (Ron and Eve, 2002). The dealers can just show the flow pattern of the air by doing some demonstration to the customers (Ron and Eve, 2002). Two smaller ducts which like an air intake hose are required in the demonstration. They just compare the flow pattern using a colour gas in the two ducts by inserting Cyclone at one duct while the other duct is without Cyclone. The duct which has Cyclone creates swirling or vortex of the flow pattern and it was believed to contribute better fuel atomization but the reasons behind it are not known (Ron and Eve, 2002). Therefore this research project aims to prove whether the claim is valid or not.

1.4 Objectives and Scope of Study

The objectives of this research project are to investigate and study the effectiveness of the static blade or simply known as Cyclone towards fuel consumption in the air intake hose, right after air passes through the air filter. The effects of using Cyclone in terms of fuel consumption in petrol engine at various throttle position can be determined. This research project is basically to carry out a study on the effect of inserting the Cyclone in the air intake hose towards fuel consumption using petrol engine test bed and interpretation of the air flow pattern inside a pipe by performing the wind tunnel experiment.

In order to meet the objectives of this dissertation, the following steps were taken:

1. Investigate and study the Cyclone application in an automobile especially car
2. Determine the effect of using a commercial Cyclone in an automobile car in terms of fuel consumption by running the experimental design

3. Fabricate 3 units of the Cyclones that made from stainless steel with different angle of the blade each of the device
4. Compare the performance properties such as fuel consumption of using the different angle of the blade on the Cyclone

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Fuel-Air Mixing in Spark Ignition (SI) Engine

In an internal combustion engine, a fuel-air mixture necessary for the combustion process in the combustion chamber of each cylinder is provided typically by a fuel injection system or a carburetor upstream of or within the inlet manifold, the combustible mixture comprising droplets of fuel of differing sizes entrained in a stream of air (Crouse & Anglin, 1993). As is well known, at relatively lower temperatures, fuel droplets tend to be of larger diameter and less homogeneously distributed in the air stream than at relatively higher temperatures.

The fuel entry point (typically by way of the carburetor or fuel injector) is generally distanced from the intake port of each combustion chamber by a length of ducting, typically comprising one or more bends. This length of this ducting is generally such that the stream of air therein adopts a flow velocity profile such that fuel droplets carried with the air stream are urged to a central section of the ducting, and away from its walls, which are typically at an elevated temperature due to the normal running of the engine (Crouse & Anglin, 1993).

Typically, the fuel droplets, being distanced away from the hot walls, are kept relatively cool inhibiting full fuel vaporization, and further, the effect of the air stream enhances coagulation of droplets into larger droplets. The result is that the fuel-air mixture reaching the combustion chamber comprises a substantially fuel-rich centrally flowing portion comprising a high proportion of fuel droplets that cannot combust rapidly enough when ignited because of their relatively large size and poor availability of oxygen due to non-homogeneous mixing of the air and fuel. The higher the engine rpm, the greater the tendency for the fuel to migrate to the centre of the air stream.

Thus, a proportion of the fuel, typically between 10% and 30% or even higher, is not properly utilize by the engine for generating power, and remains unburnt, being transformed instead into pollutants that are discharged into the atmosphere, requiring expensive catalytic converters in the exhaust system for their neutralization (Crouse & Anglin, 1993). Further, the incomplete combustion of the fuel also results in the formation of carbon deposits, reducing the service life of the ignition units, pistons, valves and the engine in general.

Numerous prior art devices attempt to increase fuel efficiency and reduce pollutants by increasing the vaporization of the liquid fuel. Fuel vaporization is achieved mechanically by passing fuel through rotating blades, past screens or swirl chambers. These devices variously employ a screen for mixing and in some cases also a heater for vaporizing fuel, some devices being complex and expensive, while others are not suitable for retrofitting except with major modifications to the engine and/or engine bay (Crouse & Anglin, 1993). In any case, the devices are not very effective for a number of reasons. Firstly, the devices are generally located at the carburetor-intake manifold junction. As such, the fuel-air mixture still has some distance to cover before entering each combustion chamber, with the result that the fuel droplets still cool, coagulate and are urged towards the center of the ducts.

Thus, the contact time between the fuel and heater tends to be very small limiting severely the extent of vaporization possible. Mixing is enhanced in the devices by the use of mesh or perforated screens. However, as has been mentioned earlier, the effectiveness of such mixing is in inverse proportion to the distance between the screen and the combustion chamber. However, a large proportion of the fuel-air mixture continues through the open end of the cone and remains unaffected. In some embodiments, an internal component such as a turn helps swirl this flow. In any case, the effects of the cone are short-lived due to its displacement from combustion chamber entry.

There is thus still the need for a fuel-air mixer that ensures that a homogenous air-fuel mixture comprising the smallest possible particles of fuel reaches the combustion chamber with the goal of obtaining complete combustion (Crouse & Anglin, 1993).

2.2 Definition of Cyclone

The Cyclone is an air-twister, designed worldwide, with 10 years of research & development behind it (Ron and Eve, 2002). It is an automotive air channeling tool that creates a swirling air motion, allowing the air to move faster and more efficiently by continuously whirling air around corners and bends (Ron and Eve, 2002), as illustrated in Figure 2.1.

There are several different designs, but many are designed to fit on the intake or carburetor of a car and purportedly optimize air or fuel flow in some way (Nolan, 1990). The US Environmental Protection Agency (EPA) is required to test many of these devices under Section 511 of the Motor Vehicle Information and Cost Savings Act, and to provide public reports on their efficacy (Nolan, 1990). Most devices on the market are found to improve fuel efficiency for about 3-5% to any statistically measurable extent (Nain and Will, 2005).

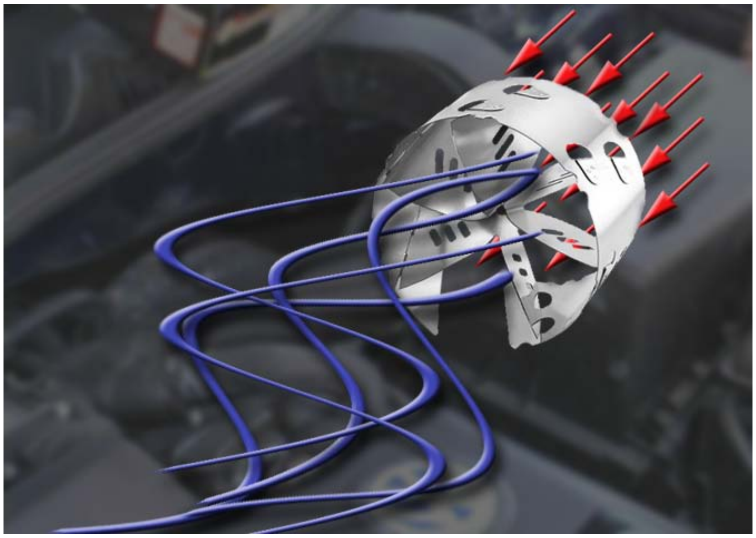

Figure 2.1: Air flow pattern through Cyclone (Ron and Eve, 2002)

Normally, the Cyclone is adjustable to fit different size air hoses, thus it can in almost any car or trucks. It is cut from a single sheet of high-grade stainless steel (Ron and Eve, 2002). Besides, it is designed such that it has no small pieces that could break off and get into the engine. The fins on the Cyclone intersect in the middle. It has an open space in the middle which contributes to superior airflow (Ron and Eve, 2002).

2.3 The Concept of Swirl Air Motion for Air Intake

The Cyclone creates a dynamic swirling tornado of air within the combustion chamber. This leads to better fuel atomization and more efficient burning as shown Figure 3. The technology behind this incredible design was developed over a period of years for the purpose of increasing horsepower in racing engines (Ron and Eve, 2002). Unlike most of the technologies, however it is easily modified for cost-effective use in normal road vehicles. Furthermore it is the only motor sport product that currently has been made available to the public (Whirley, 1991).

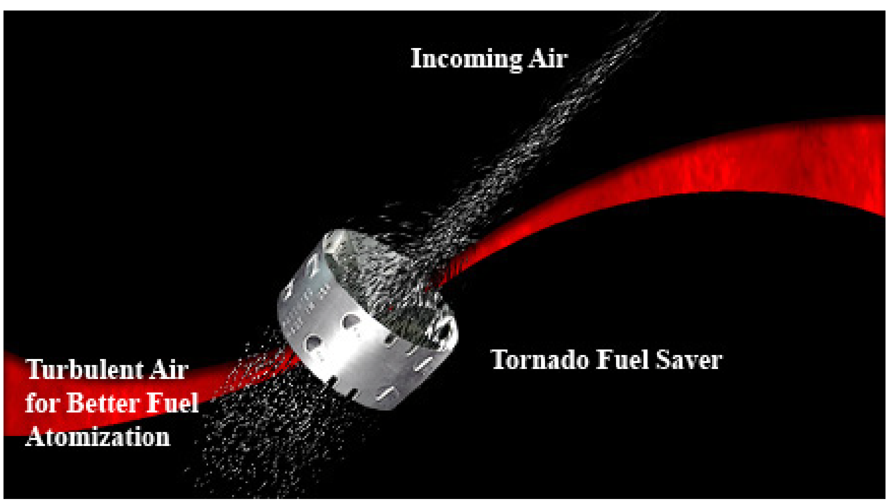

Figure 2.2: Air flow direction through Cyclone (Ron and Eve, 2002)

Fuel efficiency in its basic sense, is the same as thermal efficiency, meaning the efficiency of a process that converts energy contained is a carrier fuel into energy or work (Nolan, 1990). The overall fuel efficiency may vary for different engines or combustor and this spectrum of variance is often illustrated as a continuous energy profile. Non-transportation applications, such as industry, benefit from increased fuel efficiency, especially fossil fuel power plants or industries dealing with combustion such as ammonia production during the Haber process (Lavoie, 1970).

