R.V. COLLEGE OF ENGINEERING
BANGALORE - 560059
(Autonomous Institution Affiliated to VTU, Belgaum)

Design, Fabrication and Testing Of a Barrel Throttle Body

PROJECT REPORT
Submitted by

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In partial fulfillment of the requirements for the award of degree

Of

Bachelor of Engineering
In
MECHANICAL ENGINEERING
2013-2014

R.V. COLLEGE OF ENGINEERING - 560059

(Autonomous Institution Affiliated to VTU, Belgaum)

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

Certified that the project work entitled **"Design, Fabrication and Testing Of a Barrel Throttle Body"** carried out by **SANGRAM KESHARI ROUT (1RV10ME089), SATYA KRISHNA A. (1RV10ME090), and SHASHANK SHEKHAR SINGH (1RV10ME095),** the bonafide students of **R.V. College of Engineering, Bangalore** in partial fulfilment for the award of **Bachelor of Engineering** in **Mechanical Engineering** of the **Visvesvaraya Technological University, Belgaum** during the year 2013-2014. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirement in respect of project work prescribed for the said degree.

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DECLARATION

We, **Sangram Keshari Rout (1RV10ME089), Satya Krishna A (1RV10ME090), and Shashank Shekhar Singh (1RV10ME095)**, the students of Eighth Semester B.E., in the **Department of Mechanical Engineering** declare that the project entitled **"Design, Fabrication and Testing Of a Barrel Throttle Body"** has been carried out by us and submitted in partial fulfillment of the course requirements for the award of degree in **Bachelor of Engineering** in **Mechanical Engineering** during the academic year **2013 -2014**. The matter embodied in this report has not been submitted to any other university or institution for the award of any other degree or diploma.

Place: Bangalore **Signature**
Date:

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ABSTRACT

In a traditional spark ignition gasoline engine, the throttle body is the part of the air intake system that controls the amount of air that flows into an engine's combustion chamber. It consists of a bored housing that contains a throttle plate (butterfly) that rotates on a shaft. The problem with these traditional butterfly valves is that even at Wide Open Throttle, the thickness of the throttle plate causes obstruction to the flow of air resulting in reduced volumetric efficiency. This project is aimed at designing a better throttle body keeping in mind its manufacturability and cost effectiveness. Through this project we aim to design and simulate a barrel throttle body and verify the substantial improvement in the amount of air flowing through the throttle body at high rpms of the engine.

A barrel throttle body has two tubes one inside the other with the same hole machined in both the tubes. At full throttle it will rotate so that the holes in both the inner and outer tubes are lined up, allowing the air to pass through. The main benefit of barrel throttle is that at full throttle there is no obstruction to the airflow at Wide Open Throttle (WOT). Initially a stock butterfly valve was used to obtain the dimensions which were then fed to Ricardo, 1D engine & gas dynamics simulation software package, to obtain the boundary conditions like drop in pressure across the throttle body. Then both the throttle bodies (barrel, butterfly) were designed on Solid works. Once the design of the throttle body was ready, the boundary conditions were applied and simulations were performed to find out the mass flow rates of both the throttle bodies at different opening angles and the results were compared.

The results showed significant increase in the mass flow rate in a barrel throttle when compared to a butterfly throttle body. Also the flow patterns revealed more controlled turbulence and ease of flow in case of a barrel throttle body when compared to a butterfly valve. The results was obtained were consolidated by the experimental analysis on Flow bench. The results obtained after conducting the flow bench experiment showed that the barrel throttle body showed 14% increase in mass flow rate in comparison to the butterfly throttle body at 14 inches of pressure difference. The actual mass flow rate for barrel throttle body was found to be .055648 kg/s whereas the mass flow rate for butterfly was found to be .048544 kg/s.

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ACKNOWLEDGEMENT

Any achievement, be it scholastic or otherwise does not depend solely on the individual efforts but on the guidance, encouragement and cooperation of intellectuals, elders and friends. A number of personalities, in their own capacities have helped us in carrying out this project work. We would like to take this opportunity to thank them all.

First and foremost we would like to thank **Dr. B. S. Satyanarayana**, Principal, R.V.C.E, Bengaluru, for his moral support towards completing our project work.

We would like to thank **Dr. Ravindra S. Kulkarni**, Head of Department, Mechanical Engineering, R.V.C.E, Bengaluru, for his valuable suggestions and expert advice.

We deeply express our sincere gratitude to our guide **Mr. Sujan Chakraborty**, Professor, Department of Mechanical Engineering, R.V.C.E, Bengaluru, for his able guidance, regular source of encouragement and assistance throughout this project.

We take this opportunity to thank **RED ROOSTER RACING INTERNATIONAL PVT. LTD.** situated in Mahadevpura post for permitting us to use the flow bench equipment to carry out the experiment. We would also like to thank **MAGOD LASER** for helping us in manufacturing some of the critical components through laser cutting.

Last, but not the least, we would like to thank our peers and friends who provided us with valuable suggestions to improve our project.

CHAPTER 1

INTRODUCTION

In fuel injected engines, the throttle body is the part of the air intake system that controls the amount of air flowing into the engine, in response to driver accelerator pedal input in the main. The throttle body is usually located between the air filter box and the intake manifold, and it is usually attached to, or near, the mass airflow sensor [1]. On many cars, the accelerator pedal motion is communicated via the throttle cable, to activate the throttle linkages, which move the throttle plate. In cars with electronic throttle control (also known as "drive-by-wire"), an electric motor controls the throttle linkages and the accelerator pedal connects not to the throttle body, but to a sensor, which sends the pedal position to the Engine Control Unit (ECU). The ECU determines the throttle opening based on accelerator pedal position and inputs from other engine sensors. When the driver presses on the accelerator pedal, the throttle plate rotates within the throttle body, opening the throttle passage to allow more air into the intake manifold. Usually an airflow sensor measures this change and communicates with the ECU. The ECU then increases the amount of fuel being sent to the fuel injectors in order to obtain the desired air-fuel ratio. Often a throttle position sensor (TPS) is connected to the shaft of the throttle plate to provide the ECU with information on whether the throttle is in the idle position, wide-open throttle (WOT) position, or somewhere in between these extremes.

Throttle bodies may also contain valves and adjustments to control the minimum airflow during idle. Even in those units that are not "drive-by-wire", there will often be a small electric motor driven valve, the Idle Air Control Valve (IACV) that the ECU uses to control the amount of air that can bypass the main throttle opening. A throttle body is somewhat analogous to the carburettor in a non-injected engine. Carburettors combine the functionality of the throttle body and fuel injectors into one in order to modulate the amount of air flow and to combine air and fuel together. Cars with throttle body injection locate the fuel injectors in the throttle body, thereby allowing an older engine to be converted from carburettor to fuel injection without significantly altering the engine design [2][3][4].

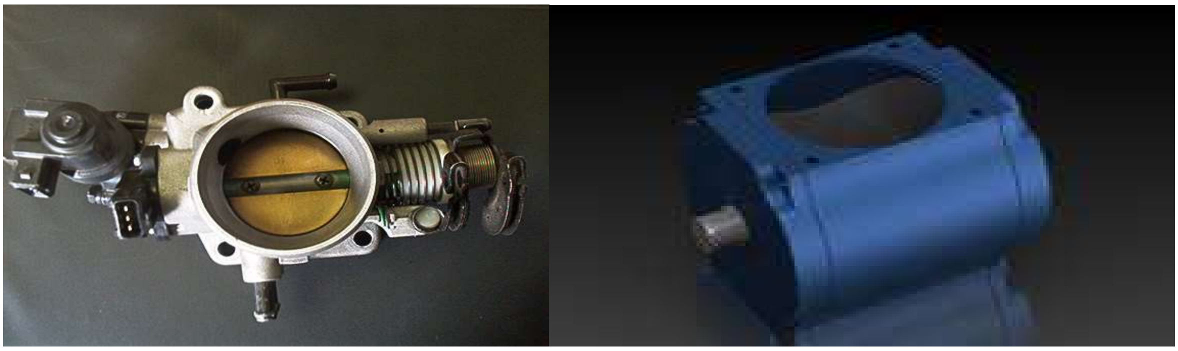


Fig 1.1 Butterfly Throttle Valve and Barrel Throttle Valve

Types of Throttle Bodies

Butterfly Throttle Body

Normal throttles use butterfly valves to control air flow into the engine. The throttle body is in fact, a large throttle valve, with a pair of linked butterfly hinged flapper valves, which are controlled by a simple mechanical linkage to the accelerator pedal [5]. Depressing the accelerator pedal will force the throttle butterfly valve to open further, increasing the flow of air through the throttle valve and instructing the Engine Control Module (ECM) to add more fuel, thus producing more power, faster speed, and acceleration. Attached to the body of the Throttle body injection unit are two sensors; the TPS throttle position sensor, and the IAC idle air control assembly. The Engine control module uses the TPS to determine the accurate position of the throttle body valve, its degree of cycling, and percentage of opening (0% to 100%). The ECM takes readings from the Idle Air Control Sensor (IAC) in order to maintain a constant idle speed during normal engine operation, during all stages of power, load, and combustion. The largest piece inside the throttle body is the throttle plate, which is a butterfly valve that regulates the airflow. Even when fully open, there is still a slight blockage of the throttle body due to the thickness of the throttle plate [1] [12].

Barrel Throttle Body

The concept of barrel throttle body is an attempt to achieve the maximum possible output of an I.C Engine. The output of an engine is directly proportional to amount of air entering the combustion chamber. It consists of roller barrels which are basically two tubes one inside the other. The outer tube will have holes on either side (usually at 180 degrees apart), which allow air to enter and exit. The inner tube will have exactly the same holes machined in them, but as it rotates inside the outer tube will blank off the holes [1] [2] [3]. With the throttle closed the inner tube will rotate right round so that the holes in the outer tube are completely blanked off. At full throttle it will rotate so that the holes in both the inner and outer tubes are lined up, allowing the air to pass through [9]. The main benefit of barrel throttle is that at full throttle there is no obstruction to the airflow at Wide Open Throttle (WOT). The great advantage is that it can be made as a continuation of the port shape, regardless of profile (slides would overlap), and thus be placed near or even in the cylinder head. This allows for a very short system to suit the 18,000+ RPM which is now common [1] [3]. This is now the preferred solution for top end engines used in Formula 1, World Super Bikes and some sports-racing engines. For example the Caterham Seven CSR is the latest model from sports car manufacturer Caterham Cars with an advanced, custom roller-barrel system that increases airflow at full throttle compared to a butterfly inlet, boosting performance.

1.1 State of art development

Internal combustion engines for passenger vehicles typically employ a butterfly valve in a throttle valve assembly to control air intake, whether it is employed in a plenum throttle or a port throttle configuration. While this arrangement works adequately, increases in horsepower can be had if the valve employed in the throttle assembly is a barrel valve rather than the conventional butterfly valve of equal port area. This is true because the butterfly valve shaft and plate remain in the airflow path, obstructing airflow at wide open throttle [5] [10]. A barrel throttle uses a flow opening through a barrel and a matching opening in a housing for the throttling orifice area from minimum to wide open by rotation of the barrel. At wide open throttle, the barrel throttle does not restrict airflow. Furthermore, barrel throttles also generally offer improved air flow sensitivity to throttle angle [1] [2] [3] [6].

This horsepower improvement has been recognized in racing engines for years where barrel valves are routinely employed. However, in racing engines the concerns are much different than in passenger vehicles. Passenger vehicles have strict fuel economy standards that must be complied with as well as concerns with good idle quality. This is one of the reasons that passenger cars typically employ butterfly valves instead of barrel valves [1].

Consequently, difficulties arise with the employment of barrel throttles in passenger vehicles that are not concerns with conventional butterfly valves or with racing engines. For instance, barrel valves are more prone to leakage than butterfly valves [1] [3]. Current practice in race engines restricts leakage around barrel throttles by using tight clearances, which makes manufacturing more difficult and causes problems of binding and high friction from thermal expansion and mechanical distortions. Although not a problem for limited production race engines, it is a concern for the high volumes at which passenger vehicles are produced. Nonetheless, passenger vehicles will also require good sealing around a barrel valve, in this case, to allow for good idle quality. Thus a good long lasting seal is required around the throttle valve [34].

In its embodiments, the present project contemplates a barrel throttle valve for use in the air stream of an intake system of an internal combustion engine. The barrel throttle valve comprises a throttle valve housing having a barrel cavity enclosed therein and a main bore extending from the barrel cavity, with the main bore and barrel cavity enclosing a portion of the air stream. The barrel throttle valve also includes means for controlling the rotational motion of the barrel valve within the throttle body to allow for selective changing of the idle air flow past the barrel [6] [7]. The simulations carried out provides us a greater understanding of how the air flow is restricted at the throttle plate and especially why the flow becomes choked at a certain pressure ratio using Computational Fluid Dynamics (CFD) and to understand the basics of discharge coefficient [8] [11] [13] [14][18].

Accordingly, an object of the present invention is to provide an idle air control system for an internal combustion engine using a pusher in a barrel throttle to precisely control air flow for engine idle conditions, thus eliminating the need for a separate idle air control passage and control system, particularly for a port throttle configuration [3].

An advantage of the present invention is that a barrel valve is provided which will precisely control air flow to provide for increased horsepower over an equivalent butterfly valve throttle of equal port size, while allowing for stable idle.

An additional advantage of the present invention is that barrel valves are employed in a port throttle configuration with minimal increase in package size from a conventional butterfly valve configuration by off-setting the primary bore in the barrel valve.

Moreover, port throttles in general are becoming more prevalent in passenger vehicles because of advantages in power output control that can be had by employing a port throttle type of design with at least one throttle valve per cylinder. Moreover, intake port barrel throttles also provide good transient throttle response.

Another concern when employing a barrel throttle rather than a butterfly valve is its increased overall size relative to the throttle plate design, creating packaging concerns in the engine compartment [1]. This is especially true for port throttle configurations, having multiple throttle valves. A desire exists, then, to employ barrel throttles in a port throttle configuration without unduly increasing its size over equivalent butterfly valves.

1.2 Motivation

Huge resources and time is dedicated by researchers to increase the efficiency of an internal combustion engines. The research is mostly dedicated optimise the cam profiles, cylinder geometries, port shape, etc. and can be judged by a parameter known as the volumetric efficiency. Volumetric efficiency is defined as the ratio of the amount of air entering the cylinders to swept volume of the cylinders. The air inducted into the combustion chambers can be controlled by a device known as a throttle body. Commonly used throttle bodies are of butterfly throttle type and offer resistance to flow at WOT. This resistance to flow inevitably reduces the efficiency of the IC engine.

Barrel throttle bodies are an advanced type of throttle which overcome this issue and are much more efficient than butterfly throttle bodies.

1.3Problem Definition

The problem faced during the development of the prototype was to manufacture an elliptical to circular transition duct. The elliptical shape would be a continuation of the shape of the optimized throttle body whereas the other end would connect to circular cross section pipe.

Also an elliptical shape of the hole is not feasible for the following reasons as it would be almost impossible to manufacture the elliptical bell mouth with our available resources.

For an elliptical profile of the bell, an air filter of the same shape is not available

A customised tube at the bottom of the barrel which accounts for the change in shape from elliptical to circular which is not easy to manufacture and such transition would account to pressure losses through the duct.

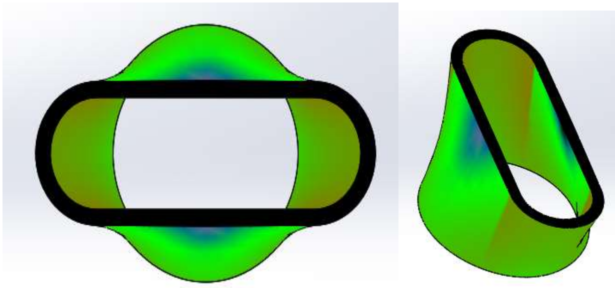


Fig 1.2. The transition duct to be manufactured for connecting the elliptical throttle to the circular duct

1.4 Objectives

The objective behind our study is to design a much more effective and efficient throttle body without losing the key features of dynamic throttle response, Idling, and to attain higher speed. The use of barrel type throttle bodies would help in increasing the efficiency of engines and leads to higher volumetric efficiency and hence more power at higher speeds. The availability of barrel shaped throttle bodies would allow the intake ducts to be made much shorter assisting in achieving high speeds in racing style engines. Also short strokes have been widely preferred. These engines allow larger intake valve to be incorporate and hence have higher efficiency. Another key objective of our project is to compare the Barrel and the butterfly throttle bodies on a flow bench.

1.5 Scope

The project has a huge scope for the fact that there is an immense need of throttle bodies that offer minimal resistance to air flow to internal combustion engines. As of now the throttle bodies used prevalently are of butterfly type with thin cross section of throttle plate and aren't the most efficient types. So the market needs to achieve high efficiency are enormous and if proper research and development goes in this domain, highly efficient throttle bodies can be devised and made widely used on all automobiles.

1.6 Methodology

A methodology was planned in order to accomplish the above listed objectives.

The engine data was acquired and the bore size (28mm) of stock throttle body and shaft diameter (5mm) was noted down. The idling RPM of the engine was taken as 2000 RPM and the redline RPM is taken as 15000 RPM as prescribed in the manual. The pressure drop across the throttle body for various RPMs and the average mass flow rate of air for idle speed was determined by the help of Ricardo wave software. A design of experiments was performed in order to optimize the dimensions of the barrel hole. Then the complete assembly as well as the individual components was designed using CAD software (Solidworks) taking into consideration the manufacturability of the parts.