In the context of transportation, the “fuel efficiency” is more commonly referred as the energy efficiency of a particular vehicle model, where its output (range, or “mileage” (Nolan, 1990) is given as a ratio of range units per unit amount of input fuel (gasoline, diesel, etc.). This ratio is given in common measures such as “litres per 100 kilometre” (L/100 km) or “miles per gallon” (mpg) (Nolan, 1990). Thought the typical measure is vehicle range, for certain applications output can also be measured in terms of weight per range units (freight) or individual passenger-range (vehicle range/ passenger capacity)(Nolan, 1990).

This ratio is based on a car’s total properties, including its engine properties, its body drag, weight, and rolling resistance (friction), and as such may vary substantially from the profile of the engine alone. While the thermal efficiency of petrol engines has improved in recent decades, this does not necessarily translate into fuel economy of cars, as people in developed countries tend to buy bigger and heavier cars (i.e. MPVs (multi purpose vehicle) will get less range per unit fuel than an economy car) (Nolan, 1990).

2.4 Internal versus External Flow

Fluid flow is classified as being internal or external, depending on whether the fluid is forced to flow in a confined channel or over a surface. The flow of an unbounded fluid over a surface such as plate, a wire, or a pipe is external flow (Cengel & Cimbala, 2006). The flow in a pipe or duct is internal flow if the fluid is completely bounded by solid surfaces. Water flow in a pipe, for example, is internal flow, and airflow over a ball or over an exposed pipe during a windy day is external flow. Internal flows are dominated by the influence of viscosity throughout the flow field. In external flows the viscous effects are limited to boundary layers near solid surfaces and to make regions downstream of bodies.

2.5 Laminar versus Turbulent Flow

Not all fluid particles travel at the same velocity within a pipe (Cengel & Cimbala, 2006). The shape of the velocity curve (the velocity profile across any given section of the pipe) as shown in Figure 2.3 depends upon whether the flow is laminar or turbulent. Some flows are smooth and orderly while others are rather chaotic. The highly ordered fluid motion characterized by smooth layers of fluid is called laminar. The word laminar comes from the movement of adjacent fluid particles together in “laminates”. The flow of high-viscosity fluids such as oils at low velocities is typically laminar. The highly disordered fluid motion that typically occurs at high velocities and is characterized by velocity fluctuations is called turbulent. The flow of low-viscosity fluids such as air at high velocities is typically turbulent (Cengel & Cimbala, 2006). The flow regime greatly influences the required power for pumping. A fluid–flow regime characterized by swirling or chaotic motion as the fluids moves along the pipe or conduit.

In turbulent flow, secondary random motions are superimposed on the principal flow and there is an exchange of fluid from on adjacent sector to another. Therefore there is an exchange of momentum such that slow moving fluid particles speed up and fast moving particles give up their momentum to the slower moving particles and slow down themselves. A flow that alternates between being laminar and turbulent is called transitional.

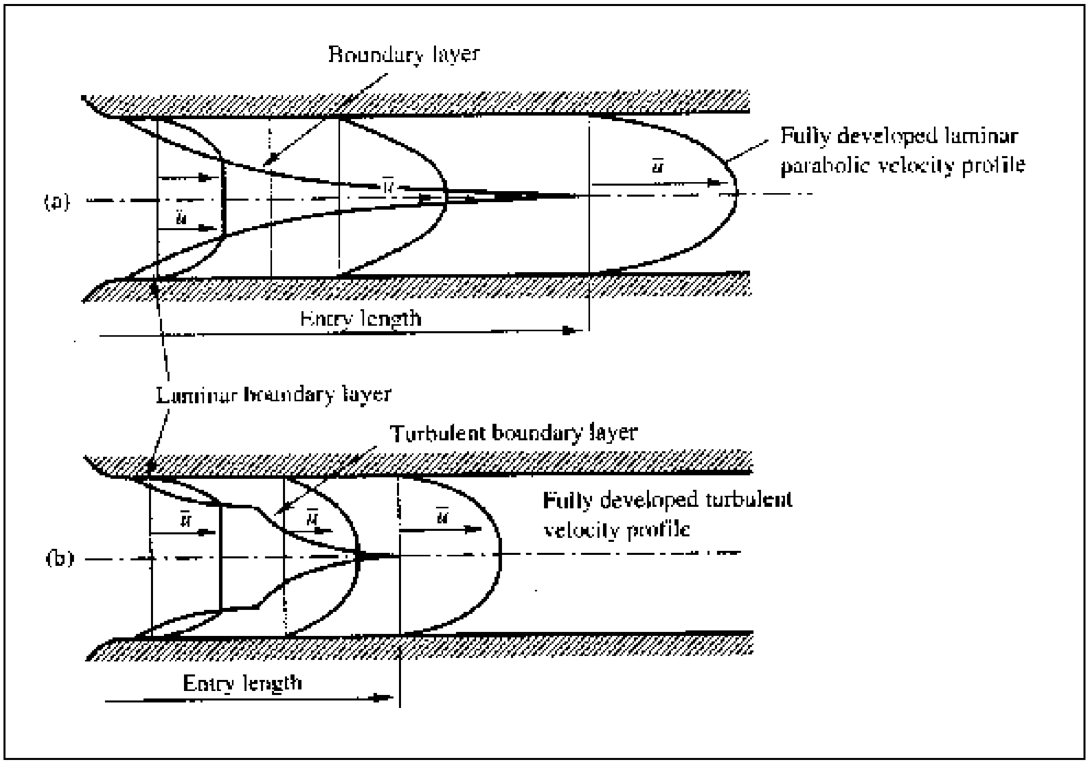

Figure 2.3: Laminar and turbulent flow velocity profiles (Cengel and Cimbala, 2006)

Swirling motion is one of the examples of turbulent flow (Cengel & Cimbala, 2006). In many practical engineering applications of axial flow, such as automotive radiator cooling fan, the swirling flow produced by the rotating blades is of no concern (Batchelor, 1967). But the swirling motion and increased turbulence intensity can continue for quite some distance downstream, and there are applications where swirl (or its affiliated noise and turbulence) is highly undesirable.

CHAPTER 3

METHODOLOGY

3.1 Overall Project Flow

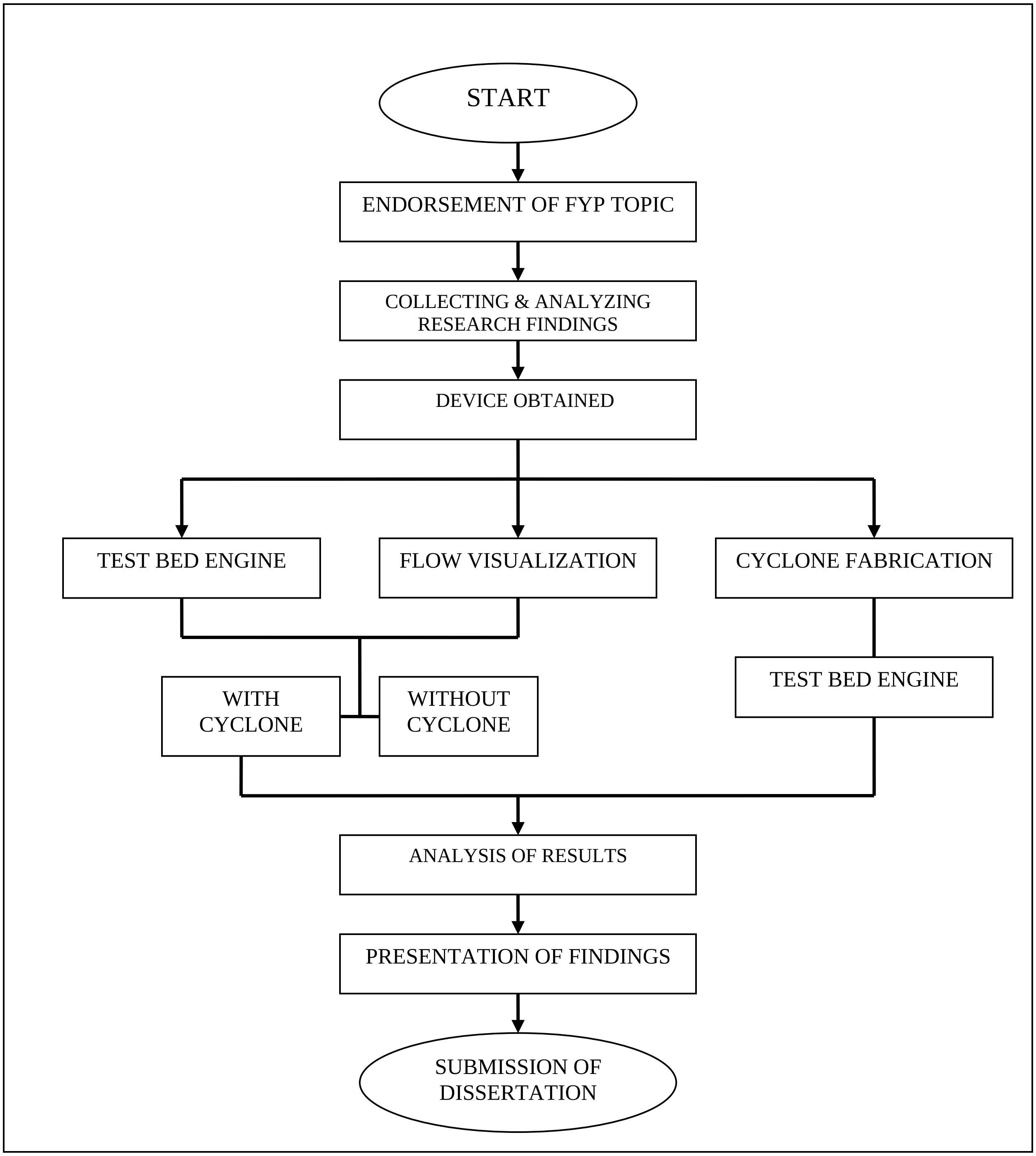

Figure 3.1: Project workflow

As shown in the Figure 3.1, the research project was started by collecting and analyzing the research findings via journals, reference books, news. A Cyclone was purchased and was tested via two experimental testing; test bed engine and wind tunnel. Both experiments were tested with and without inserting the Cyclone. In addition, three more Cyclones were fabricated with different angles and were tested in the test bed engine to identify the specific fuel consumption values.

3.2 Collecting and Analyzing the Research Findings

With reference to the objectives, the research project aims to prove the workability of Cyclone in reducing fuel consumption for a spark ignition engine car. Table 3.1 shows a list of manufacturers of intake air-swirl devices and their differences.

Table 3.1: The manufacturers of intake air-swirl devices and their differences

No.	Product	Quantity of blades	Angle of blades	Materials	Manufacturer
1	Tornado Fuel Saver	6	70º	Stainless Steel	AutoSpeed
2	Vortex Cyclone	6	70º	Stainless Steel	Ricks Distribution
3	Ningbo Fuel Saver	6	70º	Polymer	Ningbo Centre Magnetic and Electronic Co.,Ltd.
4	Cyclone Fuel Saver	6	70º	Stainless Steel	Mathis Custom Automotive LLC
5	Hiclone Fuel Saver	8	70º	Stainless Steel	Hiclone Australia Pty Ltd
6	Centron Fuel Saver	6	70º	Polymer	Centron Corpoations

The criteria involved in selecting the desired Cyclone are such as easier installation, durability, material made and the cost. For the present research, the Cyclone was purchased at one of the local car accessories retailer. The specifications of the air-swirl device used in the present project are as listed in Table 3.2:

Table 3.2: Specifications of the air-swirl device used in the present project

No.	Specifications	
1	Product	Cyclone Fuel Saver
2	Manufacturer	Mathis Custom Automotive LLC
3	Material	Stainless Steel
4	Length (in)	1.5
5	Thickness (mm)	0.7
6	Diameter (in)	2.5
7	No. of Blade	6
8	Angle of Blade	70º

Figure 3.2: Cyclone fuel saver

3.3 Constructing Testing Model and Simulation

The study was conducted by the following experiments:

i. Multicylinder test bed engine
ii. Flow visualization with smoke in wind tunnel testing

3.3.1 Multicylinder test bed engine

The purchased Cyclone was tested in Multicylinder Test Bed Engine (petrol) as shown in Figure A1.1 in Appendix 1. Thus, the testing includes some parameters that were performed with appropriate specifications. The descriptions of the testing method specification that was used are follows:

A) Engine specifications
(as shown in Tabble A2.1 in Appendix 2)

B) Fuel specification
The Petronas PRIMAX petrol (RON 92), which was purchased at the nearby retailer, was chosen during the test.

C) Load
The test was conducted in two types of loads: half load and full load. The half load was referred to the opening of the throttle position of 50% while the full load was 100% of the opening throttle position at the engine.

D) Duration
The engine was running for total two hours without non-stop for consistency results. The first hour test was not inserting the Cyclone into the air intake hose. While the remaining hour was tested by inserting the Cyclone into the air intake hose. The tests were repeated many times in order to check the repeatability of the results. Therefore in this test, the Cyclone was tested three times for each load.

E) Parameters

It is to be observed the results of the Test Bed Data Acquisition as shown in the Appendix 2. The parameter that needs to be observed is the specific fuel consumption for the both testing. The specific fuel consumption (s.f.c) is frequently used as an alternative criterion of performance and is defined as the rate of fuel consumption per kW of brake power and is expressed as follows;

$$s.f.c = m_f / b.p$$

Where m_f is the fuel flow in kg/s while b.p is the brake power in kW. As can be seen, for any given fuel the s.f.c is inversely proportional to brake thermal efficiency (η_b). Most common hydrocarbon fuels have very similar calorific values, and the s.f.c can therefore be used when comparing efficiency of engines using different fuels.

F) Location of Cyclone

The given vehicle application has an intake system consisting of a air filter box located off to the side of the engine bay and two intake hoses connected to a mass air flow sensor in between the hoses. The unit will be inserted into the second hose that is located after the mass air flow sensor leading into the throttle body. The directional airflow sticker is to be checked and ensure on the side of the unit faces toward the throttle body. The location of the installed Cyclone is shown in Figure 3.3.

Figure 3.3: The steps for installation of a Cyclone

3.3.2 Flow visualization with smoke in wind tunnel experiment

The flow visualization with smoke aims to show the difference of the air flow pattern when it passing through the cyclone inside a duct. The diagram of the wind tunnel equipment is shown in Figure 3.4. In this experiment, the preference method is using the wind tunnel that could vary the speed of the wind up to 60ms^{-1}. However in this experiment the speed of the fan was maintained at 5ms^{-1} or 18 km/hr. Normally, the wind tunnel consists of 5 main section which are settling chamber, contraction chamber, test section, diffuser section and fan drive section. Due to the bigger cross sectioned of the duct, therefore the wind tunnel duct need to perform minor modification in the test section. A cylindrical duct that was made from perspex as shown in Figure 3.6 was designed according to the diameter of the circular 3 components balance so that it could attach the duct. Silicon rubber was used to stick the cylindrical duct at the circular 3 components balance. The complete wind tunnel layout is shown in Figure A2.1 in Appendix 2.

It is believes that the air would moves in swirling motion when it passes through the Cyclone (Ron and Eve, 2002). The test was conducted in two phases which are with and without inserting the Cyclone inside a particular duct. Each phase was tested in different location of the Cyclone. Table 3.3 shows the different locations of the Cyclone that were located inside the cylindrical duct. Figure 3.5 shows the schematic picture of cylindrical duct for Cyclone locations. These procedures were performed in order to identify the point which the air starts to swirl using smoke generator during the wind tunnel testing. The specification of the wind tunnel experiment is shown in Table 3.4 while the duct specification is shown in the Table 3.5.