Flow Analysis on CFD software (Solid works flow simulation) with specified boundary conditions was performed to understand the flow patterns through the throttle bodies and to determine the mass flow rates. Mass flow rates at WOT for barrel and butterfly valve types was determined and also the idle angle for barrel throttle valve was determined. The throttle Position Sensor and the bearing to be used (sealed roller bearing ID 6mm OD 10 mm) was fixed. A drive by wire system (DbW) was selected and designed accordingly in order to facilitate the actuation of the throttle. Finally the part drawings are prepared for each part to be manufactured. The components were machined out of machinable grade Aluminium. These components along with the lip seals, E rings and fasteners were assembled together. Then testing & tabulation of results is done and the report is drafted.

1.7 Organization of project report

The report focuses on the development of a Barrel Throttle Body. The main body of the report is preceded by a table of contents including a list of figures, tables followed by the units used in the report.

The body of the thesis contains an introduction to different types of Throttle Bodies, few definitions related to the project is given, a literature survey is then done to collect information about this sphere, followed by details of the design and simulation steps and finally the results obtained from the actual flow bench analysis. The body of the report is divided into 7 chapters.

Chapter 1 gives introduction about the throttle body and how it works, different types of throttle bodies, challenges involved, its advantage over butterfly throttle body.

Chapter 2 deals with the acquisition of engine parameters and butterfly valve dimensions, boundary conditions from Ricardo Wave software, conceptual design of Barrel Throttle Body, flow analysis using Solidworks software, results from flow analysis and volumetric efficiency calculations.

Chapter 3 deals with the detailed design of the Barrel Throttle Body and the problems faced with the conceptual design. A small analysis was performed to determine the barrel diameter and a component research was done. Part design and assembly was done on Solidworks and hence part drawings were prepared.

Chapter 4 involves the fabrication of each part of barrel throttle body, assembly of the parts and information about the finishing processes which were used.

Chapter 5 gives the description of the testing instrument and the testing procedure which was used to test the Barrel Throttle Body and Butterfly Throttle Body.

Chapter 6, all the results from Solidworks and flow bench are discussed and analysed and hence theoretical and actual increase in volumetric efficiencies is determined.

Chapter 7 is a conclusion, which gives the outcome of the project work carried out and also brings out the limitations of the project and future enhancements. The basic scope of the project and the principals involved in its development has been reviewed in the chapter.

1.8 Summary

The existing butterfly throttle body allows air to pass through it but offers some resistance. This resistance reduces the amount of air inducted inside the cylinders which brings down the effective volumetric efficiency. The barrel throttle body offers no such resistance to air flow. This leads to an overall higher volumetric efficiency hence a proportional amount of fuel injected to the air inducted would produce higher power and torque.

CHAPTER 2

CONCEPTUAL DESIGN OF BARREL THROTTLE BODY AND ANALYSIS ON SOFTWARE

The conceptual design is purely based on the data and the parameters which lead to the analysis and further towards the final design. So the first step was to acquire the engine parameters and the dimensions of the Butterfly Throttle Valve.

The next step in line was to obtain the boundary condition which was done on Ricardo software which is 1D engine and gas dynamics software. Then design of experiments was carried out to optimise the barrel hole dimensions and a CAED design of Barrel Throttle Body and Butterfly Valve Throttle Body was made on Solidworks software.

Finally flow analysis was carried out on Barrel and Butterfly Throttle body at different angles to determine the flow trajectory and mass flow rate. The results obtained were tabulated and compared and then the volumetric efficiency calculations for both the throttle bodies were done using the results.

2.1 Acquisition of Engine Parameters and Butterfly Valve Dimensions.

The first step in the project was to find out the boundary conditions under which the throttle bodies operate, i.e. to find out the pressure drop across the throttle body when connected to the engine. In this case, the throttle body would be connected to SUZUKI GSX-R600 engine [22]. The engine parameters then need to be input to Ricardo Wave software to obtain the boundary conditions [20] [21].

2.1.1 Engine Parameters

Weibe's function: In an ideal combustion cycle all heat is released in an infinitely short time at the top dead centre of piston. In the real combustion cycle of engine, this heat is releasing gradually and unevenly [15]. Inserting the model of combustion to the complex mathematical simulation model of the combustion engine leads to precise results and saves time in the engine development.

The default formula for calculating the combustion in the cylinder of internal combustion engine is the equation, which was deduced by Wiebe. The Wiebe function is widely used to describe the rate of fuel mass burned in thermodynamic calculations [15]. This relationship allows the independent input of shape function parameters and of burn duration. It is known to represent quite well the experimentally observed trends of premixed spark ignition combustion. The Ricardo wave model was constructed with the values provided in the Table 1 as inputs [22].

TABLE 2.1: Engine parameters

Engine parameter	Value
Bore	67 mm
Stroke	42.5 mm
Connecting rod length	92.27 mm
Intake valve diameter	28 mm
Exhaust valve diameter	22 mm
Volumetric displacement	.599 litres
Compression ratio	12.8
Weibe's function	2
Firing order	1-2-4-3
Volumetric capacity	600 cc
Idling rpm	2000
Redline rpm	15000

2.1.2 Butterfly Valve Dimensions

A stock butterfly throttle body as seen in fig 2.1 was taken from Suzuki GSX-R600 and its dimensions were measured. The bore size of the barrel throttle body was kept the same as that of the butterfly valve throttle body so as to facilitate easy comparison between the two throttle bodies. Bore size (28mm) of stock throttle body and shaft diameter (6mm).

Fig 2.1 Stock Butterfly Throttle body of SUZUKI GSX-R600

2.2 Boundary Conditions from Ricardo Wave Software

Ricardo is a widely used engine and gas dynamics software. It is used as a tool to help predict the outcomes of different engine parameters. It's mostly used by engine developers to compare different engine geometry's and optimize various parameters like the shape of the piston, combustion chamber features, squish area, valve size, cam profile, and even the combustion parameters as Weibe's constant, CB duration, etc [19].

In our project we have used it determine the pressure variation produced at the end of ducts connected at the end of throttle body at various rpms. We have filled in as much data as we could to attain accurate results. It's an accepted norm that Ricardo's results are around 75-85% accurate. The data that were fed into the software were:

i. Engine geometry parameters- Bore, stroke, Connecting rod length, Compression ratio, valve diameters.
ii. Cam timings for both intake and exhaust valve.
iii. Butterfly valve dimensions.

2.2.1 Cam Profiles for Intake and Exhaust Valves

Cam profiles of the intake and exhaust cam shaft were determined using Co-ordinate Measuring Machine (CMM) at Carl Zeiss India (Bangalore) Private Limited.

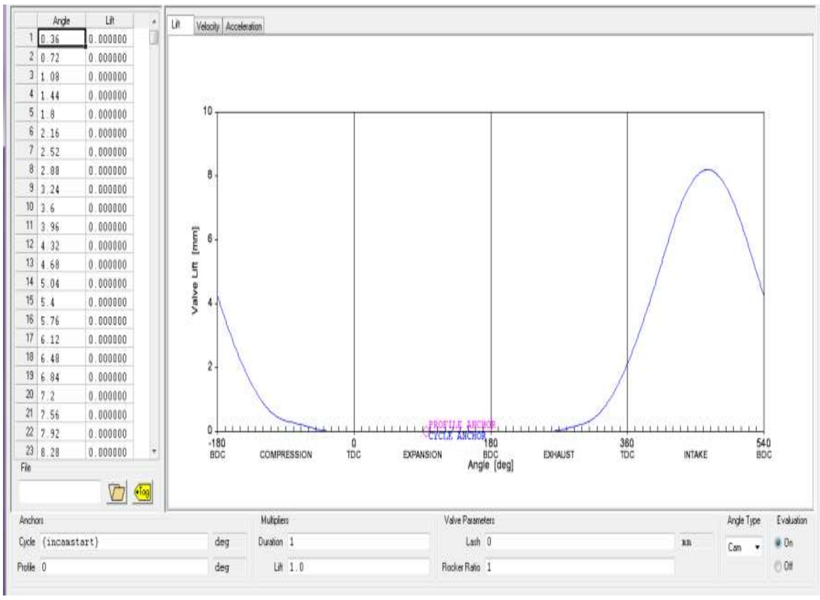


Fig 2.2 CAM profile for intake valve

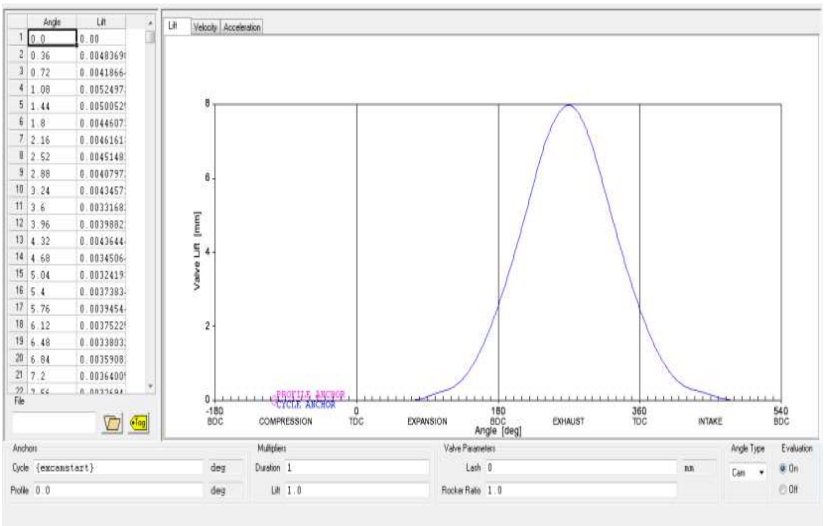


Fig 2.3 CAM profile for exhaust valve

2.2.2 Construction of Ricardo Wave Model

The Ricardo model is constructed by following the guidelines provided in the software tutorials. The wave model was constructed using basic wave elements like ducts, Y-junctions, injectors, etc. The engine model was constructed after fitting various engine parameters to the system.

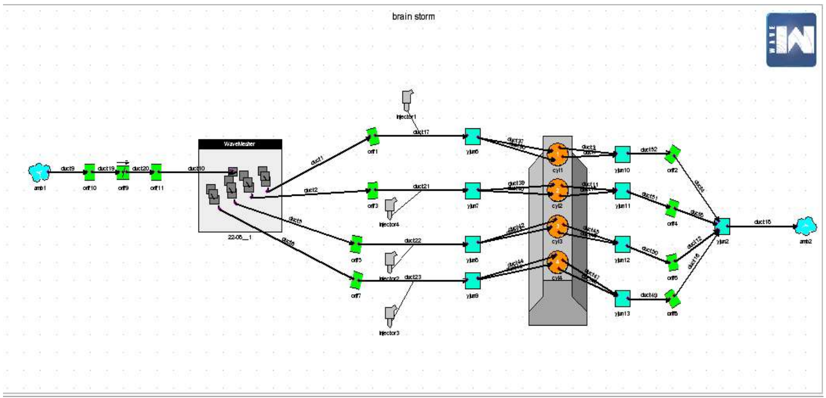


Fig 2.4 Ricardo wave model

2.2.3 Analysis Using Ricardo Model

After feeding in the cam data the simulation was run for various rpms ranging from the idling rpm till the redline rpm.

Pressure Plots were requested for the duct connected right after the throttle body.

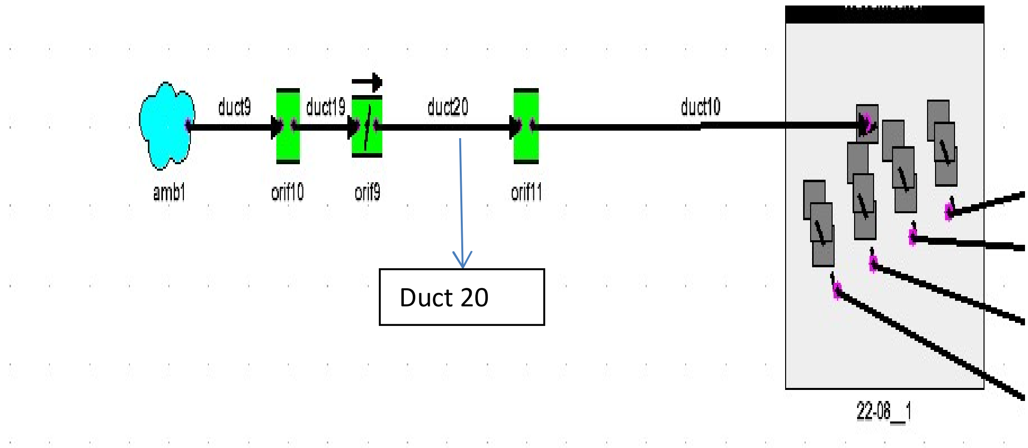


Fig 2.5 The duct connected after the throttle body

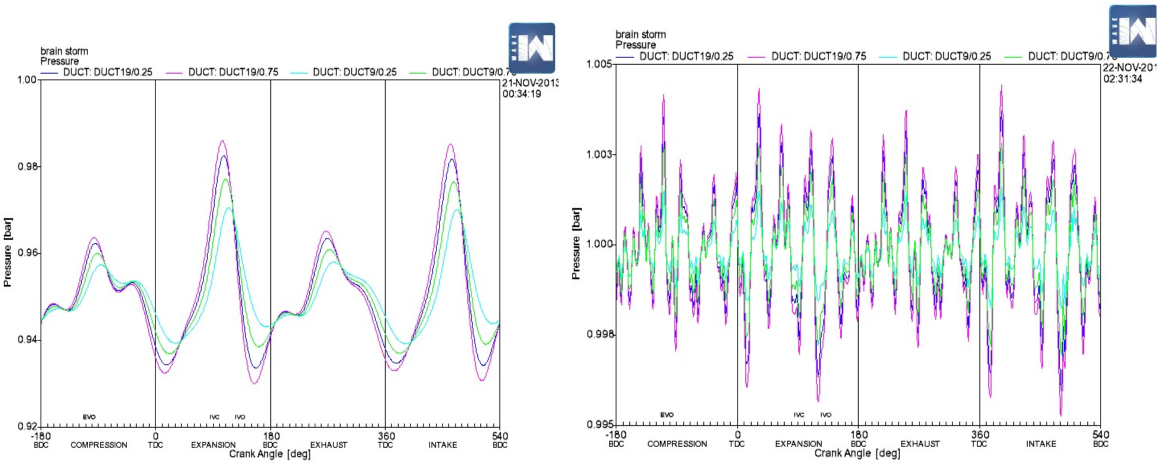


Fig 2.6 The variation of pressure across the duct at 2000 rpm and 15000 rpm

Since the plot obtained was a time dependent one, it could not be directly taken as the boundary conditions for the simulations. A thousand point data was converted to a single point data. This pressure computed was used as the boundary condition for our future CFD simulations. This was done to save computation time.

The average pressure drop was calculated to be:

- 0.93 bar at 15000rpm
- 0.9987 bar at 2000 rpm

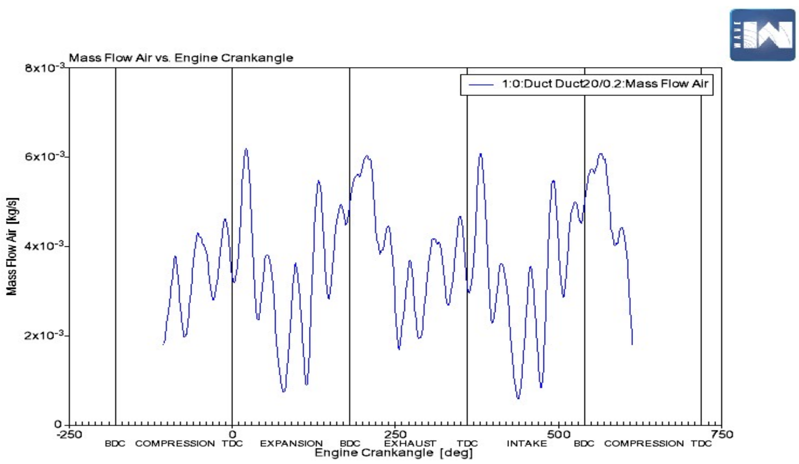


Fig 2.7 Mass flow rate of air at 2000rpm (idling)

Also another parameter which was important in our analysis was the mass flow rate of air at 2000 rpm. This parameter was used for the determination of the idling angle of our barrel throttle body. The average mass flow rate was calculated to be .0033 kg/s.

2.3 Conceptual Design of Barrel Throttle Body

2.3.1 Design of Experiments to Optimise Barrel Hole Dimensions

The cross sectional are of the barrel was fixed which was the same as the area of the stock butterfly throttle. Now a design of experiments was conducted to find the optimized dimensions for the barrel hole. The results of our experiments yielded the dimensions to be 32.08mm length and 14.00 mm radius as seen in the fig 2.8.From the table 2, we can note that the mass flow rate is maximum at the above dimensions.

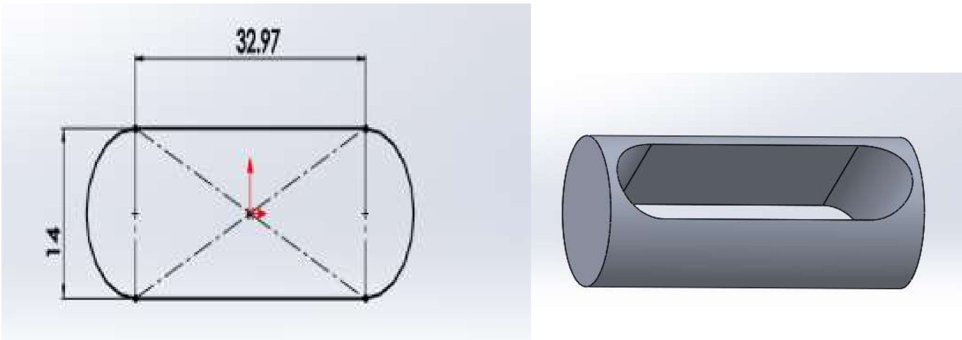


Fig 2.8 Dimensions of barrel hole

Table 2.2: Data obtained from the design of experiments

STOCK AREA	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44	615.44
RADIUS	6	7	8	9	10	11	12	13	14	6.5	7.5	6.75	7.25	7.125
BARREL AREA	113.04	153.86	200.96	254.34	314	379.94	452.16	530.66	615.44	132.665	176.625	143.0663	165.0463	159.4041
AREA OF RECTANGLE	502.4	461.58	414.48	361.1	301.44	235.5	163.28	84.78	0	482.775	438.815	472.3738	450.3938	456.0359
LENGTH	41.86667	32.97	25.905	20.06111	15.072	10.70455	6.803333	3.260769	0	37.13654	29.25433	34.99065	31.06164	32.00252
m f(KG/S)	0.0774	0.0783	0.077	0.076	0.0767	0.077	0.0779			0.0781	0.0771	0.0781	0.0783	0.078

2.3.2 CAED Design of Barrel Throttle Body

The various components of the barrel throttle body can be seen in the cut view of the 3-D model as depicted in fig 2.9. These components were then assembled on CAD along with fasteners and were evaluated for any interference. Such procedures help in reducing rework and eliminate unprecedented errors [36] [37] [38]. Also the considerations in the 3-D model are shown in fig 2.10.

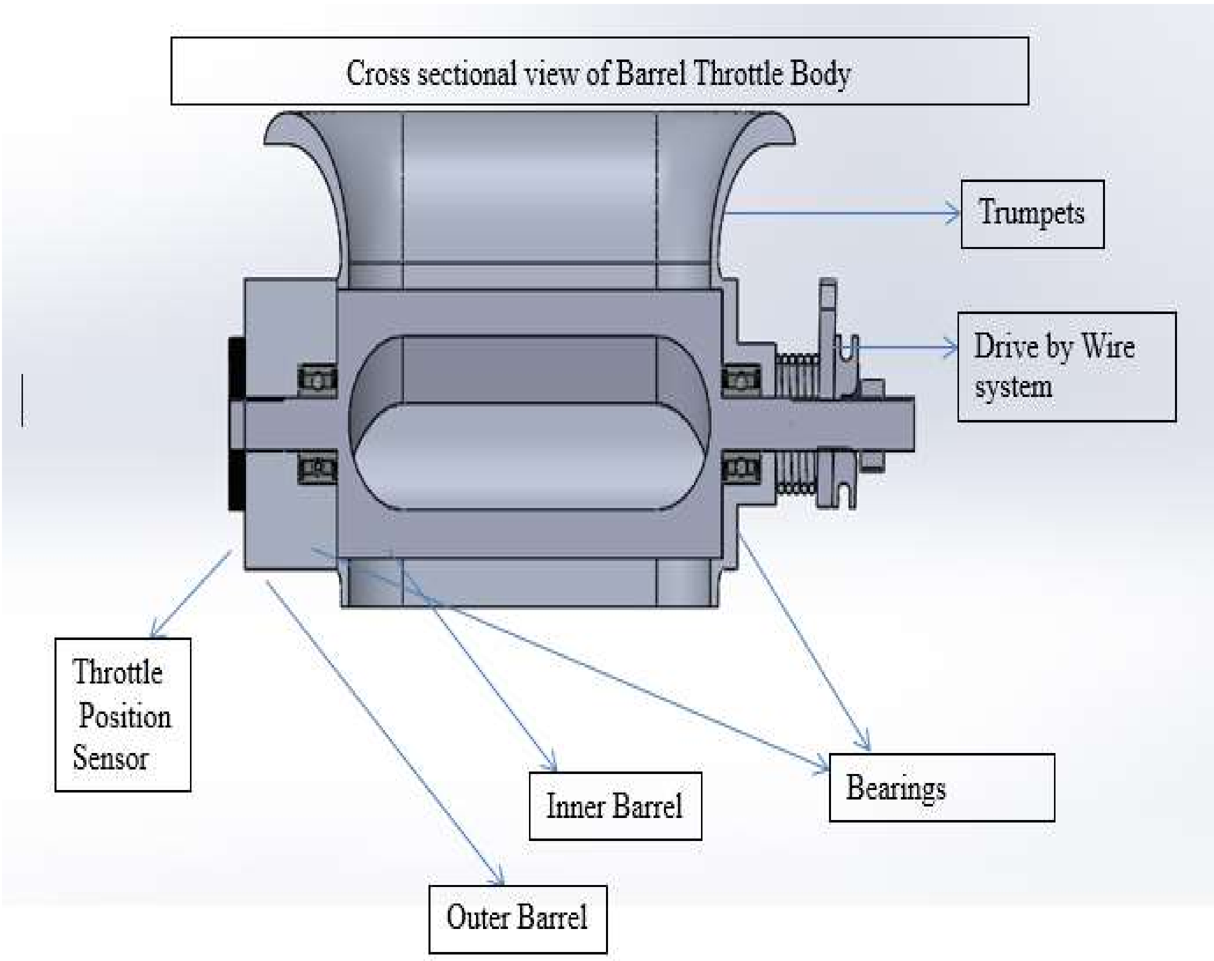


Fig 2.9 Design of barrel throttle body

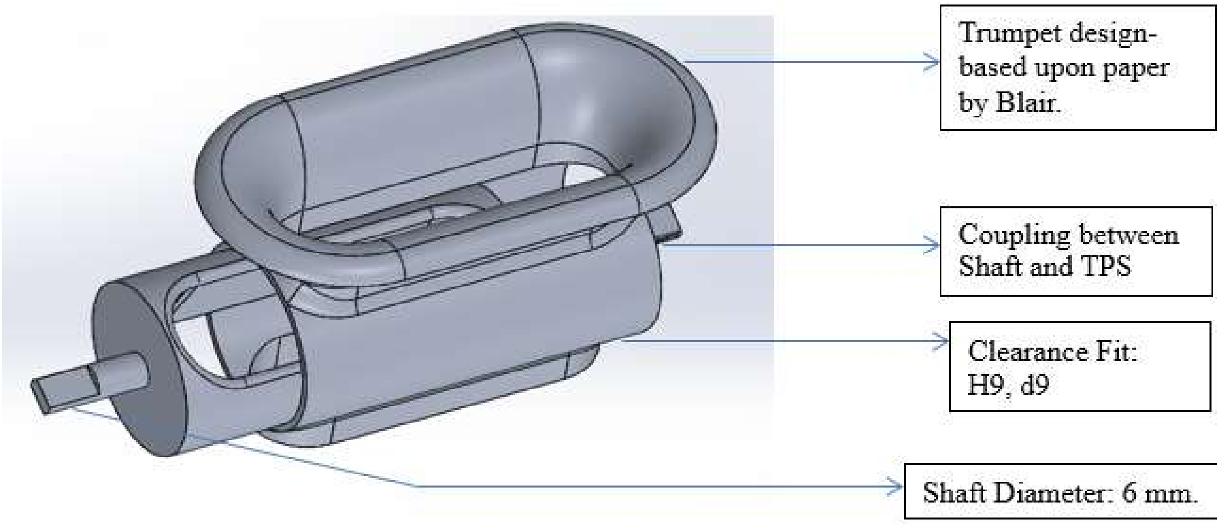


Fig 2.10 Design consideration.

Design constraints while modelling were-

- Clearance fit between the inner and outer barrel [39] [40] [41] [42].
- Shaft diameter was taken as the inner diameter of the most easily available ball bearing diameter [44].
- Trumpet designed in accordance to Blair's best bell article and further analysis for optimization [14].
- Coupling between shaft and Throttle position Sensor (TPS) and the drive by wire system (DBW).

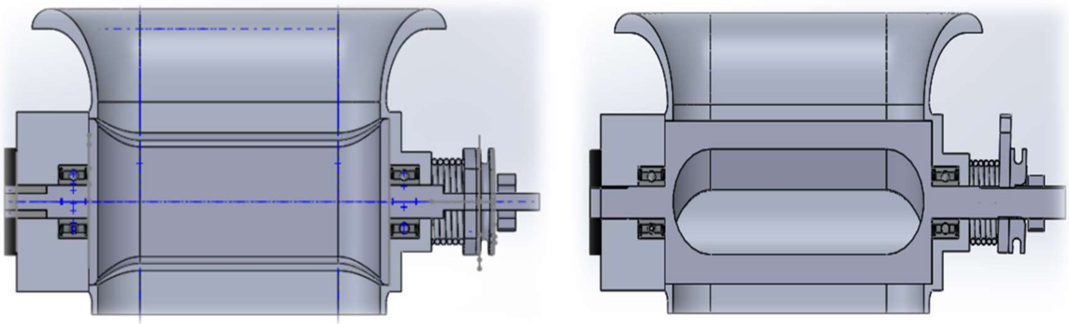


Fig 2.11 Cross sectional view of barrel throttle body

2.3.3 CAED Design of Butterfly Valve Throttle Body

The CAD model of the butterfly valve used for simulation is shown in Fig 2.12. The model was constructed as per the actual butterfly throttle body. The bore dimension of the butterfly was maintained same as the actual butterfly throttle body.

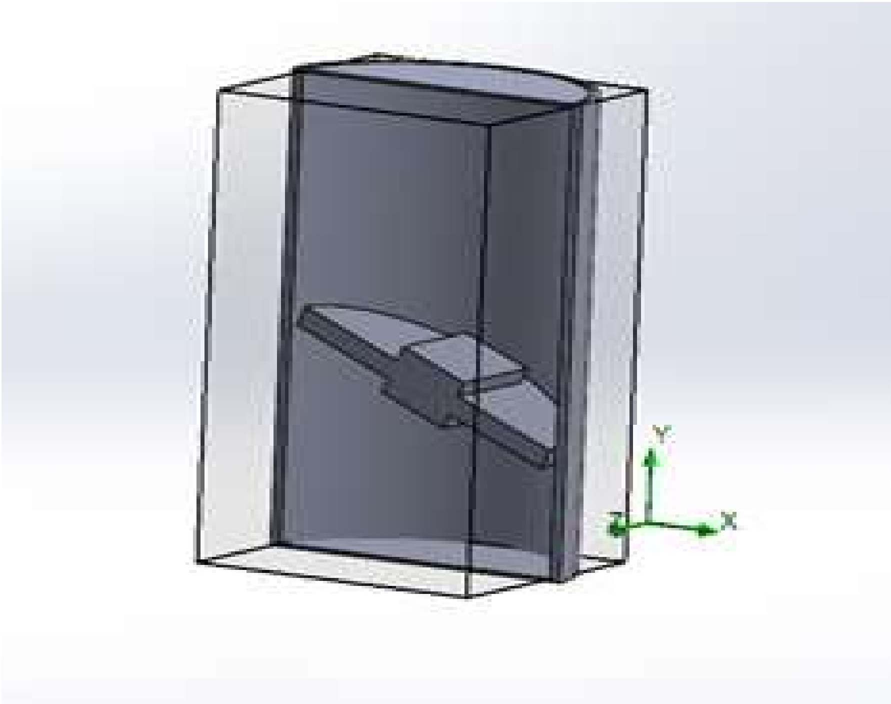


Fig 2.12 Final design of the butterfly throttle body for simulations

2.4 Flow Analysis Using Solidworks Software

The flow trajectory of air through the barrel throttle body can be seen in the figures 2.13 and 2.14. As seen there is no obstruction to air flow as it passes through the throttle body. Also from the figure 2.14 it can be observed that the mass flow rate is .0764. This value was found out when the model was constructed as per the dimensions shown in table 2.

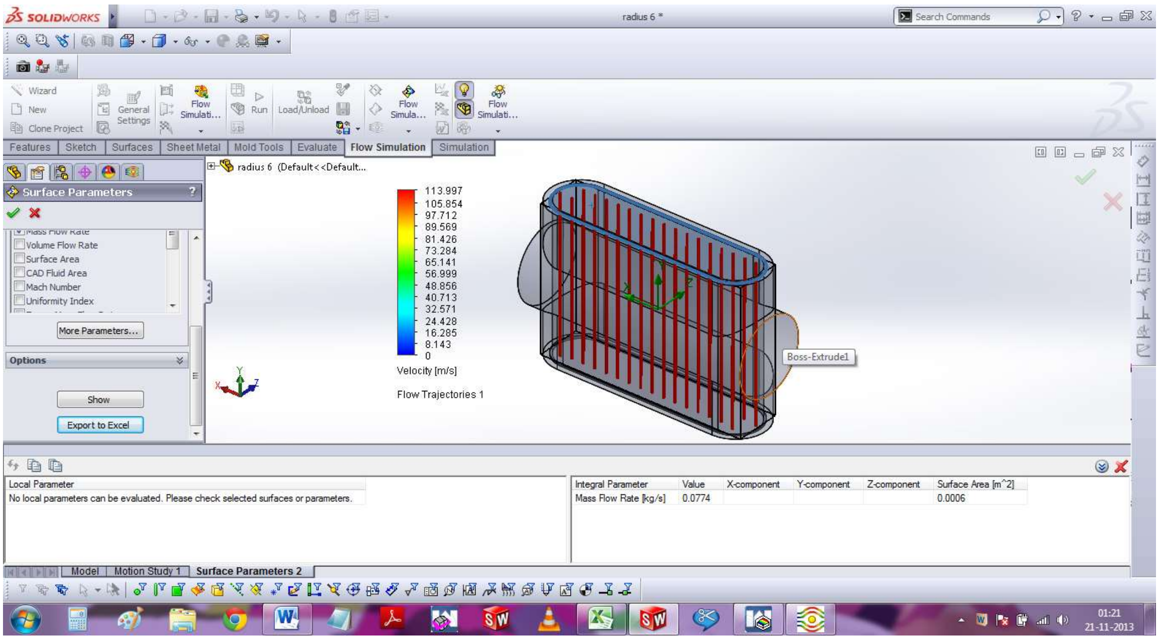


Fig 2.13 Flow trajectory for Barrel throttle body at WOT

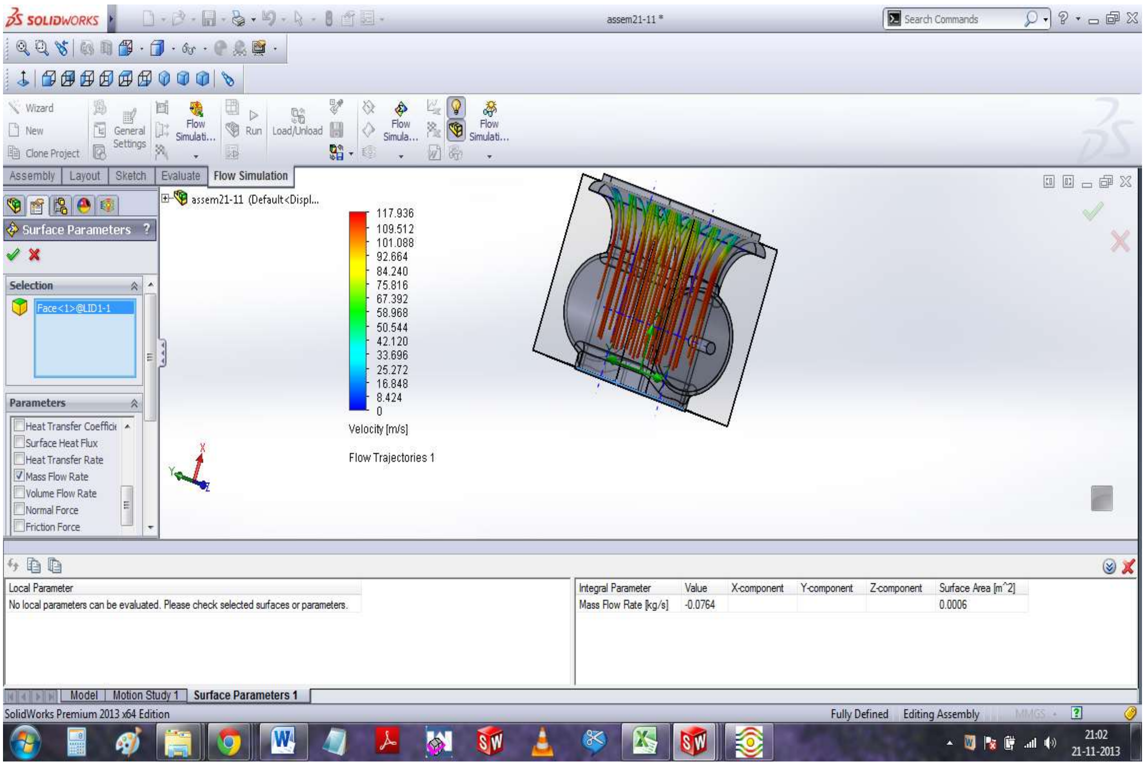


Fig.2.14 Mass flow rate at WOT= .0764 kg/s.

The figures 2.15 and 2.16 show the cut plot of the barrel throttle body at 60 degrees angle. The surface plot in fig 2.16 shows that most of the air flow is through one side of the tube and is as per expectation.