Table 3.3: 3 Locations of Cyclone in wind tunnel experiment

Location	Distance from the smoke generator nozzle (mm)
1	101.6
2	203.2
3	304.8

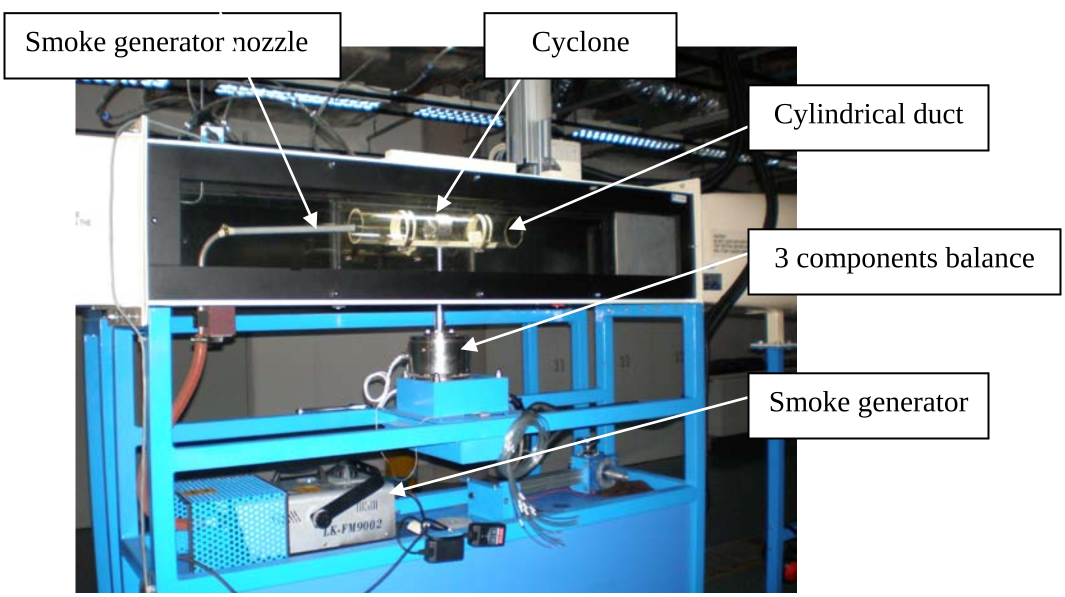

Figure 3.4: Wind tunnel setting for flow visualization experiment

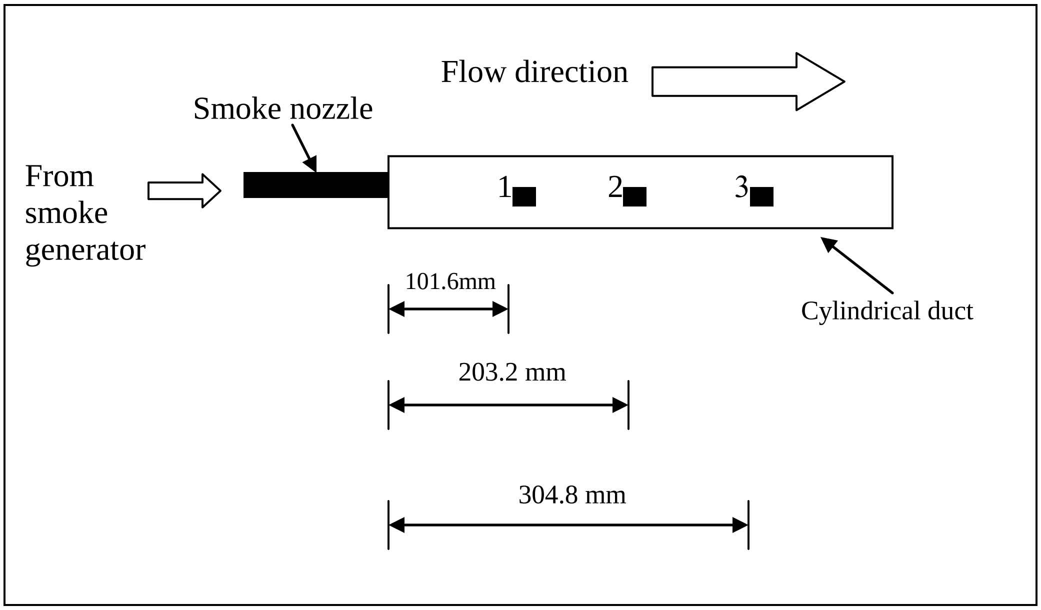

Figure 3.5: Schematic picture of cylindrical duct for Cyclone locations

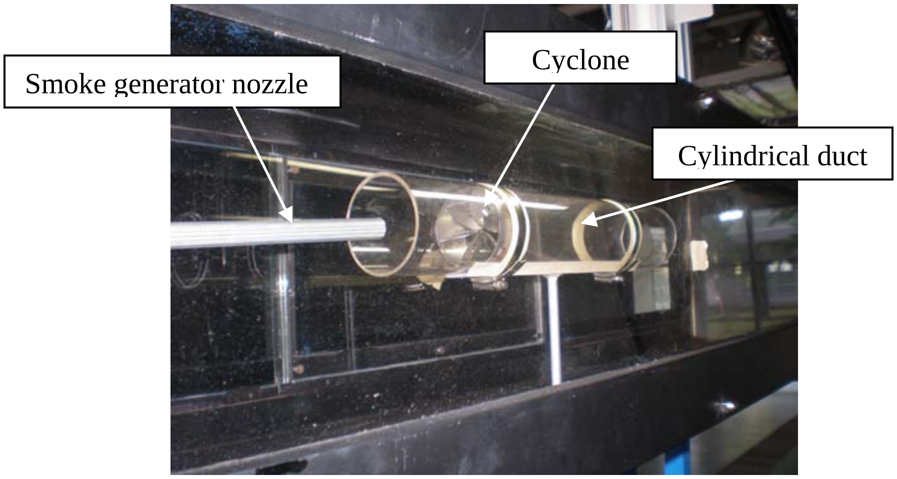

Figure 3.6: Close-up view of the perspex cylindrical duct

The Cyclones were tested inside the test section. The central portion of the tunnel is the test section sandwiched between the Inlet Duct and the Diffuser using flange. It has 300mm x 300mm cross section (inside) and 1500mm length. It fixed with transparent window on either side which facilities and viewing of the models (Cyclone). This houses smoke chest fixing points, lights for visualization and black mask fro better darkness background. The traversing mechanism is fixed on its top for the movement of total pressure total pressure probe. The holes are provided for holding the models for different studies and for taping out the pressure probes. In this experiment, the Cyclone was attached to that hole and the smoke generator was used for the purpose of flow visualization the Cyclone inside the particular duct. A camera was captured the images of the flow with and without inserting Cyclone during the smoke test.

Table 3.4: Wind tunnel specification

Type of tunnel	Low speed, Open circuit, Suction type
Test section	300H x 300D x1500L mm (Inside)
Air speed	Up to 60 meters/sec – (continuously variable)
Contraction Ration	25:1
Drive	Axial Flow Fan by DC motor with digital type Dc drive controller
Motor	11kW, 2800rpm DC motor
Overall Size	6.4L X 2.5H X 1.7W meter approximately
Power Requirement	AC, 3 phase, 415 volts, 30 Amps Electrical supply with Neutral & Earth Connections
Material of construction	Effuser, diffuser : MS Blower frames & Supporting frame : MS. construction

Table 3.5: Flow visualization test duct specifications

No.	Criterion	Specifications
1.	Material	Perspex
2.	Shape	Cylindrical (according to the diameter of circular 3 components balance)
3.	Length (mm)	457.2
4.	Thickness (mm)	3
5.	Cyclone position	101.6, 203.2 and 304.8 mm from the end of duct that facing smoke generator nozzle

3.4 Design and Fabrication Method

The improvement of the existed designed Cyclone was performed by fabricating the new one with different angle of the blades. The purchased Cyclone was used for reference. The desired new Cyclones were fabricated with different angles; 60º 70º and 80º. Overall the process involved in fabricates the new cyclone are shown in Figure 3.7:

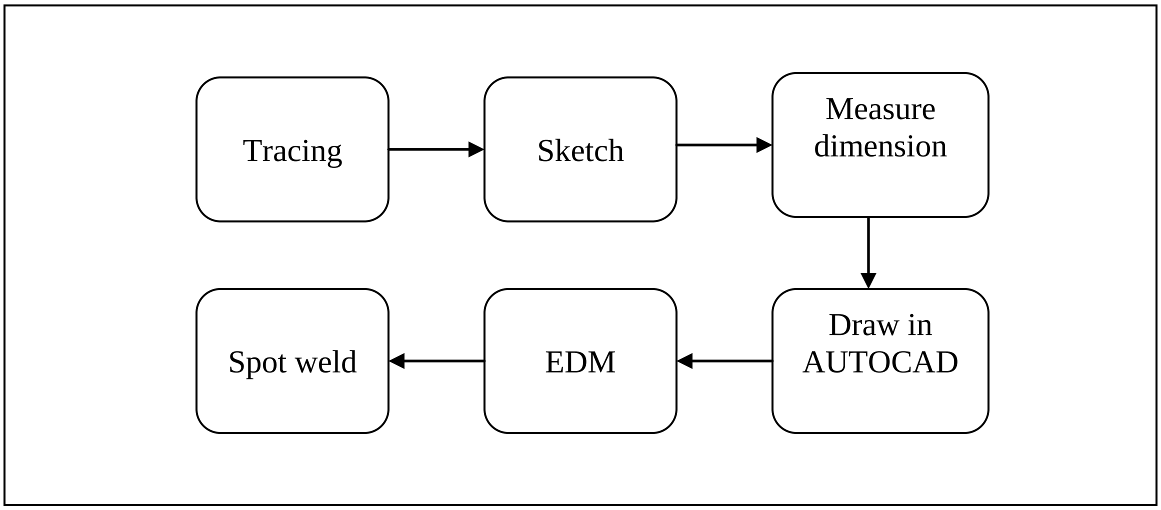

Figure 3.7: Design and fabrication process of Cyclone

At the beginning stage, the original Cyclone was traced directly by making a mould using a piece of paper. The paper was traced to the blade and the lines obtained were sketched. The dimensions of the blades were measured from the Cyclone using vernier caliper which has accuracy of 0.01 mm. The diameter of circular casing of the Cyclone was measured by using vernier caliper and the readings were taken five times for accuracy. The mould then was cut into its shape, copied and pasted into Autocad software for proper designing stage. Finally after the design was drawn, therefore it could be fabricating using EDM. The purpose of EDM is to cut the shape of the Cyclone. The technique used to fabricate them was spot weld as the materials that chosen were stainless steel.

Autocad 2004/07, integrated 2D and 3D design software was chosen to design the new Cyclone. The cyclones were refabricated in order to study the effect of blade angles during test bed engine experiment. The values of specific fuel consumption of each tested cyclone are to be compared and analyzed. The drawings of the designed Cyclone are;

a) Cyclone's blades with same dimension as the purchased Cyclone
b) Circular casing with angle of 70º
c) Circular casing with angle of 60º
d) Circular casing with angle of 80º

Note: All the drawings are shown in Appendix 3.

3.4.1 Designing Cyclone Blades

Figure 3.8 shows the parameters that involves in design the new Cyclone. The original Cyclone blades were traced directly by using a piece of paper. The arc and lines that were obtained were sketched by using a pencil and transferred into the paper with proper dimension reading for accuracy. The new designed of the blades does not have 3 stripe holes at its center (as shown in Figure 3.8) as the original Cyclone objectives are not interested in investigates the shapes of blades instead of the angles of blades. After the sketch was completed, the design was copied into Autocad software and pasted into the drawing window. Because the Autocad could not read and dimension the arc that has been drawn by free hand during sketching, therefore the arc was drawn by estimates the radius of the circle that has the closest and most likely to that arc that has been sketched. Because the original Cyclone was mass production unit, therefore the 100 percent accurate dimension could not be obtained for the best accuracy. Furthermore the new Cyclone blades were fabricated with each piece blade instead of two pieces of blade that are bent as the original cyclone. The new Cyclones were designed with tolerance ± 1.0 mm. The completed design for new cyclone is shown in Appendix 3.

3.4.2 Designing Cyclone Circular Casing

The dimension of the original cyclone casing was taken appropriately by using caliper and rope measurement with the precision of 0.1 mm. The same procedure to design the casing was applied as designing Cyclone blades. The designs were drawn into Autocad software. Because the casings have no arc except for the fillet at the edge of the casing, therefore the dimension were accurate with the original cyclone. The fillet was drawn approximately with radius of 2 mm as it does not affect the flow visualization instead sharp edge for safety design.