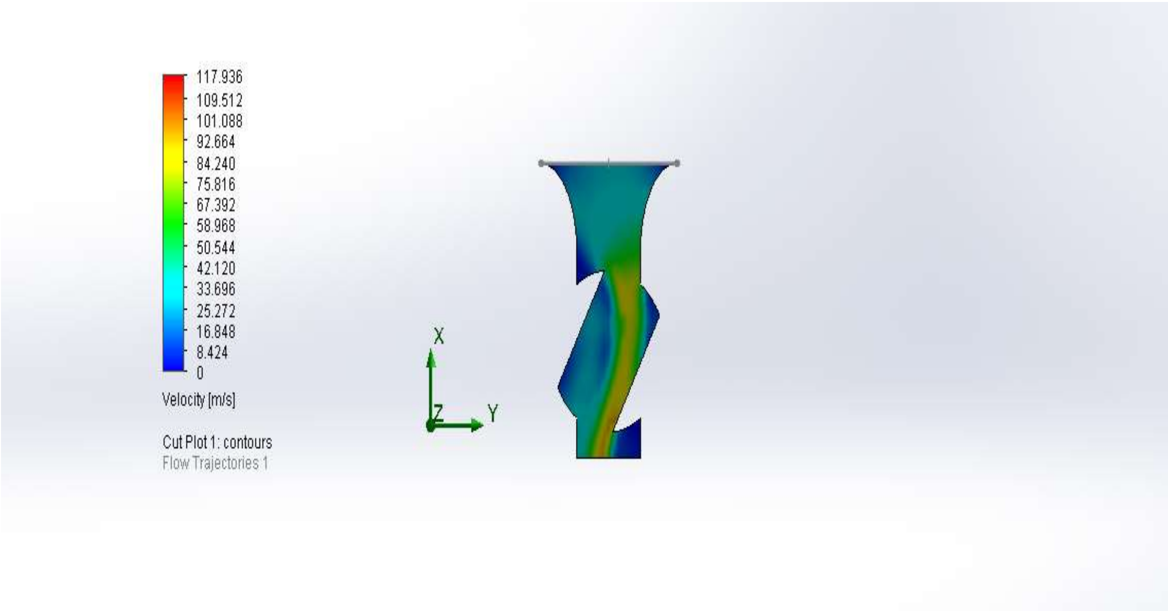


Fig. 2.15Velocity Cut plot analysis for barrel throttle

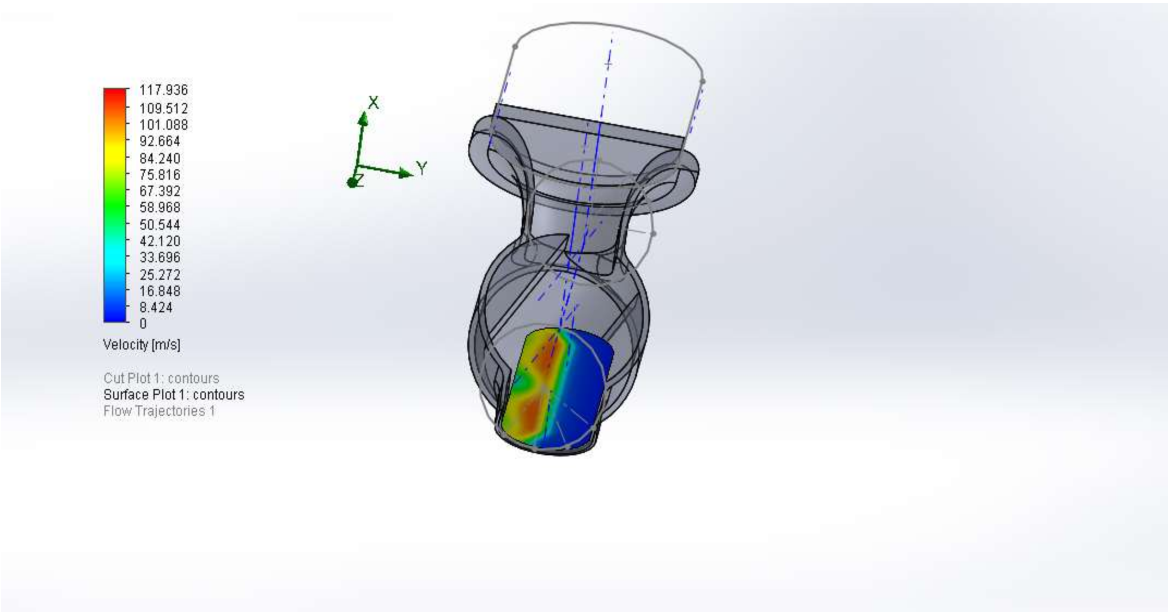


Fig.2.16Velocity surface plot for barrel throttle

As seen in the figure 2.17 the air flow trajectory through butterfly throttle is hindered by the presence of the central shaft. It can be observed from the velocity cut plot in the fig 2.18 that the velocity is maximum at the least cross sectional area.

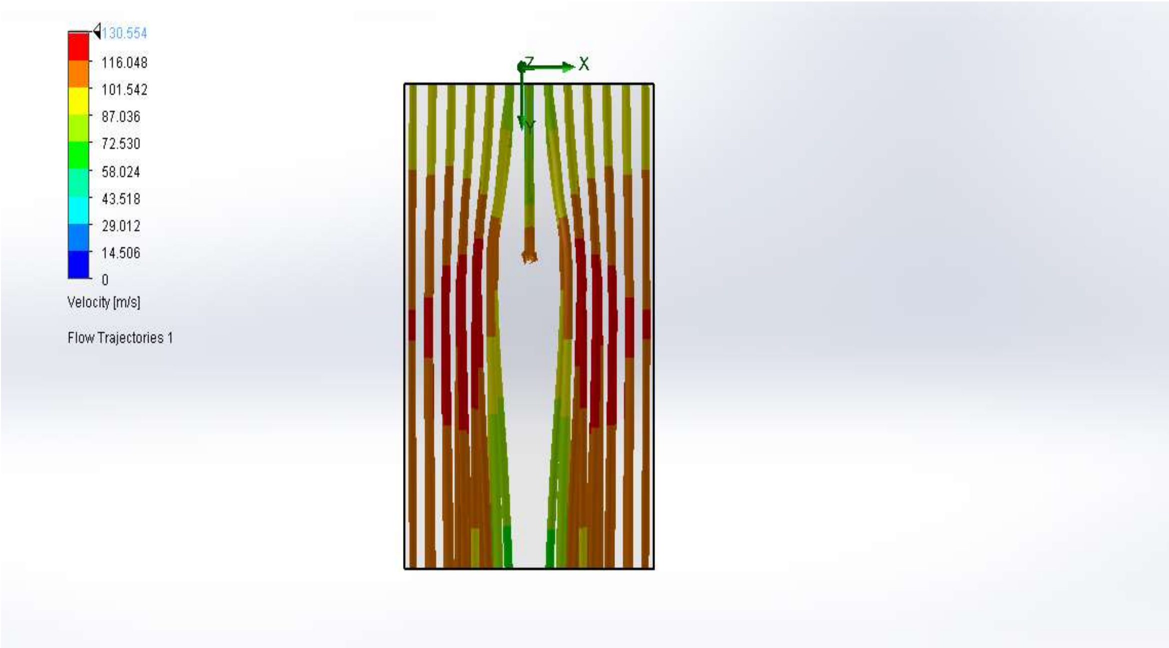


Fig.2.17 Flow trajectory for butterfly throttle

Fig 2.18 Velocity cut plot for butterfly throttle body.

The velocity surface plot in fig 2.19 depicts that the flow is unevenly distributed when the throttle is kept at an angle. The velocity flow trajectory in fig 2.20 shows the velocity to be maximum at the least cross-sectional area and minimum at the maximum possible cross sectional area.

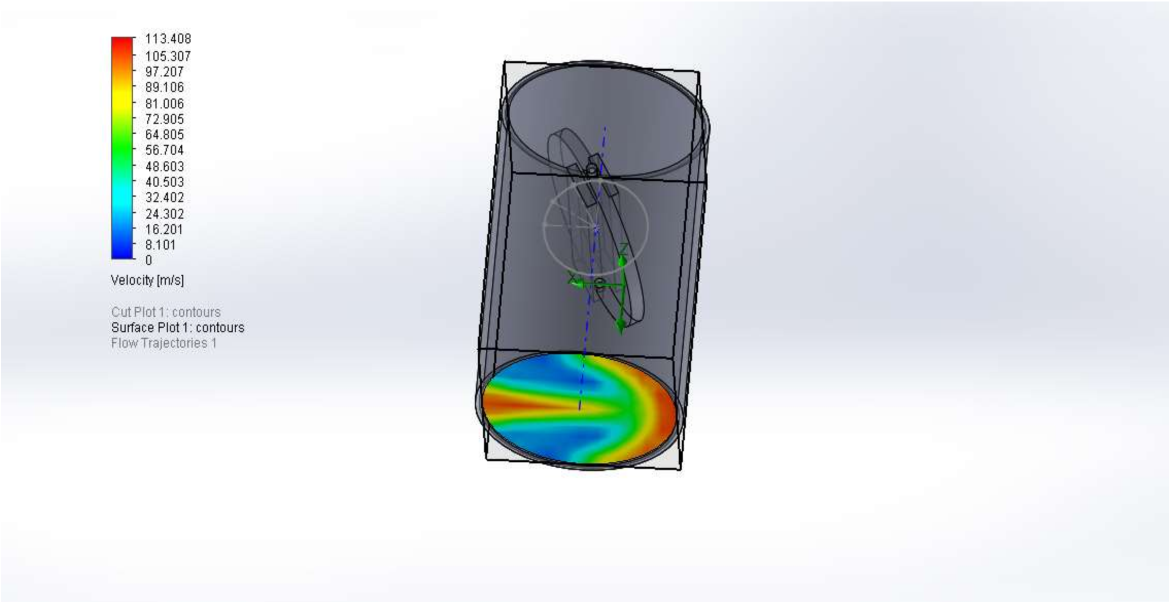


Fig 2.19 Velocity surface plot for butterfly throttle

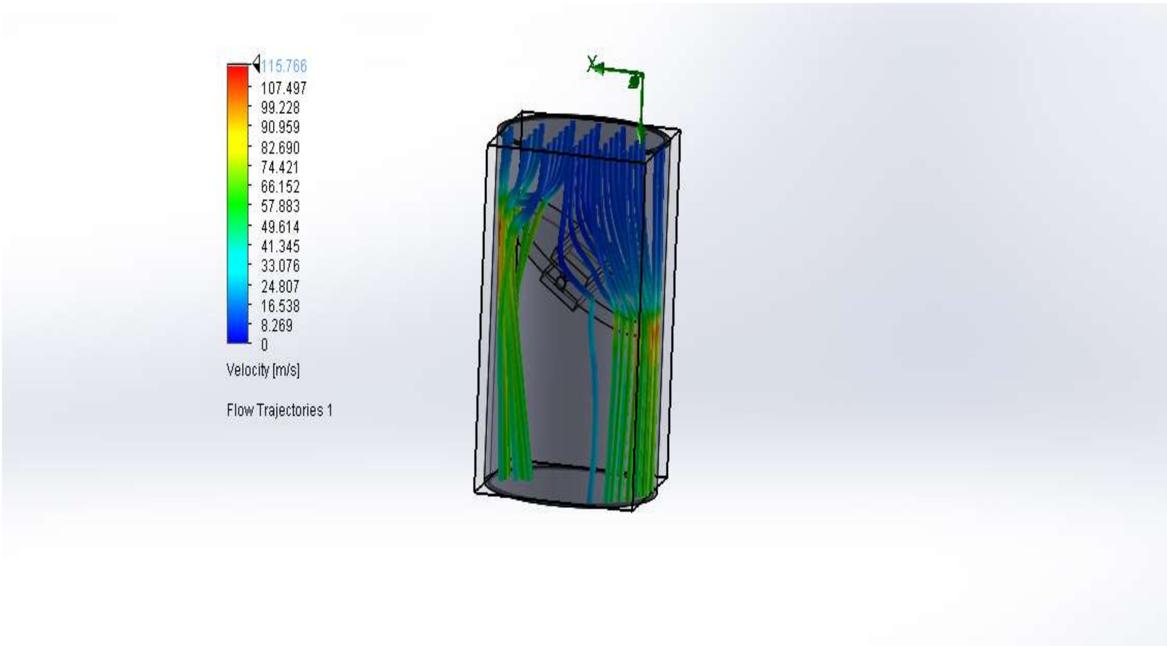


Fig.220 Flow trajectory for butterfly throttle for idling

After conducting numerous analysis, the idling angle for butterfly throttle body was found to be 16 degrees. The mass flow rate at this angle was same as found as the mass flow rate obtained from Ricardo wave at idling speed.

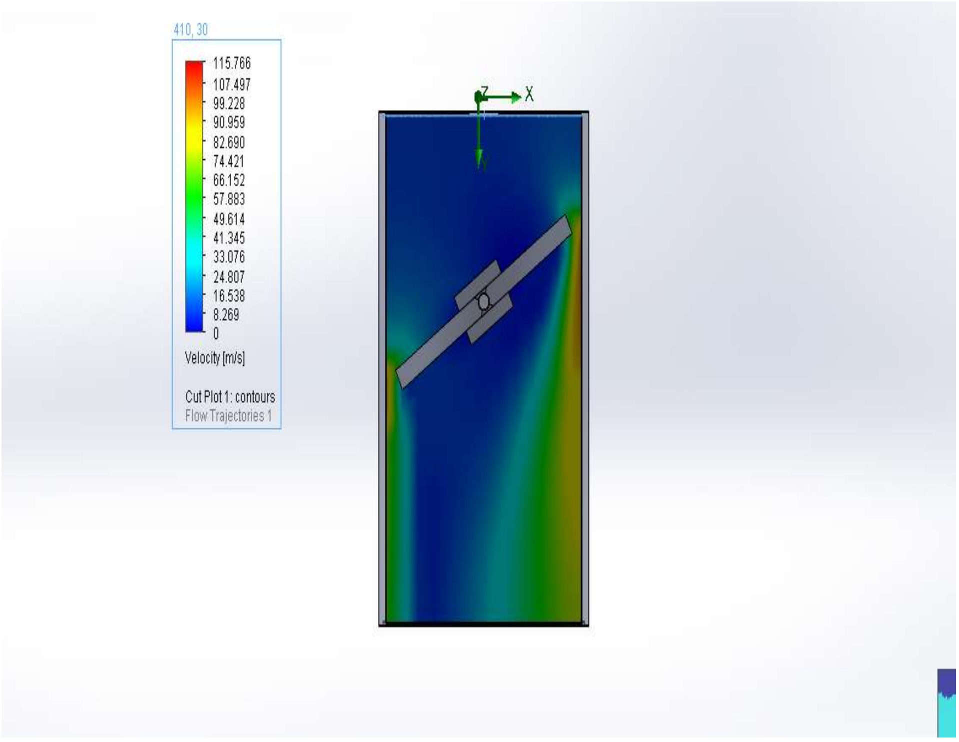


Fig.2.21 Velocity cut plot for Butterfly throttle body at idling angle

2.5 Results from Flow Analysis

At Wide Open Throttle (90 degrees), the results found out for butterfly and barrel throttle bodies are as follows. The barrel throttle body showed massive advantage over the butterfly valve throttle body at wide open throttle (WOT). The results obtained from analysis on Solid works Flow Simulation are shown in the table 3. For the volumetric efficiency calculation, the mass flow rates for butterfly throttle body and the barrel throttle body has derived from the table 3.

Table 2.3: Comparison of the results obtained from Solidworks.

ΔP	ΔP	Mass Flow rate Theoretical (Butterfly)	Mass Flow rate Theoretical (Barrel)
(Inches of water)	(Bar)	(Kg/s)	(Kg/s)
10	0.024917	0.0356	0.0557
11	0.027409	0.0376	0.0574
12	0.029901	0.0392	0.0583
13	0.032393	0.0408	0.0596
14	0.034884	0.0422	0.061

2.6 Volumetric Efficiency Calculations

- Engine speed = 10,000 rpm
- Mass air flow rate for barrel throttle body=0.0422kg/s at ΔP= 14 inches of water (From Table 3).
- Intake air temperature =26 degrees C

Density of air at 26 degrees C= 1.1839 kg/m^3

Equation 1

$$AVF = \frac{MF_k}{d_2}$$

Where:

AVF = Actual volumetric flow rate (m^3 /s)

MF_K = Mass flow rate taken (kg/s)

d_2 = Density of air for the intake air (kg/m^3)

AVF= 0.0422 / 1.1839 = 0.0356 m^3 /s (Butterfly)

Equation 2

$$TAF = \frac{(ED)(rpm)(VE)}{(ES)(C)}$$

Where:

Rpm = maximum design rpm

TAF = Theoretical air flow (m^3 /s)

VE = Volumetric efficiency (100% theoretical)

ED = Engine displacement (cm^3)

ES = Engine stroke (2 for a four stroke engine)

C = Conversion factor from cm^3 to m^3

Solving for TAF:

$$TAF = \frac{(599cm^{3})(10{,}000rpm)(1)}{(2)(100^3\ cm^3/m^3)(60s/min)} = 0.0499m3\ /s$$

Equation 3

$$VE = \left(\frac{AVF}{TAF}\right) \times 100\,\%$$

Where:

VE = Volumetric Efficiency (%)
AVF = Actual volumetric flow rate (ft^3/minute)
TAF = Theoretical air flow rate (ft^3/minute)

Solving for VE:

VE = (0.0356 / 0.0499) *100= **71.34 % for butterfly valve**

For **barrel** throttle body;

Assuming same engine rpm and temperature

Mass air flow rate- 0.0558 kg/s

AVF= 0.0558/ 1.1839 = 0.0471 m3/s

TAF= 0.0499

VE = (0.0471/ 0.0499) *100= 94.38 % for Barrel throttle body

Increase in volumetric efficiency = **23.04 %**

Assuming the other factors on which volumetric efficiency depends, which are-

- Fuel
- Heat Transfer-High Temperature
- Valve Overlap
- Fluid Friction Losses
- Choked Flow
- Closing Intake Valve After BDC
- Intake Tuning
- Exhaust Residual to remain constant.

2.7 Summary

The chapter describes the conceptual design of Barrel Throttle Body which was done using the engine parameter and Butterfly Valve dimensions. The boundary conditions were obtained using Ricardo software which is 1D engine and gas dynamics software and then the CAED models of both throttle bodies were prepared using Solidworks software. Flow analysis was performed on both the throttle bodies to obtain the flow trajectories and mass flow rates. The results obtained were tabulated and compared and then the volumetric efficiency calculations were carried out for both the throttle bodies.

CHAPTER 3

DETAILED DESIGN OF BARRELTHROTTLE BODY

As this particular project is about designing, fabricating and testing the Barrel Throttle Body, firstly the problem statement was analysed thoroughly. Understanding the requirements and the guidelines plays a huge role in the development of the design and selection of the components.

The next step was the most important one and this was to analyse and determine the barrel diameter which was done on software using a set of iterations. Subsequently a component research was done so that the final design of the Barrel Throttle Body should be based on the exact specifications of the components.

Now after all this was done the part designs and part drawings of inner and outer barrels were prepared using the exact specifications and dimensions of the components and finally the assembly of parts was done on the Solid works software.

3.1 Analysis To Determine Barrel Diameters

The minimum diameters of barrels were found out by simulation in such a way that at 0 degree there is no flow of air. The bore diameter was kept 28 mm.

A set of iterations were performed on the software by changing the diameters of the inner and outer barrels to find the minimum inner barrel diameter, such that at fully closed condition there is no flow of air.

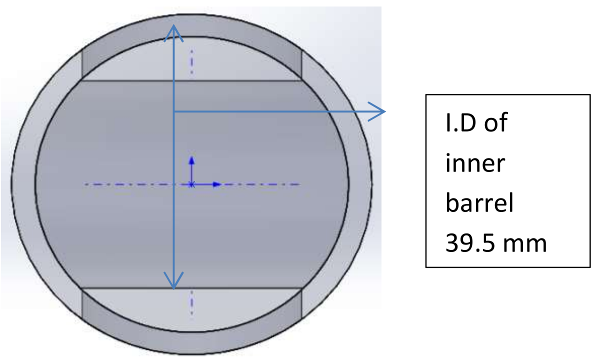


Fig 3.1 Inner barrel diameter

3.2 Component Research

3.2.1 Throttle Position Sensor

A throttle position sensor (TPS) is a sensor used to monitor the position of the throttle in an internal combustion engine. The sensor is usually located on the butterfly spindle/shaft so that it can directly monitor the position of the throttle. In this case the shaft would be a projection of the inner barrel. Hence the diameter of the shaft depends on the TPS.

After extensively searching for a hollow shaft throttle position sensor (TPS), an in-house component shown in fig 3.4 was fixed. The TPS had housing for a shaft of 6 mm. The accurate mounting point of this TPS was found out by CMM.

Fig 3.2 Throttle position sensor

3.2.2 Bearings

Bearings are used to allow relative motion between the inner and outer barrels i.e. to allow the inner barrel to rotate within a fixed outer barrel.

Deep groove sealed roller ball bearings of ID 6mm and OD 10mm were bought for the component. There were two options of bearings: needle or ball bearings [44].

Needle bearings are lighter but can ball bearings are easily available. Deep groove sealed roller ball bearings of ID 6mm and OD 10mm weigh 2g whereas needle bearings of the same size weigh 0.8g. The weight difference between them is not too significant as the overall product weighs around 400g. Hence deep groove sealed roller ball bearings were chosen. Sealed ball bearings were chosen to prevent any dust or other particles in the incoming air to affect the working of the bearings.

3.2.3 Lip Seals

Radial shaft seals, also known as lip seals, are used to seal rotary elements, such as a shaft or rotating bore [32] [33] [34]. They consist of two main parts:

- A cylindrical outer covering of sheet steel (case) or an elastomer that has the requisite interference fit to seal statically against the housing bore.
- A sealing lip made of an elastomeric or thermoplastic material that seals dynamically and statically against the shaft. The lip has a sealing edge that is formed by moulding, cutting or grinding. It is normally pressed against the surface of the shaft, with a defined radial load, by a spring [35]. The spring present in the lip seal can be seen in the cross-sectional view in fig 3.5.
- Lip seal of ID 6mm, OD 9.94mm, thickness 2mm are used.

Fig 3.3 Lip Seals

3.2.4 Circlips

A circlip is a type of fastener or retaining ring consisting of a semi-flexible metal ring with open ends which can be snapped into place, into a machined groove to permit rotation but to prevent lateral movement [46].

There are three basic types: internal, external, E type.

Both external and internal circlips could not be used as they were not available in the 6-10 configurations. Hence we used E circlips of ID 4mm and OD 9.5mm.

3.3 Part Designs and Part Drawings

3.3.1 Inner Barrel

The components designed were assembled on solid works. On evaluation when no interference was found the drawings were made. The individual drawings of the two most critical components are shown in the figures 3.6 and 3.7. It can be seen that the outer diameter of the inner barrel was kept slightly lower than the inner diameter of the outer barrel.

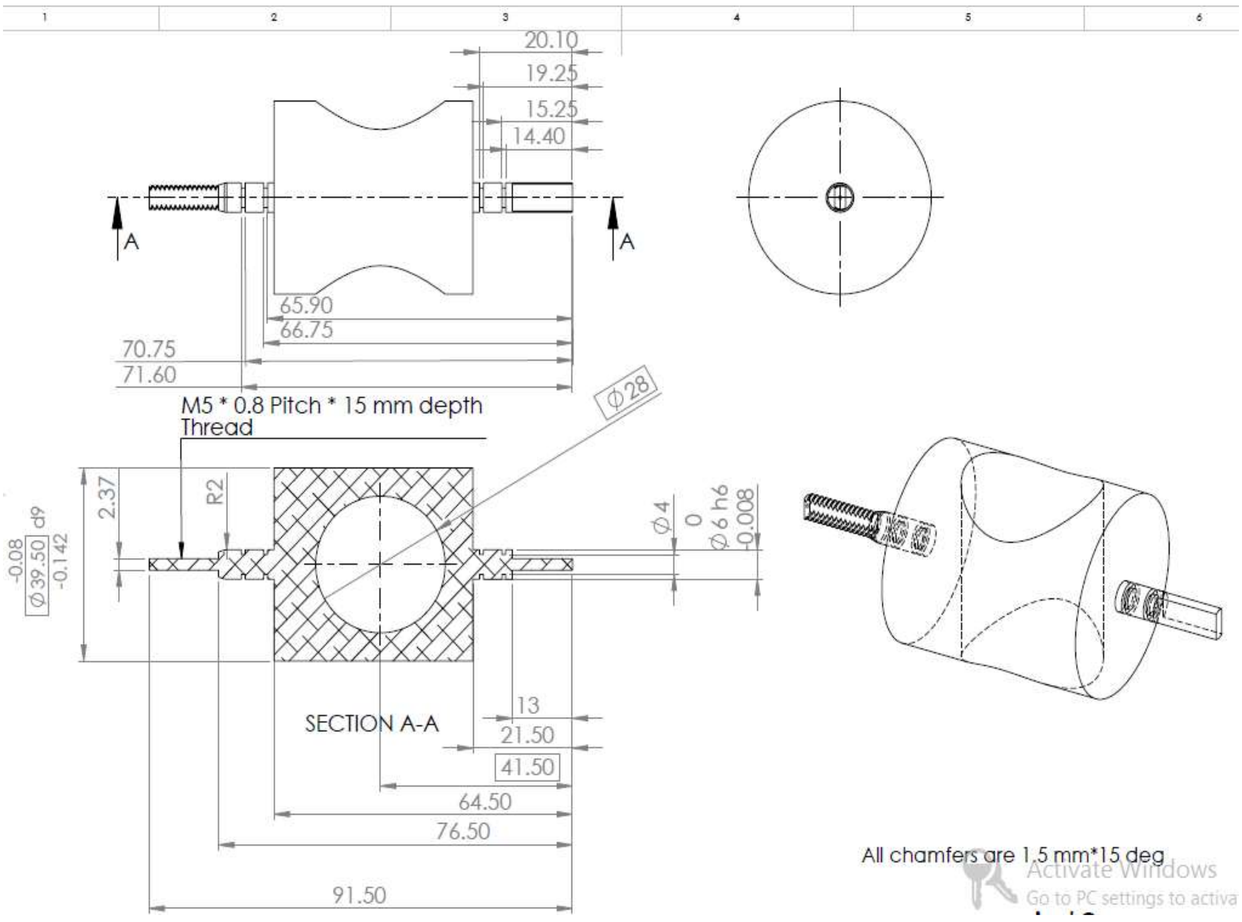


Fig 3.4 Inner barrel drawing

Min. OD of the inner barrel= 39.50mm

Bearing tolerances:

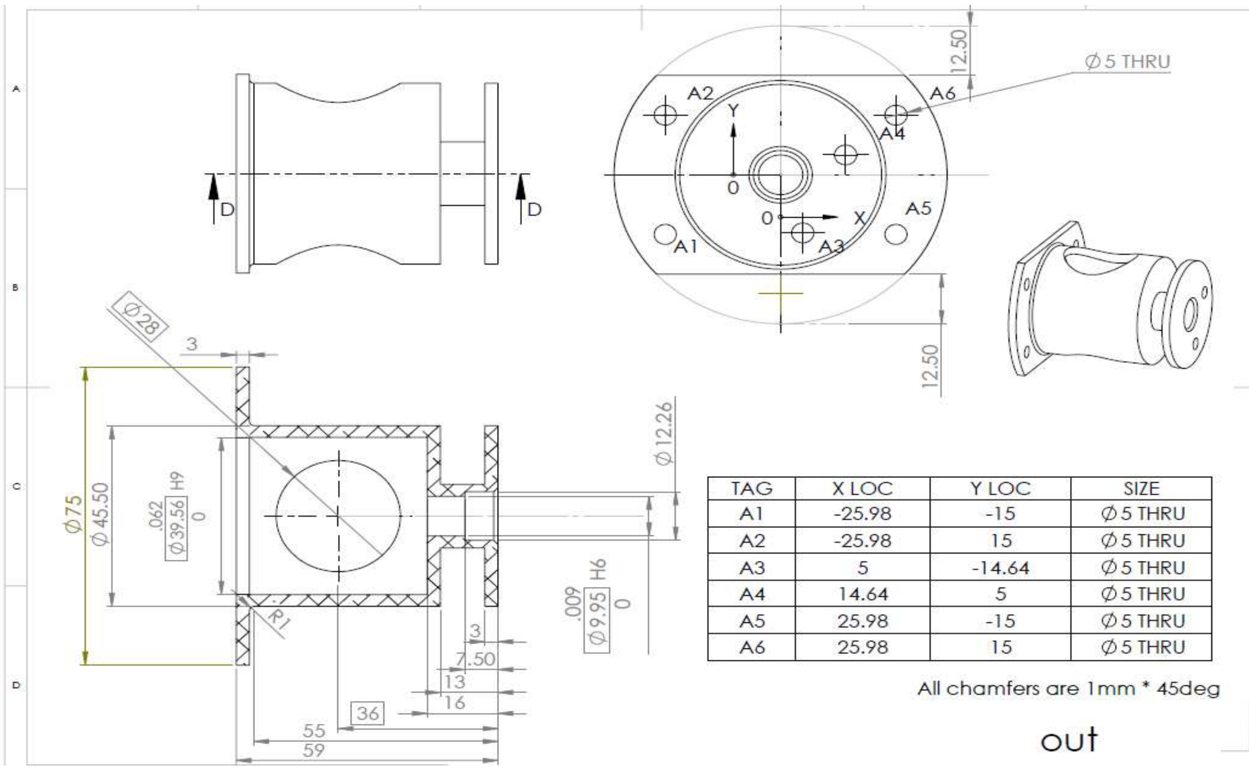
- For static load and inner ring rotating, in case of deep groove ball bearings under 18mm: Shaft tolerance h6 (transition fit) 0 to -8 micron is used.
- For the inner barrel clearance fit d9 is used: -80 to -142 microns. {H9 d9 is a standard fit}

Rotary shaft seals chamfer details for easy installation [32]:

Chamfer angle – 15 degrees

Chamfer length (for shafts up to 10mm) - 1.3mm

3.3.2 Outer Barrel



TAG	X LOC	Y LOC	SIZE
A1	-25.98	-15	Ø 5 THRU
A2	-25.98	15	Ø 5 THRU
A3	5	-14.64	Ø 5 THRU
A4	14.64	5	Ø 5 THRU
A5	25.98	-15	Ø 5 THRU
A6	25.98	15	Ø 5 THRU

Fig 3.5 Outer barrel drawing

Min. OD of the inner barrel= 39.50mm.

Bearing tolerances:

- For static load and inner ring rotating, in case of deep groove ball bearings under 18mm: Hole tolerance h6 (transition fit).
- For the outer barrel clearance fit H9 is used: 62 microns to 0 microns. {H9 d9 is a standard fit}

The final assembly of components along with the sensor on solid works is shown in fig 3.9. The exploded view provides a better idea of the various components involved in the assembly along with the fasteners.

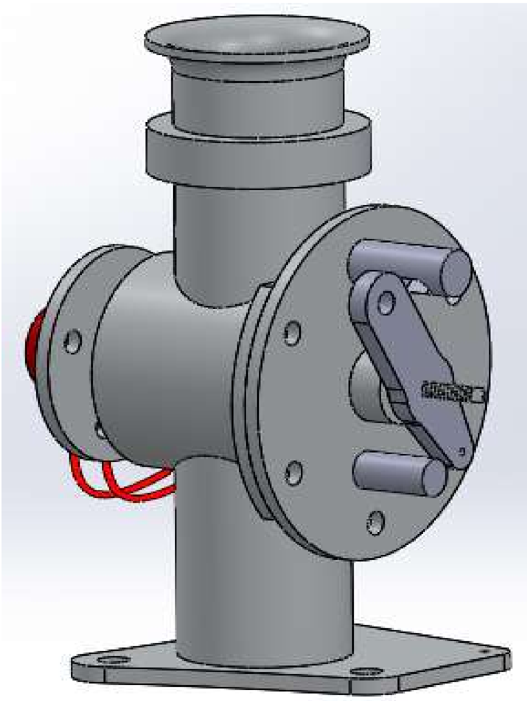


Fig 3.6 Final assembly of components on Solidworks.

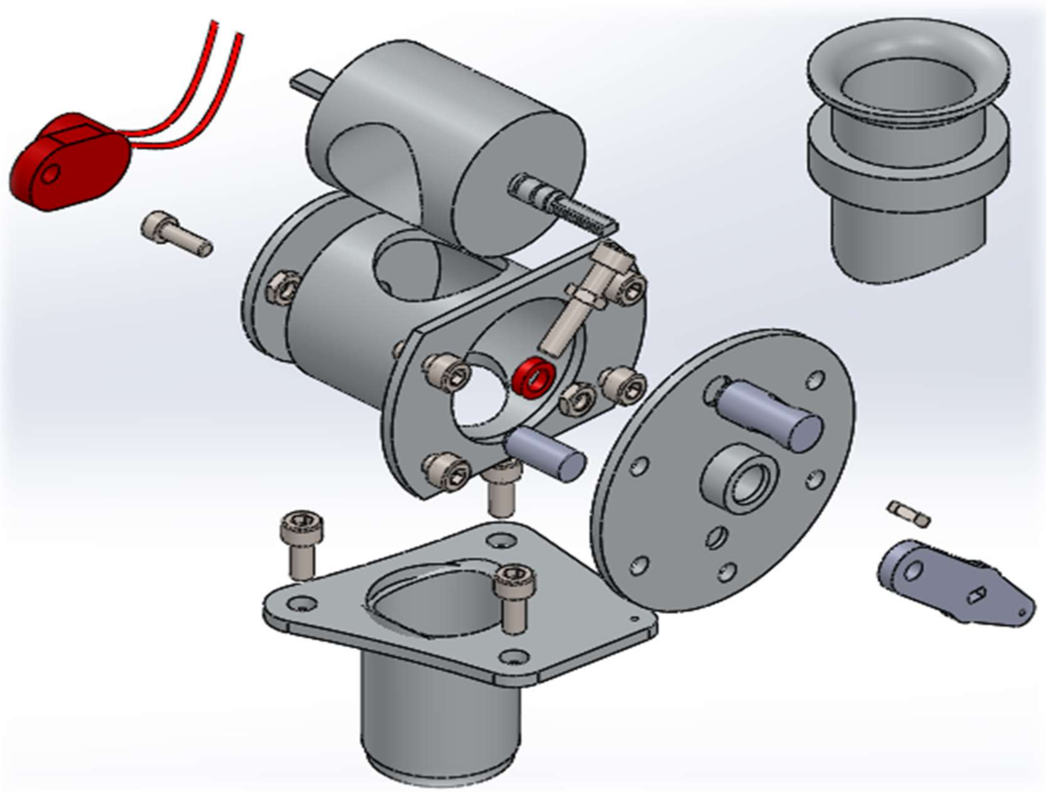


Fig 3.7. Exploded View of the Assembly

3.4 Summary

The chapter describes the detailed designing procedure which was carried out keeping in mind the design constraints and the problem statement. It includes the determination of the barrel diameter through analysis and the component research which was done for the ease of designing. Different components were selected as per the requirement and hence based on their dimensions the part design and part drawings were made. Also the parts were assembled on the designing software Solidworks.

CHAPTER 4

FABRICATION OF BARREL THROTTLE BODY

Manufacturing the components as per the drawings was a challenge and was a critical part of the project. In order to achieve comparable results between the analytical and the experimental analysis, the manufactured model had to be dimensionally close to the manufactured model. Various methods of manufacturing were devised. The final method chosen was based upon the cost and ease of manufacturability [36] [37] [38] [43].

4.1 Possible manufacturing methods

The team devised there were three feasible ways to fabricate the components designed on Solidworks.