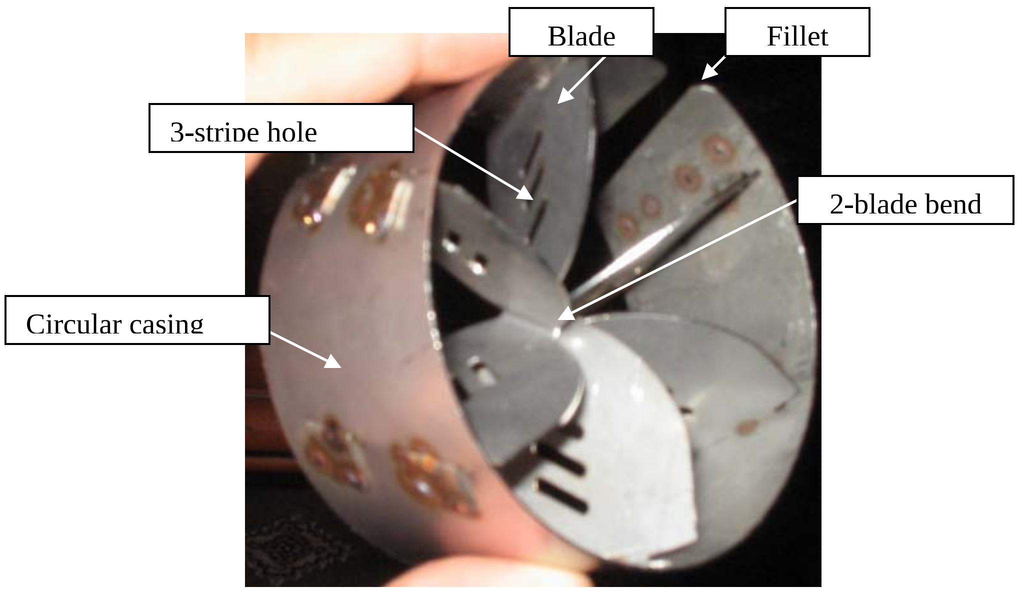

Figure 3.8: Parameters in design the Cyclone

Table 3.6: The additional units of new Cyclone

No.	Criterion	Specifications
1.	Material	Stainless Steel
2.	Shape	Cylindrical (according to the shape of Cyclone)
3.	Length (mm)	63.5
4.	Thickness (mm)	0.7
5.	No. of blades	6
6.	Diameter (mm)	63.5
7.	Angle of blade	60^o ,$70\ ^o$ and 80^o of each unit of Cyclone

3.4.3 Electircal Discharge Machine (EDM)

EDM is one of most accurate manufacturing process available for creating complex or simple shapes and geometries within parts and assemblies. EDM works by eroding material in the part of electrical discharges that form an arc between an electrode tool and work piece. EDM manufacturing is quite affordable and a very desirable manufacturing process low counts or high accuracy is required. The EDM system consists of a shaped tool or wire electrode and the part. The part is connected to a power supply. The work piece is immersed in dielectric (electrically nonconducting) which is circulated to flush away the debris to create a potential difference between the work piece and tool. The cutting pattern is CNC controlled and the drawing from the AUTOCAD is to be transferred into the system for cutting process. The EDM equipment that was used during the fabrication is shown in Figure 3.5:

Figure 3.9: The EDM equipment, for Cyclone fabrication

3.4.4 Spot Welding

Spot welding is typically used when welding particular types of sheet metal. Thicker stock is more difficult to spot weld because the heat flows into the surrounding metal more easily. Spot welding can be easily identified on many sheet metal goods, such as metal buckets. Aluminum alloys can also be spot welded. However, their much higher thermal conductivity and electrical conductivity mean that up to three times higher welding currents are needed. This requires larger, more powerful, and more expensive welding transformers. Perhaps the most common application of spot welding is in the automobile manufacturing industry, where it is used almost universally to weld the sheet metal to form a car. Spot welders can also be completely automated, and many of the industrial robots found on assembly lines are spot welders. Thus, the spot welding was chosen to fabricate the new Cyclone with the aid and guidance from the technicians.

3.5 Conducting Multicylinder Test Bed Engine for New Cyclone

Three units of new Cyclone were fabricated with different angles of the blade: 60º, 70º and 80º (as shown in the Appendices). The effects of the different angles were tested in Multicylinder Test Bed Engine by measuring the specific fuel consumptions. The testing was conducted with half load (50%) and full load (100%) of throttle position with the engine speed increment of 500rpm until it reaches 4000rpm. Each of the throttle position will be conducted their testing by inserting each of the different Cyclone.

Shown in Table 3.7 and Table 3.8 are the desired measurements with the new Cyclone and the testing procedure.

Experiment 1: Engine speed at 1000rpm with 50% of throttle position

Table 3.7: The half load testing procedure of new Cyclone at 1000rpm

Angle of blade	Specific Fuel Consumption (kg/kW·h)			
	Results 1	Results 2	Results 3	Average
60º				
70º				
80º				

Experiment 2: Engine speed at 1000rpm with 100% of throttle position

Table 3.8: The full load testing procedure of new Cyclone at 1000rpm

Angle of Blade	Specific Fuel Consumption (kg/kW·h)			
	Results 1	Results 2	Results 3	Average
60º				
70º				
80º				

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Experiment 1: Multicylinder Test Bed Engine

4.1.1 Half Load without Cyclone

Table 4.1 shows the results of multicylinder test bed engine with half load testing without Cyclone. The parameters that were obtained are such power output, brake power, mass fuel flow rate and specific fuel consumption.

Table 4.1: Half load test bed engine parameters without Cyclone

Speed (rev/min)	m_f (kg/s) $*10^{-3}$	Power output (B.H.P)	Brake power (kW)	m_f (kg/hr)	specific fuel consumption (s.f.c)
1000	0.737	14.1	10.515	2.653	0.252
1500	0.983	17.8	13.274	3.539	0.266
2000	0.983	15.6	11.633	3.539	0.304
2500	0.983	12.1	9.023	3.539	0.392
3000	0.983	9.0	6.711	3.539	0.527
3500	1.106	6.5	4.847	3.981	0.821
4000	0.983	1.8	1.342	3.539	2.634

Data Analysis (without Cyclone)

Specific fuel consumption:

$$s.f.c = \frac{m_f}{b.p}$$

Where :

s.f.c : specific fuel consumption (kg/kW·hr)

b.p. : Break power (kW)

m_f : Fuel mass flow rate (kg/s)

Sample calculation:

When the engine was run at half load,

Using the speed at 1000RPM:

BHP = 14.1

$$\text{Brake Power} = \text{BHP} \times \frac{1\text{kW}}{1.341\ \text{BHP}}$$

$$= 14.1 \times \frac{1\text{kW}}{1.341\ \text{BHP}}$$

b.p = 10.515 kW

$$m_f = \frac{\text{fuel flow x density(petrol)}}{60}$$

= 0.06 x 0.737/ 60

= 7.37 $\times 10^{-4}$ kg/s

Brake Power = 10.515 kW

Fuel Mass Flow, kg/h = 2.653 kg/h

The specific fuel consumption was:

s.f.c = (2.653/ 10.515)

= 0.252 kg/kW·hr

Therefore the values for specific fuel consumption (s.f.c) for the half load testing without inserting the Cyclone was 0.252 kg/kW·hr.

4.1.2 Half Load with Cyclone

Table 4.2 shows the result of the multicylinder test bed engine with full load testing with inserting Cyclone into the air intake hose. The parameters that involves in calculating the s.f.c values are such as mass fuel flow rate, power output and brake power. Table 4.3 shows the s.f.c values for both half load testing with and without Cyclone in multicylinder test bed engine experiment.

Table 4.2: Half load test bed engine parameters with Cyclone

Speed (rev/min)	m_f (kg/s) $*10^{-3}$	Power output (B.H.P)	Brake power (kW)	m_f (kg/hr)	specific fuel consumption (s.f.c)
1000	0.737	13.9	10.365	2.653	0.256
1500	0.983	17.6	13.125	3.539	0.269
2000	1.106	15.6	11.633	3.981	0.342
2500	0.983	12.1	9.023	3.539	0.392
3000	0.983	8.7	6.488	3.539	0.545
3500	0.983	5.6	4.176	3.539	0.847
4000	0.983	1.7	1.268	3.539	2.791

Table 4.3: Half load specific fuel consumption with and without Cyclone

Engine speed (rpm)	**s.c.f (kg/kW.hr) without cyclone**	**s.c.f (kg/kW.hr) with cyclone**
1000	0.252	0.256
1500	0.266	0.269
2000	0.304	0.342
2500	0.392	0.392
3000	0.527	0.545
3500	0.821	0.847
4000	2.634	2.791

From the data obtained, a graph of specific fuel consumption (kg/kW.hr) versus engine speed (rpm) was plotted for the throttle position 50% or half load as shown in the Figure 4.1. The graph shows that the increase of fuel consumption starts to develop at 1500 rpm and kept increasing up to 4000 rpm. The highest increments of fuel consumption are when the engine starts to speed from 3500 to 4000 rpm. From the results, the values of s.f.c were slightly higher than the testing without inserting Cyclone. The reason behind this was due to the improper location of the Cyclone that was attached at the nearest point of the intake manifold system. Because the provided length of the air intake hose was 1.47 metre attached at the engine, the cyclone act as a blockage thus restrict the amount of air that would flow inside the hose.

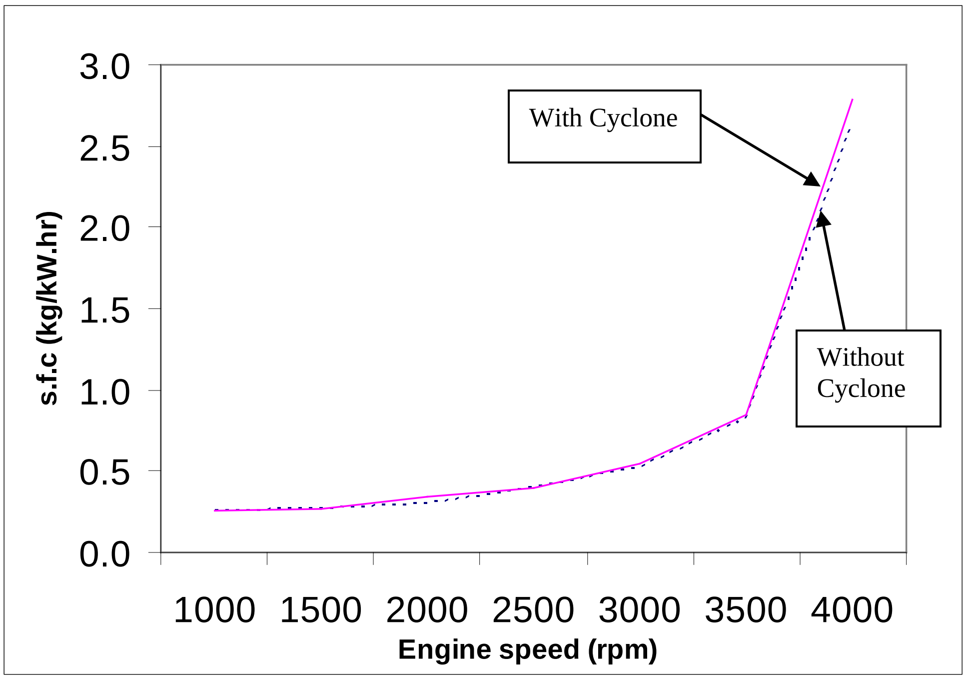

Figure 4.1: Half load graph of s.f.c vs. rpm

4.1.3 Full Load without Cyclone

The parameters that involves in calculating the s.f.c values were shown in the Table 4.4 for the test bed engine without inserting the Cyclone in the air intake hose.