1) Rapid Prototyping (RPT)-Advantages-
   Easy to manufacture, Speed, Flexibility, No further machining process required, cost.
   Disadvantages- Rework is not applicable, Low tolerances, COST ($1/cm3).
2) CNC machining-
   Advantages- High tolerances met, good finish
   Disadvantages- Operation, cost, time.
3) Turning, DRO drilling and Milling, Grinding-
   Advantages- Cost saving, easy accessibility, high tolerances met, good finish achieved.
   Disadvantage- Time consuming.

Process decided: Turning, Drilling, Milling and Grinding (Based upon available resources and cost reduction).
Material Used: Aluminum commercial grade.

4.2 Fabrication of Parts

4.2.1 Fabrication of Inner Barrel

The inner barrel was turned on a conventional lathe. The inner barrel had provision to couple the motion of the actuator for throttling action and to the sensor. The through bore for the barrel was reamed out. A slight transition fit was desired between the inner and outer barrel to prevent air leakages and was achieved through grinding. Further since air flow was dependent on the surface roughness of the passage, the grinding process rendered smooth surfaces. Bearings fit and e clips grooves were also incorporated.

4.2.2 Fabrication Of Outer Barrel

The outer barrel was turned out of an aluminium block. The outer barrel had mounting holes of the throttle position sensor and the covering plate. Again the outer barrel was ground internally to obtain transition fit as desired between the inner and outer barrel.

While welding the bell to outer barrel, certain portions were encountered where the welding torch could not reach. Hence the design was slightly modified so that the torch could have accessibility to weld [29] [30] [31]. The inaccessible portions can be clearly seen in the fig 4.1.

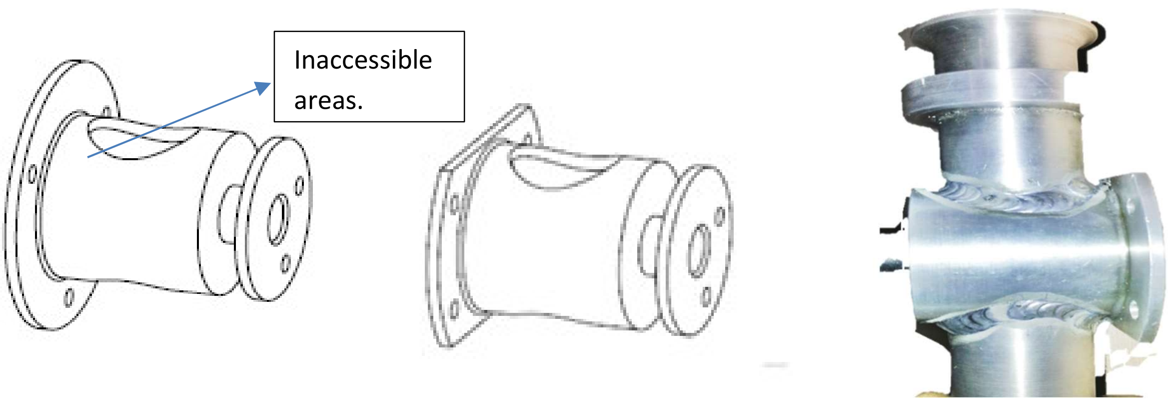


Fig 4.1 The original design v/s modified design of the outer barrel to allow accessibility of the welding torch.

4.2.3 Fabrication Of Mounting Plate

The mounting plate was machined using water jet (4000 bar).

A water jet cutter, also known as a water jet or water jet, is an industrial tool capable of cutting a wide variety of materials using a very high-pressure jet of water, or a mixture of water and an abrasive substance.

Water jet was used as it does not create burrs and can create holes of even 1.5 mm diameter present on the plate. Because of the high level of force used, thin, small, parts do not fare well.

The disadvantage of water jet is that low positional accuracy (0.75mm) and low repeatability (0.16mm) leading to high variations in dimensions of small slots.

4.2.4 Fabrication Of Actuator

The slot in the actuator could only be manufactured through unconventional processes, hence water jet or laser were the possible methods.

A couple of samples cut out at Magod Laser through water jet cutting did not yield the desired results. The slot dimensions being too small water jet cutting, laser cutting yielded perfect results. The actuator was cut using a CO_2 laser at Goodwill Industries, Peenya. Laser cutting works by directing the output of a high-power laser, by computer, at the material to be cut. The material then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. [24] [25] [26].

Laser cutting was used to obtain the 3x5 slot on the actuator.

4.2.5 Fabrication Of Bell, Covering Plate, Pipe

The bell was machined on a conventional lathe and continuously checked on a radius gauge. The covering plate and pipe were also manufactured through the same machining process. Laser cutting provided the profiles for welding the pipe and bell.

4.3 Welding

Some of the components were welded together using aluminium TIG welding. Gas tungsten arc welding, also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld [29]. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapours known as a plasma [30] [31]. Some of the unprecedented difficulties during the welding process called for slight rework on the model. Some of the weld edges were beyond the reach of the welding torch. Slight alterations to the design ensured that this was overcome.

4.4 Finishing Process

The finishing processes used to achieve the smooth surface were achieved through grinding. Smooth surfaces offer less resistance to air flow. Fig 4.2 compares the solid works model with the actual model.

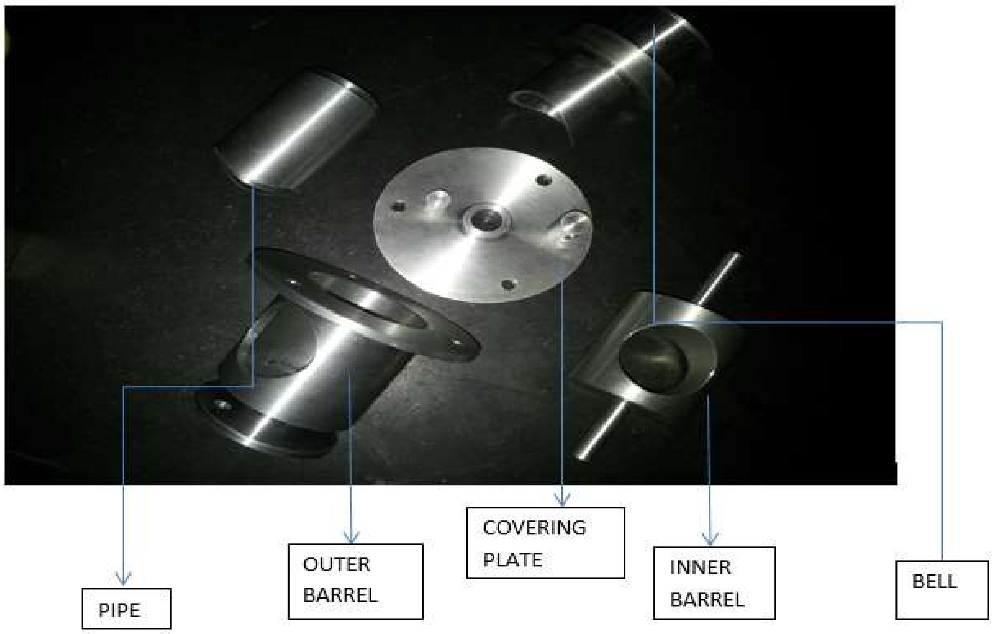


Fig 4.2 Manufactured Components

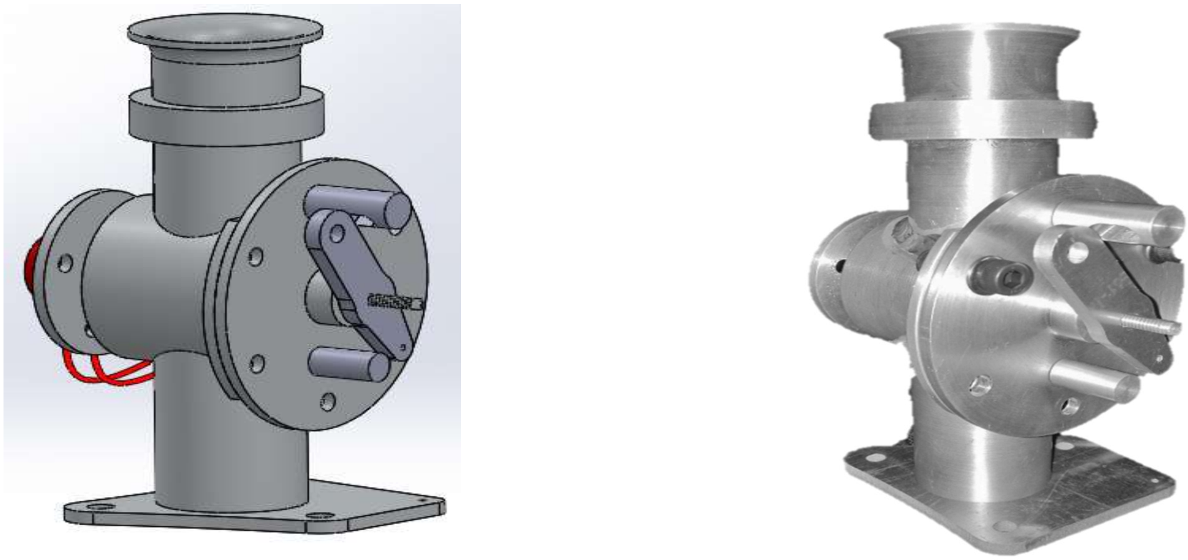


Fig 4.3 Assembly on Solidworks: Actual assembly

4.5 Summary

The chapter describes the fabrication of different parts using different fabrication processes. The fabrication of inner barrel was done taking into consideration the bearing fir and the e clip grooves. The outer barrel was machined to obtain transition fit as desired between the inner and outer barrel. The mounting plate and actuator were machined using water jet. Then the parts were welded together using aluminium TIG welding.

CHAPTER 5

TESTING OF THE BARREL THROTTLE BODY ON FLOW BENCH

In order to carry out the final testing the Barrel Throttle Body was taken to an air flow bench. The orifice size was much larger than barrel housing size. Hence an adapter tube was manufactured out of acrylic sheet and nylon [19]. The different parts of adapter tube were assembled using glue to make sure it was leak proof. The flow bench used for the experiment was a Superflow make SF-120 model. The specifications of the model are shown in table 4.

Finally the testing was carried out using the boundary conditions. The percentage flow and volume flow rate was noted down from the graph set provided. The testing was done with and without the air filter. Various iterations were conducted by changing the pressure differential.

5.1 Flow Bench Equipment

5.1.1 Specifications: SF-120

Table 5.1: Specification of flow bench

Calibration test pressure	10" of water
Range	0-185 cfm
Capacity	160 cfm @ 10" of water
Power	120 VAC, 15 A
Weight	100 lbs (46 kg)
Maximum Pressure	15” of water

Fig 5.1 Flow bench apparatus at RED ROOSTER

5.1.2 Need, Design and Manufacturing of Adapter Kit

An adapter tube is a necessity when using a flow bench. The orifice size on the bench was found to be 70 mm which is much larger than the barrel housing size. Hence an adapter tube was manufactured out of acrylic sheet and nylon. Acrylic sheet was used since it was specified by the engineers at “RED ROOSTER PERFORMANCE”.

DESIGN

The adapter tube was machined in 3 different parts:

1) Upper plate
2) Pipe
3) Lower plate

The parts were then assembled together using glue (araldite) to ensure it was leak proof and is shown in the fig 5.2. The lower mounting plate had holes aligned with respect to the holes on the flow bench rig. Similarly the upper mounting plate had holes aligning with the mounting of the throttle bodies. Since both the barrel and the butterfly had same mounting holes, the same adapter kit could be used for both the systems.

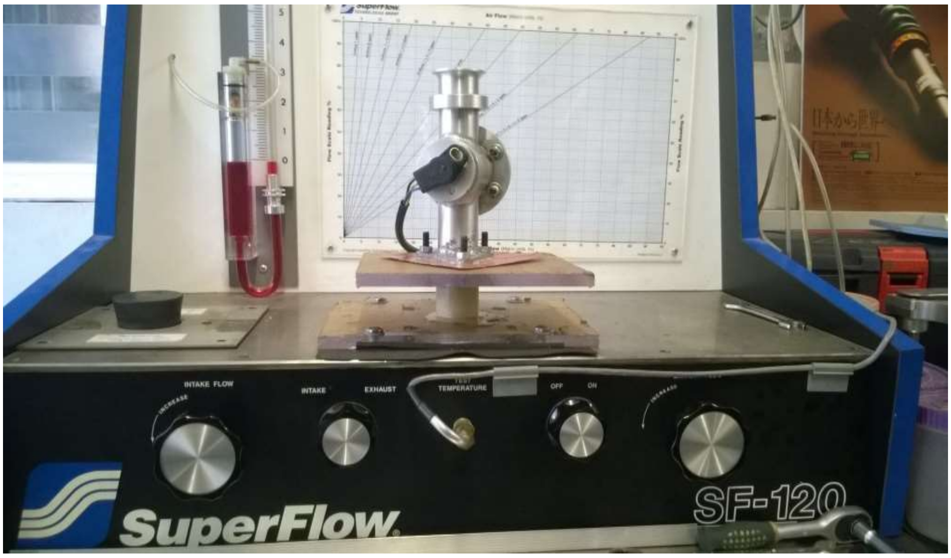


Fig 5.2 The Barrel Throttle being tested on the flow bench.

5.2 Testing Procedure

The maximum pressure drop permissible at the flow bench apparatus was found to be 15 inches of water which is 0.0373 bar. This was well within the boundary conditions at which the simulations were earlier conducted which was 14 inches of water and hence the experiment was run without any difficulty.

The flow bench equipment consists of a compressor, an “inclined percentage of flow” indicator. The inclined percentage of flow tube provides with the possible scope of improvement and is a measure of the existing flow to the maximum possible flow rate for the given pressure drop. The red liquid used in the manometer had a specific gravity of 0.826.

Firstly start the machine and set up the pressure differential to as desired. Note down the percent flow and locate the value for volume flow rate on the graph set provided with along the equipment corresponding to the number of orifices open. The graph is shown in the fig 5.3.

The experiment was conducted even gave conclusive results about the obstruction to flow offered by the air filter. Difficulties in setting up the exact angles apart from the wide open and closed positions prevented the experiment from being carried out on other angles. Various iterations were conducted by changing the pressure differential.

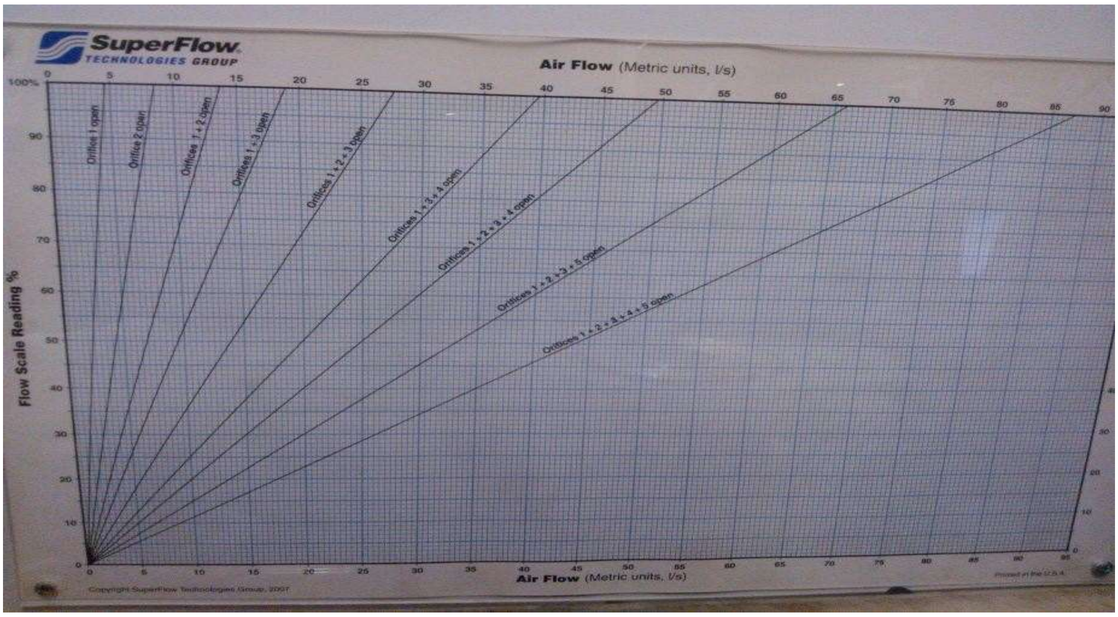


Fig 5.3 The graph used for reading the volume flow rate. (L/s)

5.3 Summary

The chapter describes the testing procedure of the Barrel Throttle Body on the flow bench. It also includes the specifications of the flow bench which was used for the testing. Since the orifice size was much larger than the size of barrel housing, hence an adapter tube was manufactured and it was made sure that it is leak proof. Finally testing was carried out with and without air filter and the results were noted down.

CHAPTER 6

RESULTS AND DISCUSSIONS

The results obtained from the flow bench experiment provide a better understanding of the obstruction offered by the "Butterfly throttle body shaft" and by the air filter. With the help of these results we can quantify the advantage of the "Barrel throttle body" over the "Butterfly throttle body". The experiment temperature: 26 Celsius.

6.1 Butterfly Type Throttle body- Theoretical analysis results v/s Experimental Analysis

Table 5 compares the actual mass flow rate and the analytical mass flow rates for butterfly throttle body. It can be seen from fig 6.4 that the percentage difference between is two is consistent.