Table 4.4: Full load test bed engine parameters without Cyclone

Speed (rev/min)	m_f (kg/s) $*10^{-3}$	Power output (B.H.P)	Brake power (kW)	m_f (kg/hr)	specified fuel consumption (s.f.c)
1000	1.474	15.7	11.708	5.306	0.453
1500	1.720	27.2	20.283	6.192	0.305
2000	1.965	36.7	27.368	7.074	0.258
2500	2.702	48.6	36.242	9.727	0.268
3000	3.439	60.4	45.041	12.380	0.275
3500	4.176	66.5	49.589	15.034	0.303
4000	5.036	78.4	58.464	18.130	0.310

4.1.4 Full Load with Cyclone

Table 4.5 shows the result of multicylinder test bed engine with full load testing with inserting Cyclone inside the air intake hose. Table 4.6 shows the s.f.c values for both half load testing with and without Cyclone in multicylinder test bed engine experiment.

Table 4.5: Full load test bed engine parameters with Cyclone

Speed (rev/min)	m_f (kg/s) $*10^{-3}$	Power output (B.H.P)	Brake power (kW)	m_f (kg/hr)	specified fuel consumption (s.f.c)
1000	1.474	14.8	11.037	5.306	0.481
1500	1.720	27.2	20.283	6.192	0.305
2000	1.965	36.3	27.069	7.074	0.261
2500	2.702	48.5	36.167	9.727	0.269
3000	3.439	59.7	44.519	12.380	0.278
3500	4.176	66.5	49.590	15.034	0.303
4000	5.036	78.1	58.240	18.130	0.311

Table 4.6: Full load specific fuel consumption with and without Cyclone

Engine speed (rpm)	s.c.f (kg/kW.hr) without cyclone	s.c.f (kg/kW.hr) with cyclone
1000	0.453	0.481
1500	0.305	0.305
2000	0.258	0.261
2500	0.268	0.269
3000	0.275	0.278
3500	0.303	0.303
4000	0.310	0.311

From the result obtain, there was no improvement in term of specific fuel consumption when the Cyclone was inserted inside the air intake hose during the test bed engine testing. This was shown in the Figure 4.2 which the s.f.c values versus engine speed (rpm) was plotted. The reason behind this was due to the improper location of the Cyclone that was attached at the nearest point of the intake manifold system. Because the provided length of the air intake hose was 1.47 meter attached at the engine, the Cyclone acted as a blockage thus restrict the amount of air that would flow inside the hose.

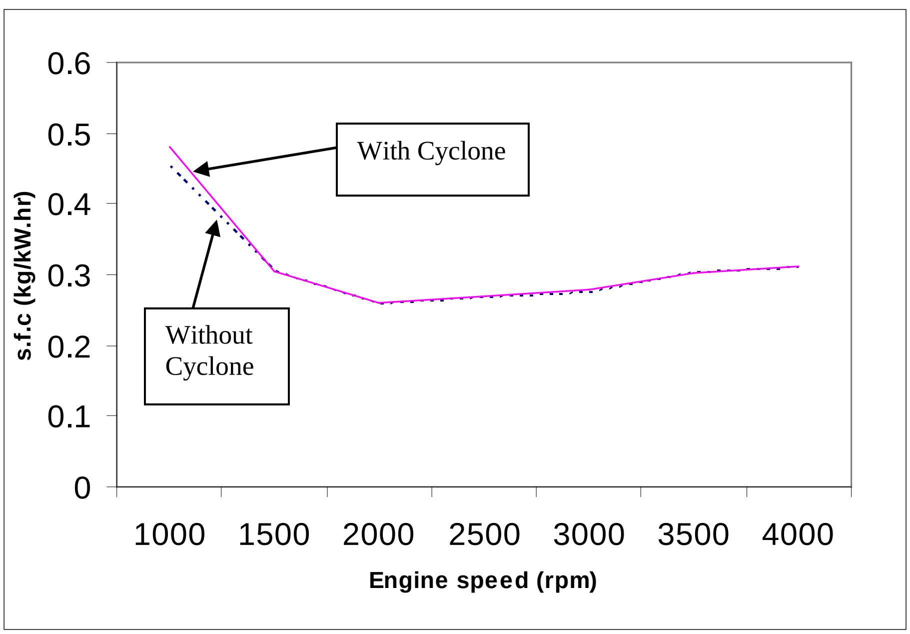

Figure 4.2: Full load graph of s.f.c vs. rpm

4.2 Experiment 2: Wind Tunnel

4.2.1 Air Flow Visualization without Cyclone

In this experiment, the flow pattern of the air was visualized and captured by using a digital camera. From the observation, the smoke flow passes through the cylindrical duct was random and stratified. As shown in the Figures 4.3 and 4.4, the air flows with occupying the total area of the duct. There was no swirling effect when the air flows inside the cylindrical duct without Cyclone installation.

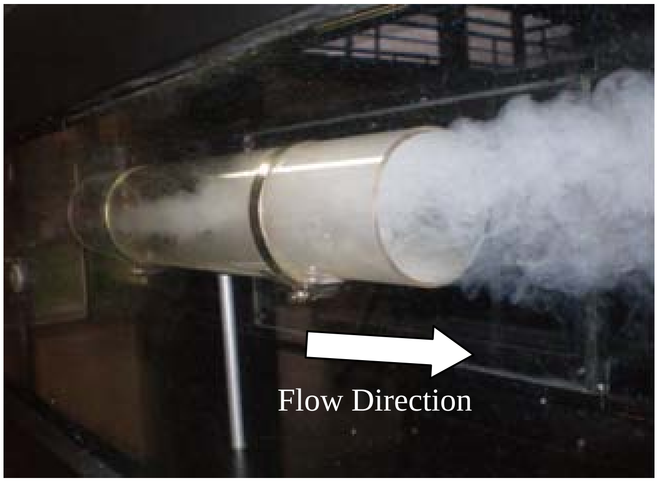

Figure 4.3: Air flow visualization without inserting Cyclone

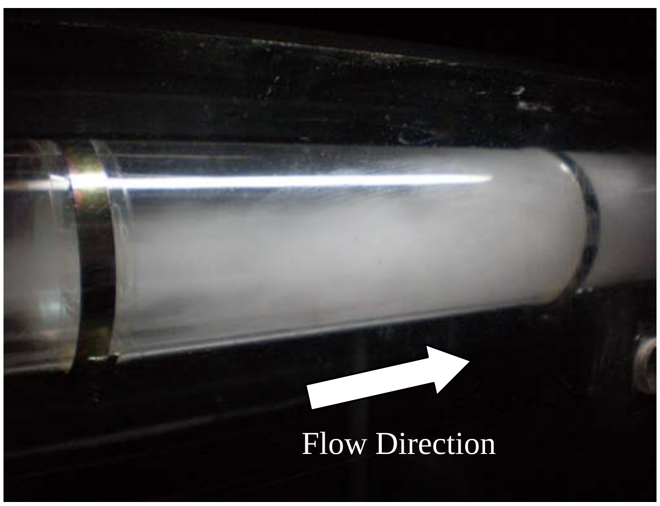

Figure 4.4: Air flow visualization inside the duct

4.2.2 Air Flow Visualization with Cyclone

From the observation, when the Cyclone was inserted at the location 1 as described in Section 3.3.2, which is 101.6 in from the smoke generator nozzle, the air swirling after it passes through Cyclone. The swirling effect could be visualized at the end of the cylindrical duct as shown in the Figure 4.5.

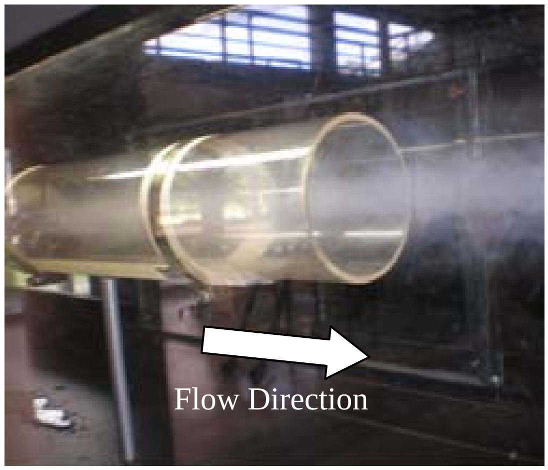

Figure 4.5: Flow visualization at Cyclone attachment at location 1

While in the wind tunnel testing for location 2, which the Cyclone was located at the middle of the cylindrical duct, the swirling effect could also be seen right after the air passes through it. However, the swirling flow was not so clearly that could be seen at the end of the cylindrical duct as shown in the Figure 4.6.