Table 6.1: Butterfly Type Throttle body

ΔP (Inches of water)	ΔP (Bar)	Percentage of flow	Volume flow rate (L/s)	Mass flow rate Theoretical (Kg/s)	Mass Flow rate Actual (Kg/s)	Percentage difference-Butterfly
10	0.024917	70	34.5	0.0359	0.040848	13.78272981
11	0.027409	74	36.5	0.0376	0.043216	14.93617021
12	0.029901	78.7	38	0.0392	0.044992	14.7755102
13	0.032393	81	40	0.0408	0.04736	16.07843137
14	0.034884	84	41	0.0422	0.048544	15.03317536
14 (With Air filter)	0.034884	76	37		0.043808	

6.2 Barrel Type Throttle body- Theoretical analysis results v/s Experimental Analysis

Table 5 compares the actual mass flow rate and the analytical mass flow rates for barrel throttle body. It can be seen from fig 6.3 the percentage difference between is two is varies between 8 to 16 %.

Table 6.2: Barrel Type Throttle body

ΔP (Inches of water)	ΔP (Bar)	Percentage of flow	Volume flow rate (L/s)	Mass flow rate Theoretical (Kg/s)	Mass Flow rate Actual (Kg/s)	Percentage difference-Barrel
10	0.024917	80	39.5	0.0557	0.046768	16.03591
11	0.027409	84	41.5	0.0574	0.049136	14.39721
12	0.029901	87	42.5	0.0583	0.05032	13.68782
13	0.032393	90	44.5	0.0596	0.052688	11.60473
14	0.034884	93.5	47	0.061	0.055648	8.77377
14 (With air filter)	0.034884	81	40		0.04736	

From the figures 6.1 it can be seen that the actual mass flow rate is lesser than the analytical mass flow rate, which is expected.

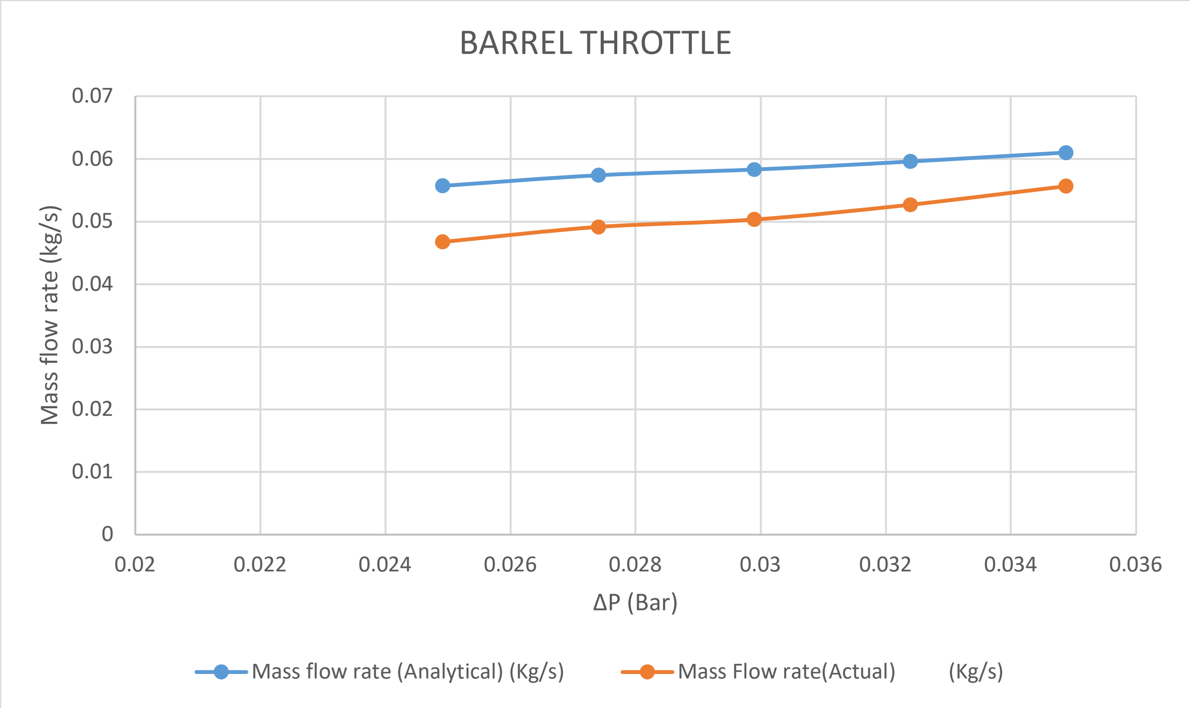


Fig 6.1 Theoretical v/s actual mass flow rate-Barrel

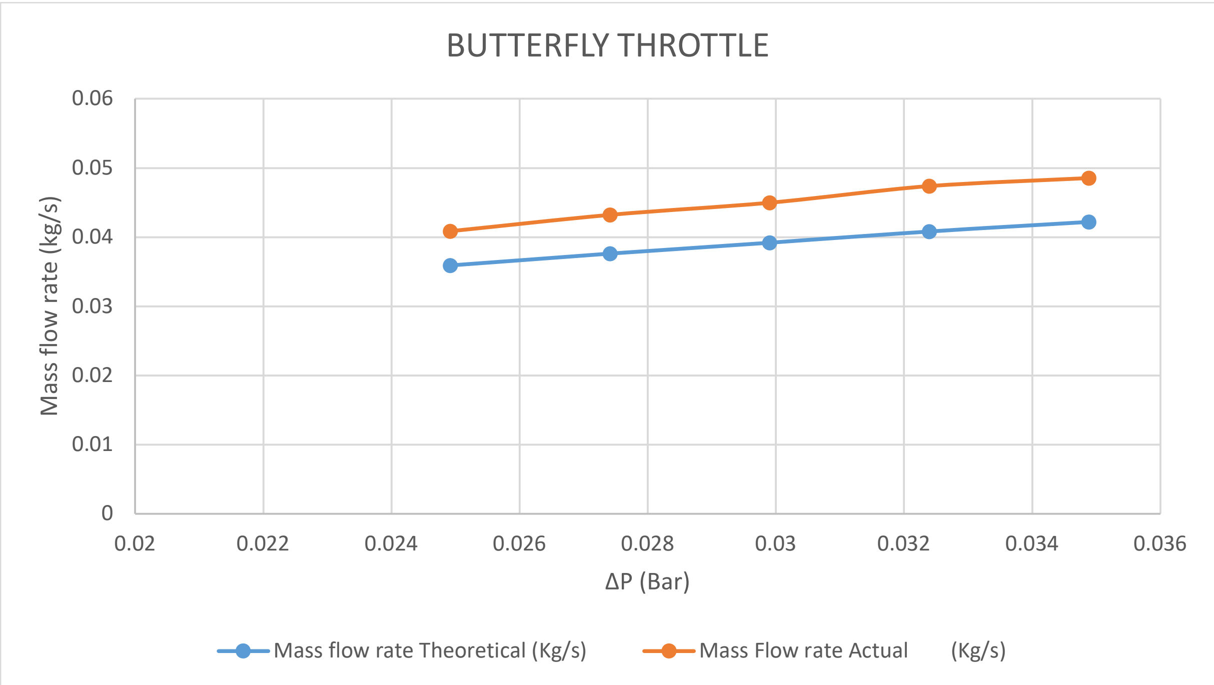


Fig 6.2 Theoretical v/s actual mass flow rate-Butterfly

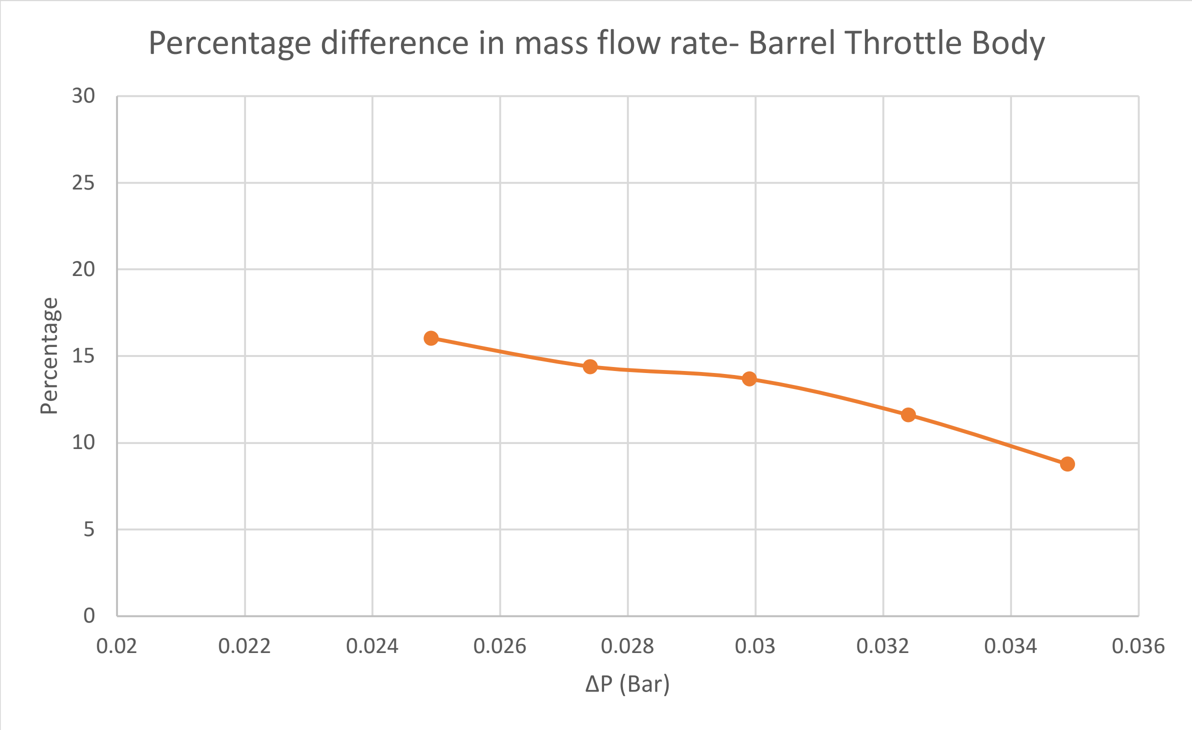


Fig 6.3 Percentage difference between Actual mass flow rate & Theoretical Mass flow rate- Barrel throttle

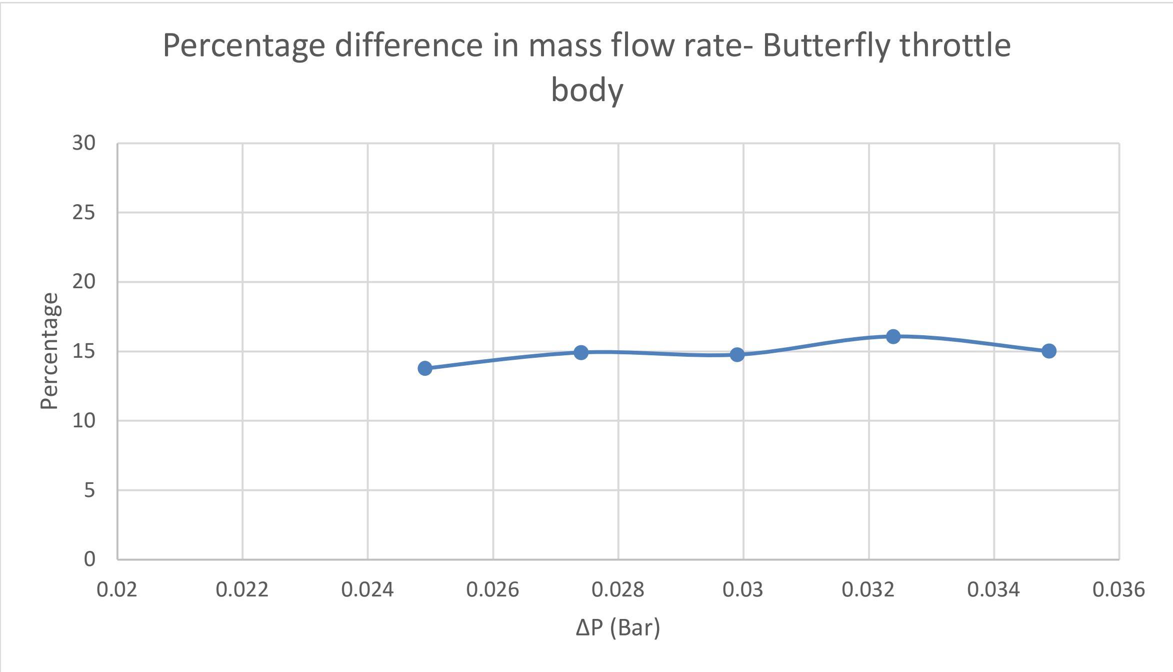


Fig 6.4 Percentage difference between Actual mass flow rate & Theoretical Mass flow rate- Butterfly Throttle

Table 7 shows that there a consistent increase in mass flow rate when comparing barrel with butterfly throttle. From the figures 6.5 and 6.6, both analytical as well as actual results show that the barrel throttle performs better than butterfly throttle. Fig 6.7 shows the improvement to be varying between 11-14%.

Table 6.3: Comparison of actual mass flow rate of barrel v/s butterfly

ΔP (Inches of water)	Volume flow rate-Barrel (L/s)	Volume flow rate-Butterfly (L/s)	% improvement
10	39.5	34.5	14.49275
11	41.5	36.5	13.69863
12	42.5	38	11.84211
13	44.5	40	11.25
14	47	41	14.63415

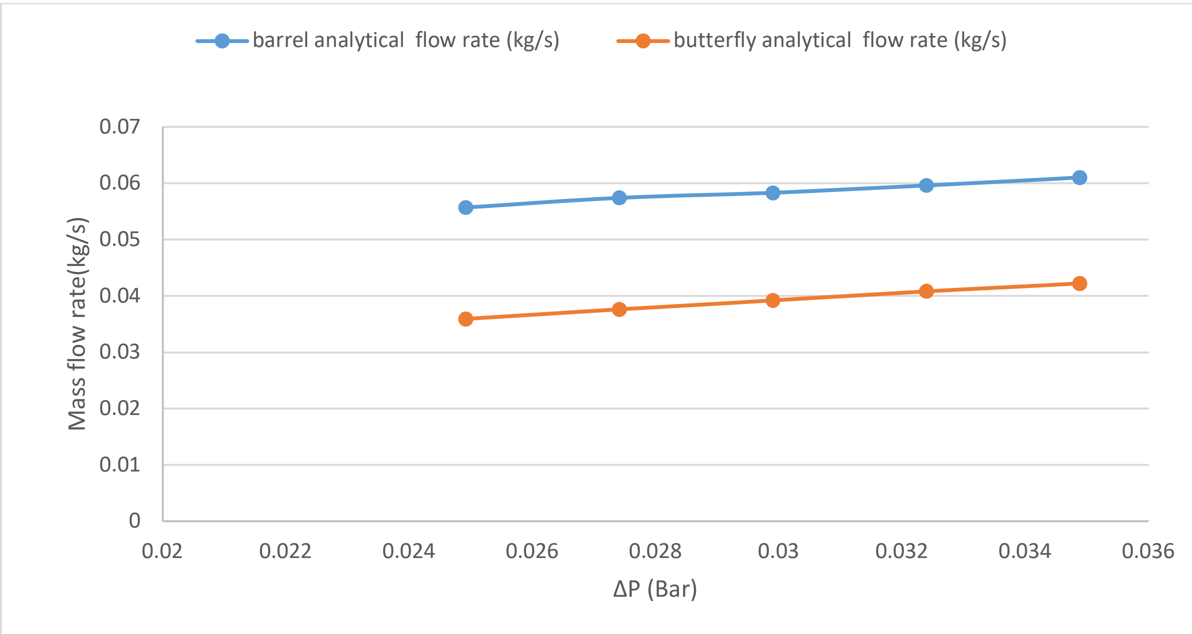


Fig 6.5 Comparison between theoretical Mass flow rates of Barrel & Butterfly throttle bodies.

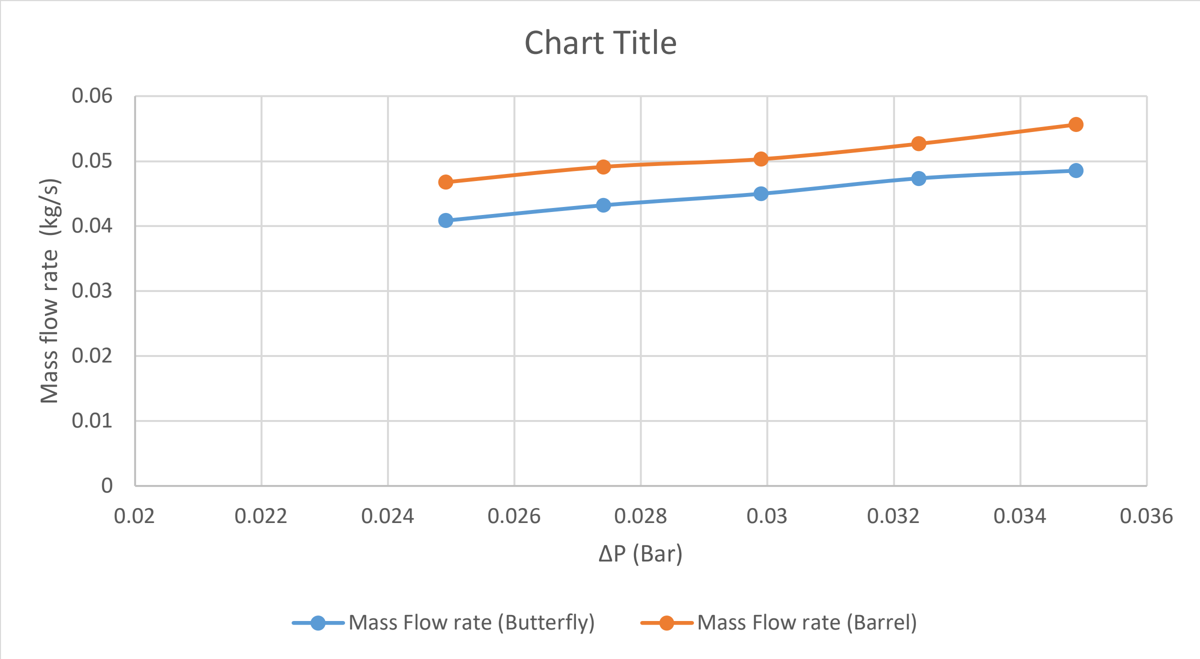


Fig 6.6 Comparison between actual Mass flow rates of Barrel & Butterfly throttle bodies.

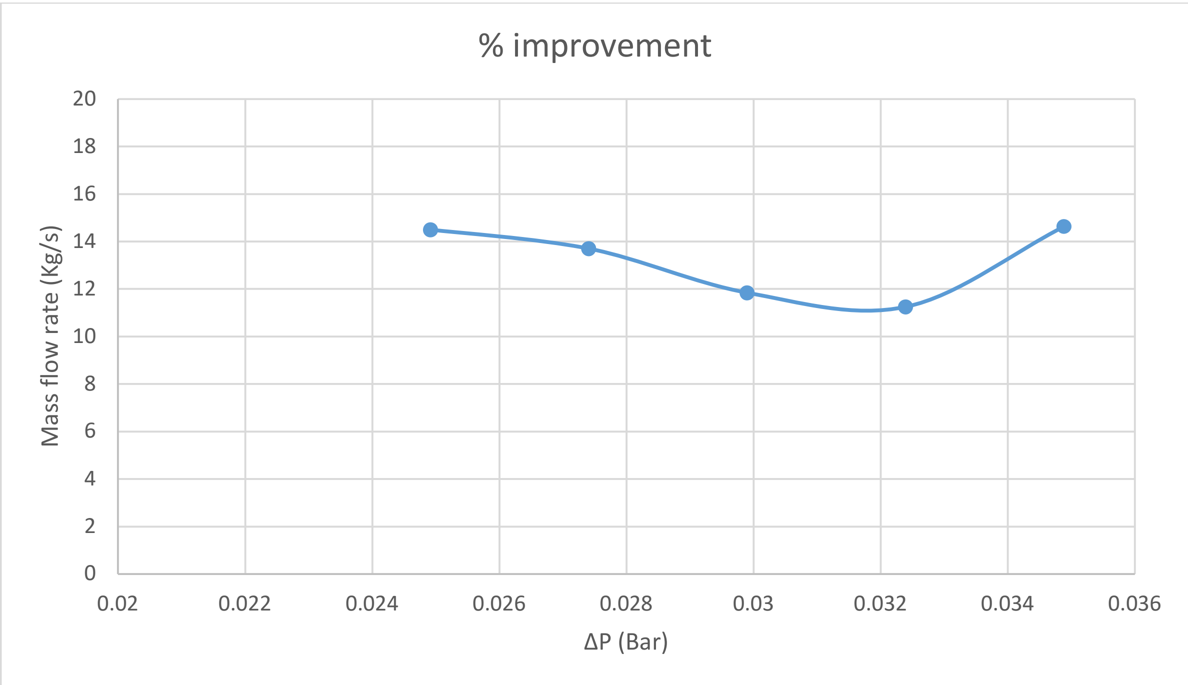


Fig 6.7 % Improvement due to the use of barrel throttle body.

6.3 Summary

In this chapter all the final results are tabulated. For Butterfly Throttle Body the percentage difference between theoretical and actual mass flow rate was 13-16% for 10-14 ΔP (Inches of water). Also for Barrel Throttle Body the percentage difference between theoretical and actual mass flow rate was 8-16% for 10-14 ΔP (Inches of water). During comparison of actual mass flow rate of Barrel and Butterfly valve it was seen that there is improvement of 11-14% for 10-14 ΔP (Inches of water).

CHAPTER 7

CONCLUSIONS

As seen from the result tables and plots in Chapter 6, the barrel throttle body has a substantial difference when compared to butterfly throttle body at wide open throttle. This 14 % increase in air flow rate would be of drastic help in the output of the engine and the performance of the car. The amount of fuel to be injected inside the cylinders would also have to be increased to bring the air fuel mixture to around stoichiometric ratios. The effects of increased air flow on fuel economy are beyond the scope of this project.

We can conclude that by use of barrel throttle body there will be appreciable amount of reduction in drag and controlled turbulence leading to increased horsepower. Also as the amount of air entering the engine is increased for the same size of the bore, the maximum rpm or the redline rpm at which the engine chokes also increases. Thus the engine can reach higher rpms facilitating the production of more over square engines.

An over square engine allows for more and larger intake valves in the cylinder head therefore there are lower friction losses (due to the reduced distance travelled during each engine rotation) and lower crank stress (due to the lower peak piston speed relative to engine speed).

7.1 LIMITATIONS OF THE PROJECT

The Barrel Throttle Body fabricated is cost effective but in comparison to the Butterfly Throttle Body it is larger in size. So it needs more mounting space comparatively and this makes its mounting difficult. Also elliptical shape of the barrel hole was not possible because an elliptical bell mouth is very difficult to manufacture and that to just a single unit. An air filter of the same shape is not available.

7.2 FUTURE ENHANCEMENT

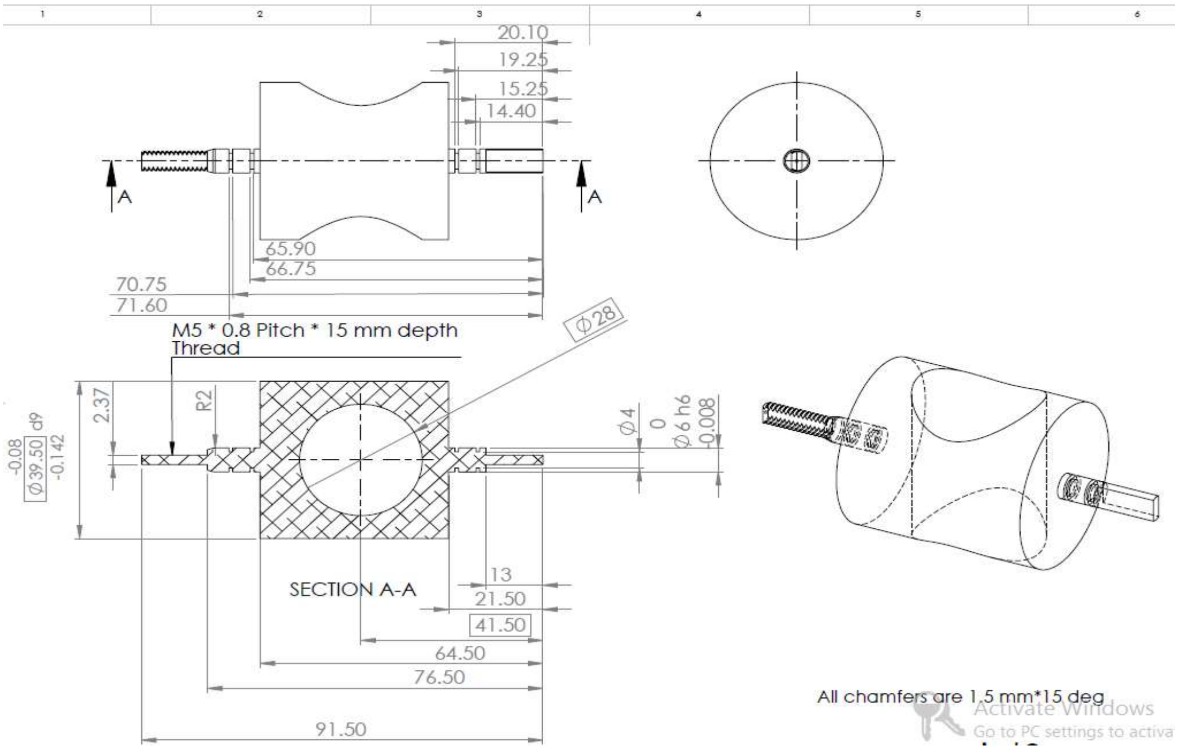
Mass flow rate at various angles of the throttle body can be found out to compare the performance of the barrel throttle with the butterfly throttle at mid-range rpms.

Also various parameters like surface finish, heat conductivity of the material, flow trajectories and turbulences that affect the flow can be altered and the corresponding results documented.

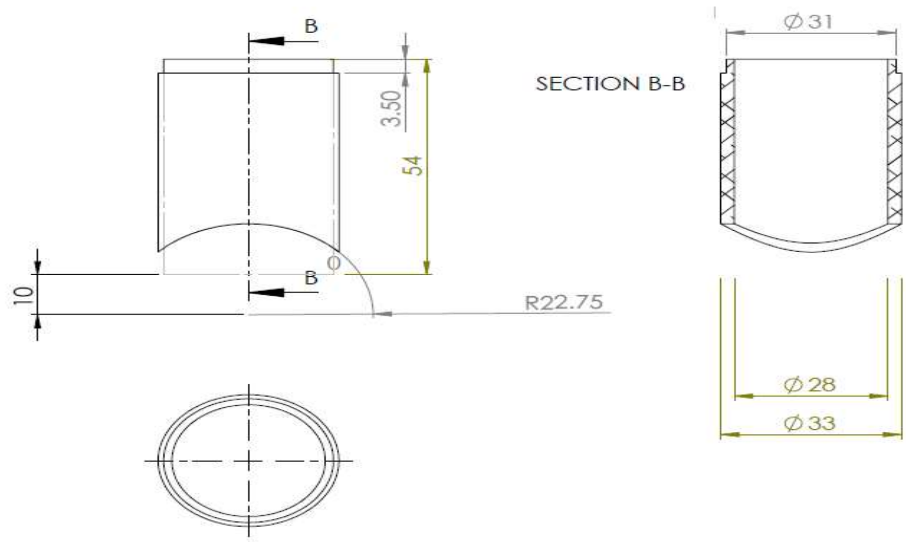
Further the effects of barrel throttle body on fuel economy can also be tested and validated experimentally.

APPENDIX-1

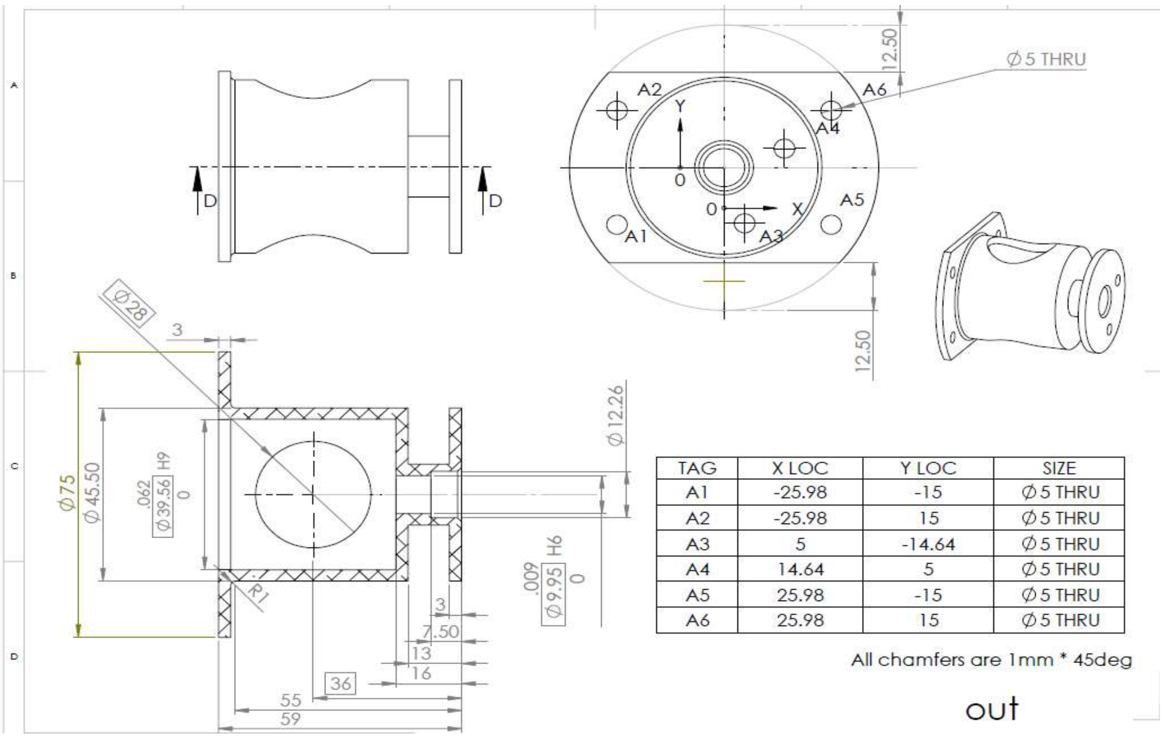
Part drawings:



INNER BARREL

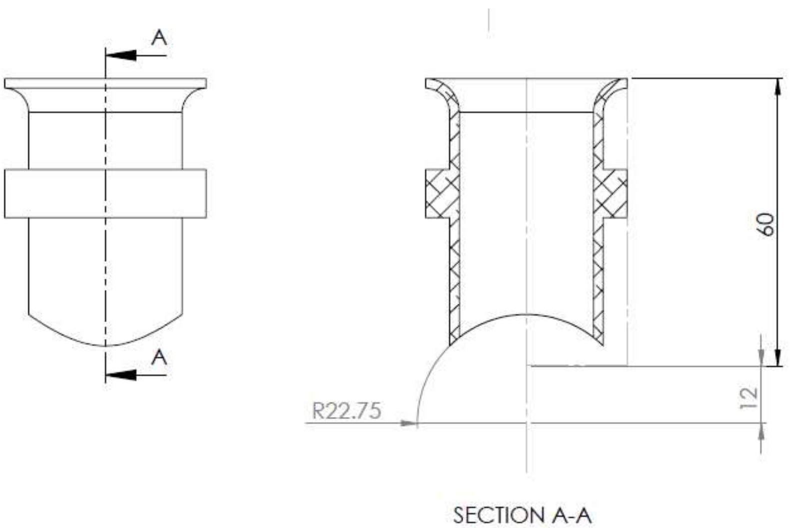


PIPE

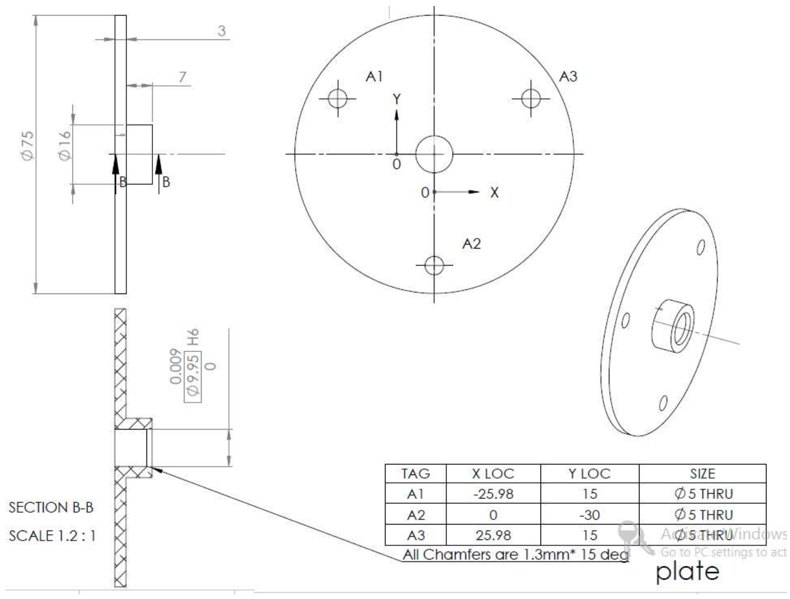


TAG	X LOC	Y LOC	SIZE
A1	-25.98	-15	Ø 5 THRU
A2	-25.98	15	Ø 5 THRU
A3	5	-14.64	Ø 5 THRU
A4	14.64	5	Ø 5 THRU
A5	25.98	-15	Ø 5 THRU
A6	25.98	15	Ø 5 THRU

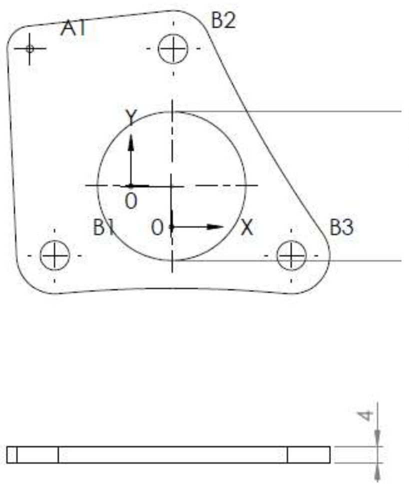
OUTER BARREL

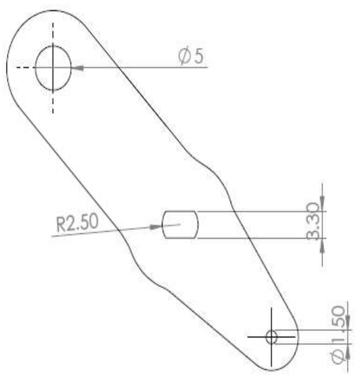


BELL



COVERING PLATE





MOUNTING PLATE **ACTUATOR**

Glossary

DbW : Drive by Wire

ECU : Engine control unit

TPS : Throttle position sensor

WOT : Wide open throttle

IACV: Idle Air Control Valve

ECM : Engine Control Module

CFD : Computational Fluid Dynamics

ICE : Internal Combustion Engine

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