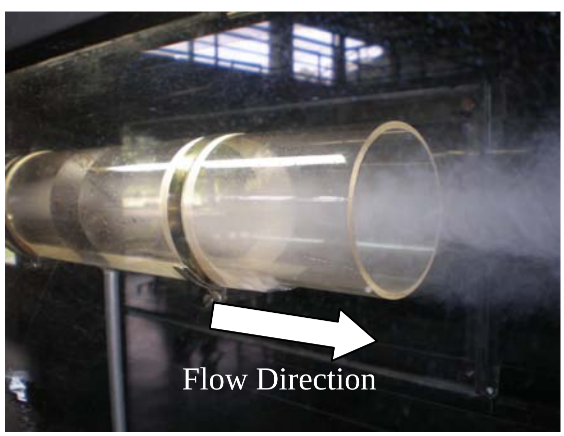

Figure 4.6: Flow visualization at Cyclone attachment at location 2

From the wind tunnel experiment at location 3 which the Cyclone was located 304.8 mm distance from the smoke generator nozzle, it was observed that the air swirling effect can be seen after it passes through it. The Figure 4.7 shows the air swirling effect occur as the air moves in turbulent manner which the centre of the air flows was thicker at that zone.

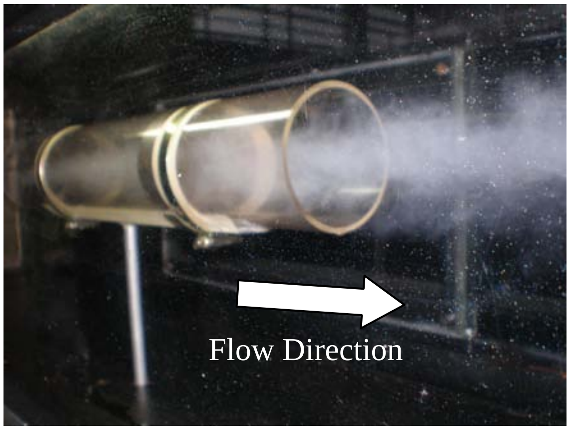

Figure 4.7: Flow visualization at Cyclone attachment at location 3

4.3 Fabrication of new Cyclones

Three (3) units of additional new Cyclones have been fabricated using the EDM machine and spot welding procedure. Figure 4.8, Figure 4.9 and Figure 4.10 show the Cyclones with 60º, 70º, and 80º blade angles respectively. These cyclones will be tested using the multicylinder test bed engine to study the effects of the blade angles towards fuel consumption. However due to equipment failure during the first stage experimental of testing, these devices could not be tested.

Figure 4.8: 60º blade angle Cyclone

Figure 4.9: 70º blade angle Cyclone

Figure 4.10: 80º blade angle Cyclone

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The operating characteristic of an intake air-swirl device which is known as Cyclone is studied to determine it's practically in reducing the fuel consumption of a spark ignition engine. The modification of air flow by such device has been claimed to increase the swirling effect of the intake air flow which could enhance the mixing between the air and fuel thus could improve fuel consumption during the combustion process. The study was conducted at various engine speeds and throttle position using a multicylinder test bed engine. However, from the engine test, it was shown that with the Cyclone installed in the air intake hose of the engine, both 50% and 100% throttle positions resulted in increase in the fuel consumption. The results contradicted with the claims by the manufacturers of 3 to 5% reduction in fuel consumption when operated with Cyclone. The specific fuel consumptions (s.f.c) with the presence of the Cyclone were expected to be slightly lower than that without Cyclone. The reason behind this was probably due to the improper mounting location of the Cyclone, which was attached at the nearest point of the intake manifold system. Because the length of the air intake hose for this engine test bed was 1.47 meter (i.e very long as compared to that in a car), the Cyclone possibly acted as a blockage thus restricting the amount of air that could flow into the manifold.

As the equipment broke down for retesting of the Cyclone, the validity of the claims could not be proven. In addition the new cyclones with different blade angles were also not able to be tested as the engine test bed was not repaired.

From the wind tunnel experiment, it was shown that Cyclone did affect the air flow pattern when it was inserting inside the duct. At different locations of Cyclone attachment, it was observed that the air flowed in swirling motion after it passed through the Cyclone. Hence, it indicated the capability of Cyclone as a mechanical device that could produce swirling affect.

As a recommendation for future work, the multicylinder test bed engine should be performed again with a few aspects that should be taken into consideration. The test could be performed with several repetitions. The location of the Cyclone attachment should be identified at different locations as the point of swirling affect started to develop might vary with length. Figure 5.1 shows the possible attachment of the Cyclone inside the air intake hose of the engine (white circle).

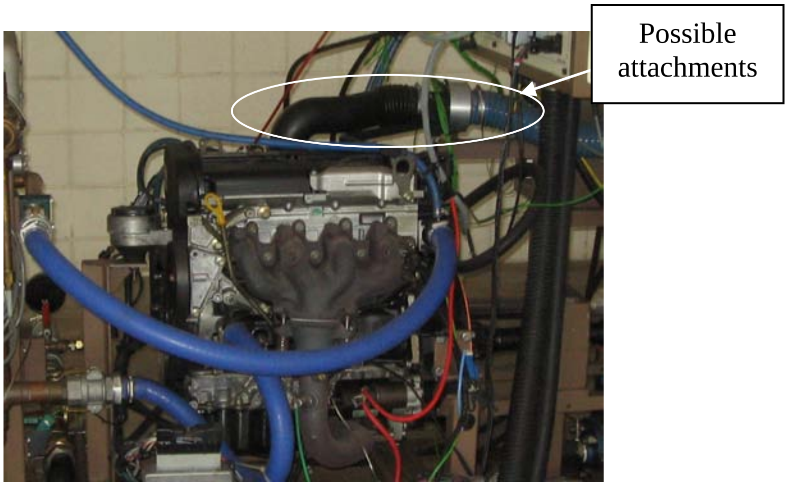

Figure 5.1: Possible Cyclone attachment at the engine

Furthermore the length of the air intake hose should be reduced to adequate length for flow of air in continuous swirling motion. Proper length of the hose is expected to produce sufficient volumetric efficiency when flowing into the intake manifold of the engine. Finally, retesting of multicylinder test bed engine experiment is recommended in order to prove the validity of the claims thus relate the effect of the varying blade angles of a Cyclone to meet the objectives of the research project.

CHAPTER 6

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APPENDIX 1

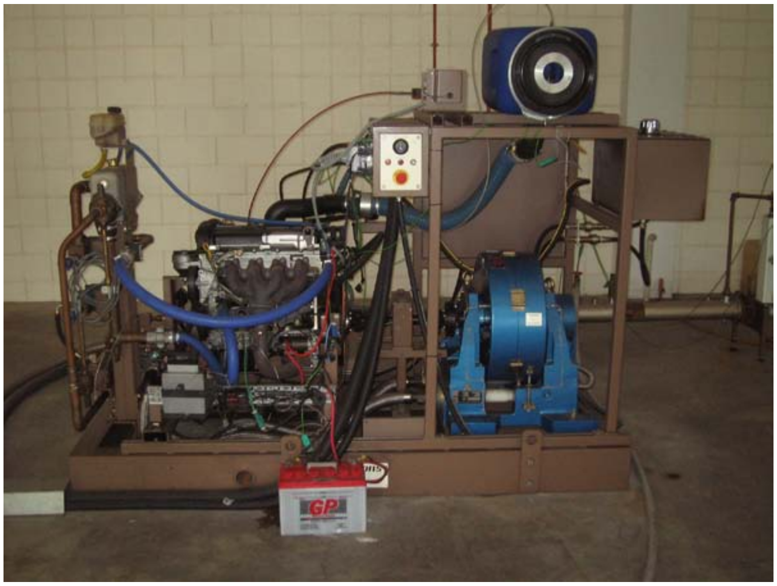

Figure A1.1: Multicylinder Test Bed Engine

Figure A1.2: Data Acquisition Test Bed Engine

APPENDIX 2

Table A2.1: FORD- Engine Technical Data

Engine-General	**1.8 DOHC 16V**
Emission standard	83 US
Identification code	RDA
Firing order	1-3-4-2
Bore (mm)	80,6
Stroke (mm)	88,0
Cubic capacity (cc)	1796
Compression ratio	10:1
Max. engine speed (rev/min)	5950
Power output (DIN-kW) at 5500 rev/min	77
Power output (DIN-PS) at 5500 rev/min	105
Torque (Nm) at 4000 rev/min	153

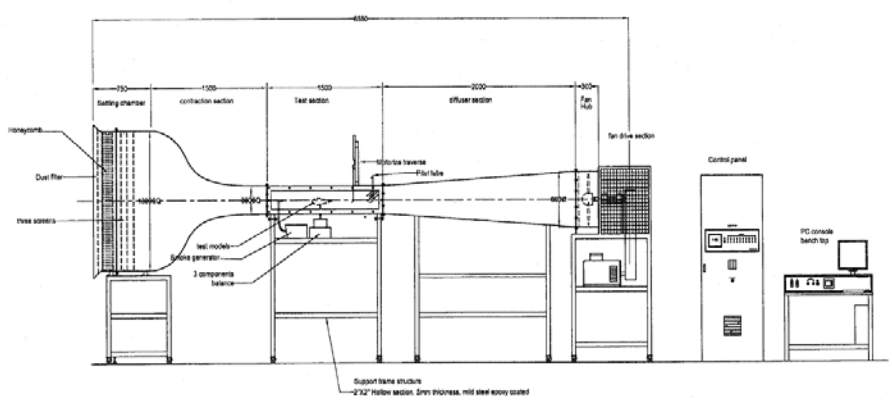

Figure A2.1: WT04 Sub-sonic Wind Tunnel layout

APPENDIX 3

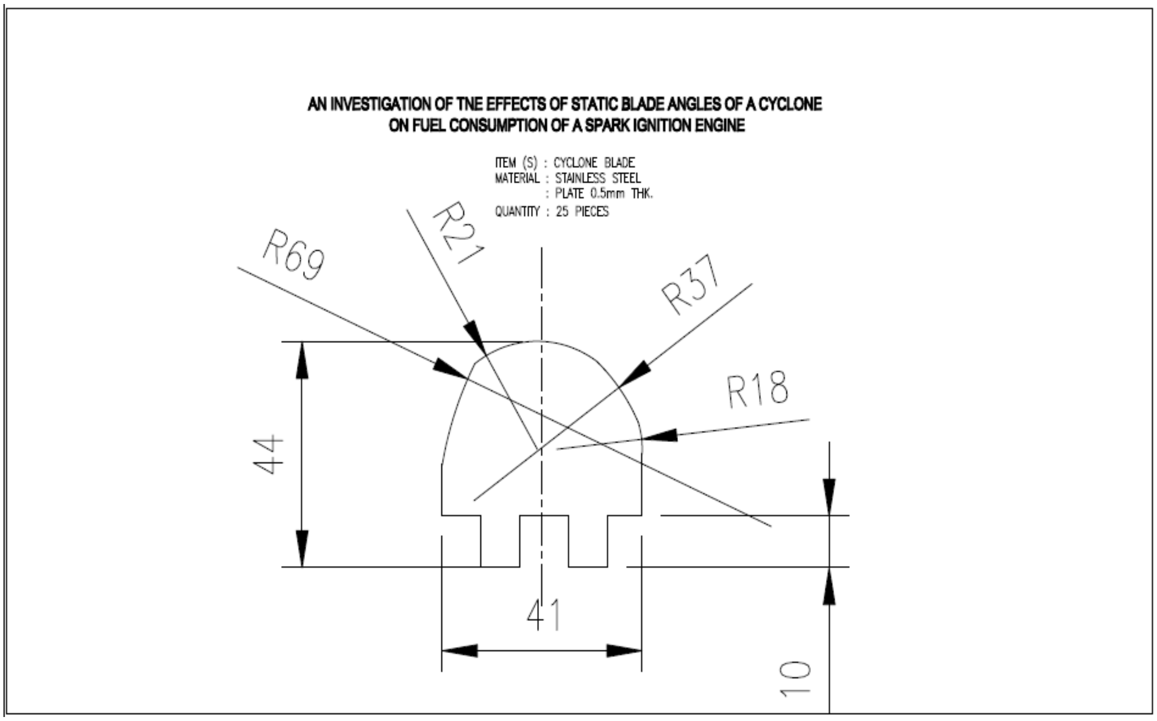

Figure A3.1: Drawing of Cyclone Blade

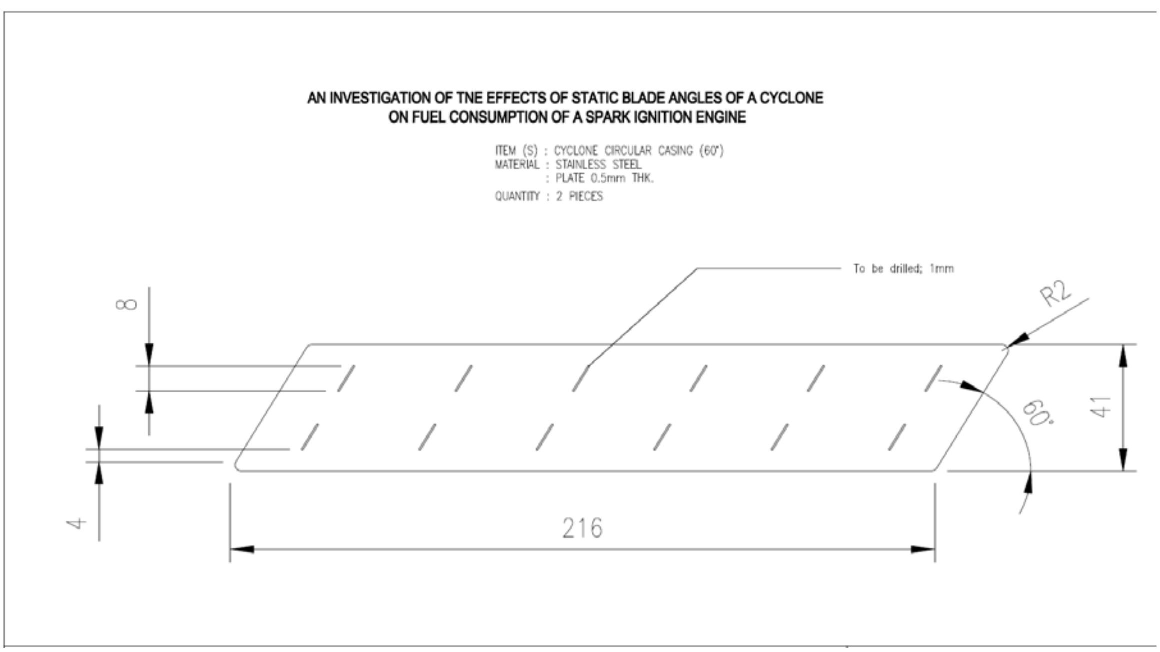

Figure A3.2: Drawing of Circular Cyclone Casing with 60º

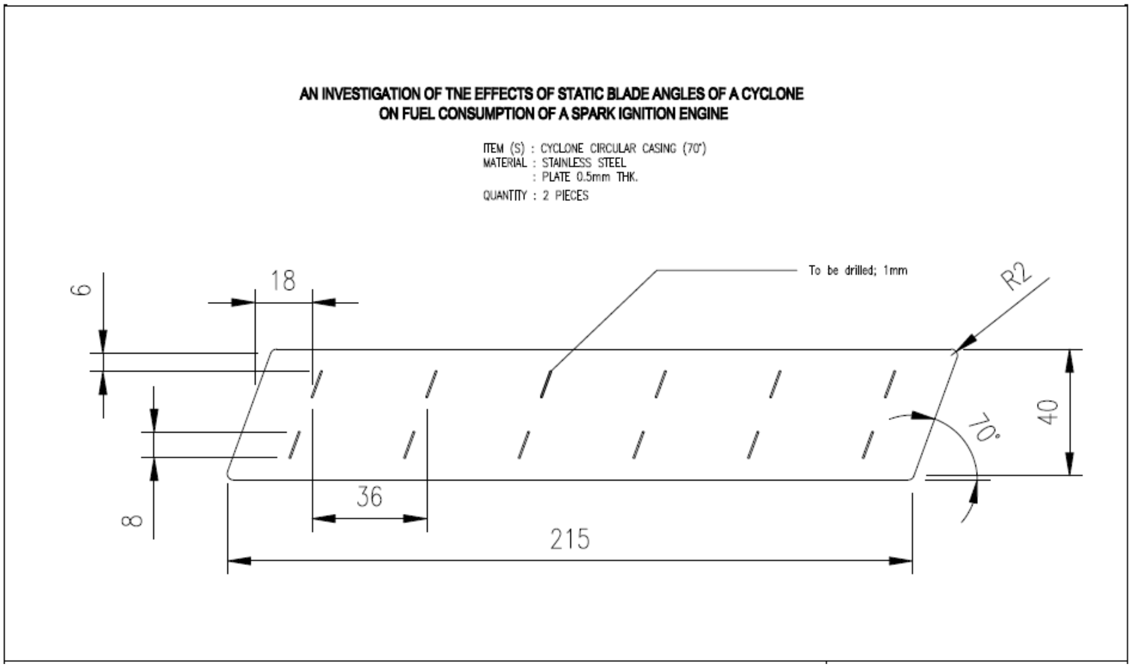

Figure A3.3: Drawing of Circular Cyclone Casing with 70º

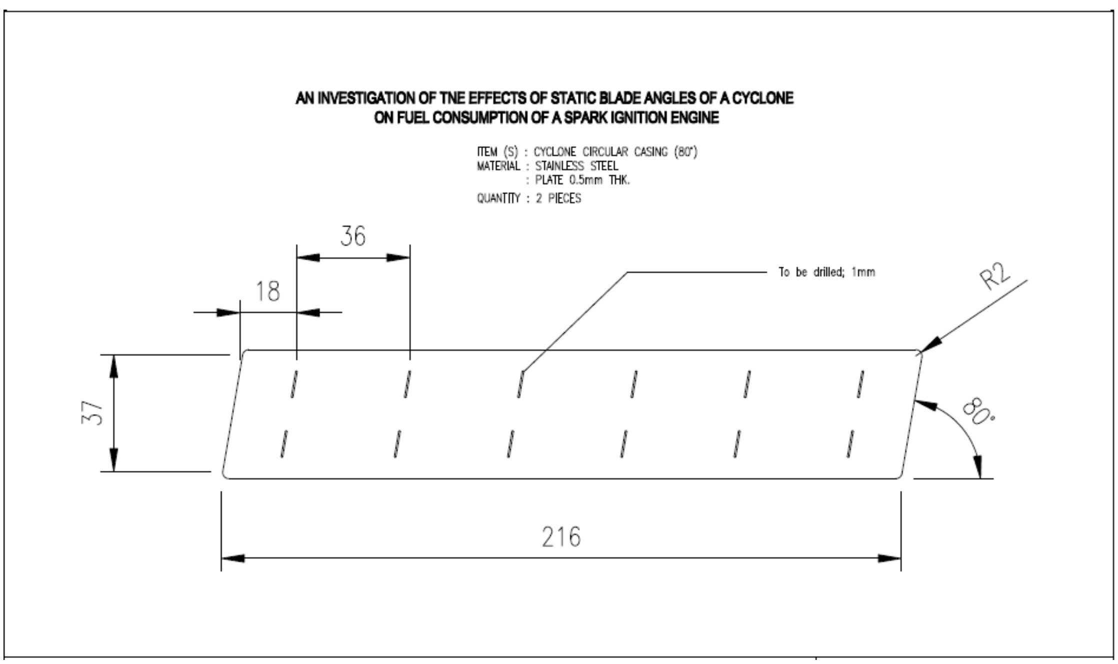

Figure A3.4: Drawing of Circular Cyclone Casing with 80º