DESIGN, ANALYSIS, FABRICATION AND TESTING OF VARIABLE LENGTH INTAKE MANIFOLD FOR SMALL 4S ENGINES

A PROJECT REPORT

Submitted by

SRIRAM. B [Reg No: RA1411011010019]
R. SHREYAS [Reg No: RA1411011010042]

Under the guidance of

Mr. M. JEROME STANLEY
(Assistant Professor, Department of Automobile Engineering)

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BONAFIDE CERTIFICATE

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SIGNATURE

Mr. M. JEROME STANLEY
GUIDE
Assistant Professor
Dept. of Automobile Engineering

SIGNATURE

Dr. M. Leenus Jesu Martin
HEAD OF THE DEPARTMENT
Dept. of Automobile Engineering

Signature of the Internal Examiner

Signature of the External Examiner

ABSTRACT

The thesis describes the work of developing a variable length intake manifold with RAM supercharging effect for smaller 4 stroke engines, resulting in increase in volumetric efficiency, a flatter torque curve and increased fuel efficiency. RAM supercharging in intakes is a well-known phenomenon and is a proven technique to increase volumetric efficiency. With proper designing, volumetric efficiency of more than 100 percent can also be obtained at certain rpm. The project aims to use the advantage of RAM supercharging at all the speed ranges and at the same time introduce the technology in the smaller engines. The biggest drawback with ram supercharging is that it works only for a particular speed range, which is highly unpractical and not well suited on road conditions but with variable length manifold the problem of limited RPM range can be solved.

ACKNOWLEDGEMENTS

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Sriram. B

Shreyas. R

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CHAPTER 1

INTRODUCTION

Tuning corresponds to adjusting the length of intake runner so that the pressure wave arrives exactly at the time when the inlet valve opens. This effect is also called as inertial ram effect and length is decided by Chryslers Ram Theory and David VizardâĂŹs rule. The project can help in improving volumetric efficiency and fuel economy by a factor of 5-10percentage each.

To achieve the objective, Experimental Methodology is adapted. The first part of the thesis included high amount of research and hence literature survey was done and various papers and books were considered before the designing of the actual part began. After the basic concepts were understood, the calculations for runner length for different RPM zones was carried out. Along with runner lengths, diameter of the runner and volume of the resonating chamber is carried out. Once the calculations are carried out, a model is made in CAD using Solidworks as the tool. ANSYS is then used for checking the flow simulations at a particular rpm. Comparison between the stock intake and the new intake can be made using the flow analysis report. To vary the length as per the throttle input a stepper motor coupled with an Arduino board is used. The input for the Arduino is given by pick up sensor installed at the crankshaft of the engine which senses the engine rpm.

The testing of the intake required dynamometer and since two wheeler dyno facility of the university is not working properly and because it is difficult to obtain a two wheeler dyno in a student level, a rope brake dynamometer was also developed. The rope brake dynamometer accuracy was checked by reinstalling the stock intake and the torque graph was plotted.

A conventional intake in an engine does the work of supplying air to the intake port of the engine by creating a pressure difference between the atmosphere and the combustion chamber. An intake manifold, hence should be designed with utmost care and should produce the desired result.

In an Intake Manifold there are two parts of a wave, compression wave and rare faction

wave. The breathability or Volumetric Efficiency of an engine can be improved using both, compression and rare faction wave. At certain RPMs the volumetric efficiencies of more than 100percent can also be achieved, thus increasing the torque output and performance of the engine, as a result of better combustion.
The compression moving ridge is generated when the momentum of the melodic phrase David Low is halted suddenly by the closing of intake valve. This compression moving ridge change of location rachis and forth along the closed intake moon curser length. Tuning corresponds to adjusting the length of intake stolon so that this pressure Wave arrives exactly at the fourth dimension when the recess valve outdoors. This impression is also called as inertial Aries effect and length is decided by St. David VizardâĂŹs rule. Another undulation is the rarefaction or sucking moving ridge , This low pressure wave is generated at the time of the sucking accident of the engine, travels upstream to air-flow, gets reflected from the inlet boundary(open intake end) as a high pressure wave, travels downstream towards the combustion blank space . This compression wave if shuffle to arrive at proper time, by proper design of intake manifold paper length increases local density of inlet air flow. This effect is sometimes referred to as natural supercharging or acoustic supercharging.
Before getting into the specifics of designing certain parameters had to be ascertained. The engine on which the experiment would be carried out and for which the intake would be tuned. The experiment sees the use of Honda Activa 109.2cc engine for the testing. The engine is mounted separately on a self-made engine rig. The EFI Kit comes with a software called ProCAL.software gives the advantage of tuning and adjusting the parameters to obtain the required air fuel ratio. the ssoftware is easy to use and can be controlled and learned within couple of months. there are two ways of tuning the engine aas per the wish, speed density and alpha-N method. the alpha -N method is based on TPS or throttle based mapping of the engine. the speed ednsity method is the more better and reliable way of creating the map. The ECU is tuned to operate at stoichiometric (14.7:1) ratio so that there is no advantage gained because of fuel injection.

Figure 1.1: ECOTRONS COMPONENTS

CHAPTER 2

LITERATURE SURVEY

As Sir Isaac Newton quoted the theory, first law about motion, law of inertia, the working principle of RAM supercharged Intake Manifold was born. The first law states that: An object at rest tends to stay at rest and an object in motion tends to stay in motion. Ram Induction is based on this law.

Visualize the intake cycle of the engine as air flowing through the manifold runner, past the valve, and into the cylinder. Everything is ok and dandy till the valve shuts.

The law of inertia involves play as a result of the air being in motion, it should be remaining in motion. however the air cannot go to any other place as the valve is shut therefore it piles up against the valve in a chain reaction. With one piece of air stilt au courant ensuing piece of air on ensuing on ensuing, the air becomes compressed. This compressed gas needs to go thereforemewhere so it turns around and flows back through the manifold runner within the variety of a pressure wave.

This pressure wave bounces back and forth in the runner and if it arrives back at the

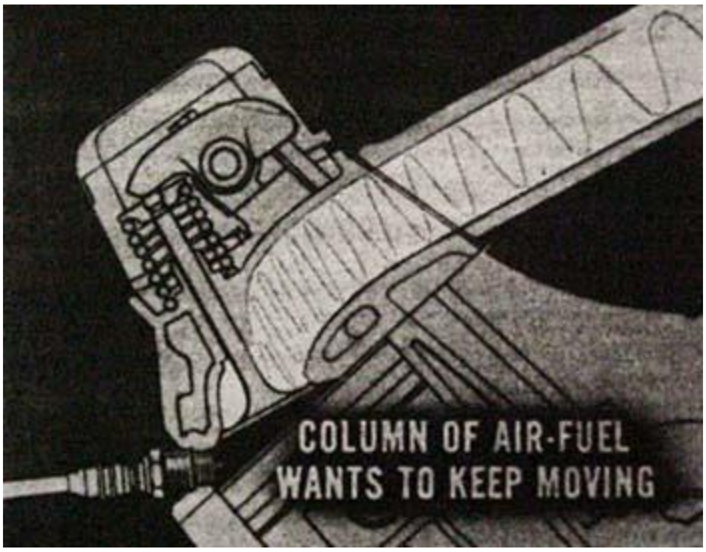


Figure 2.1: PRESSURE WAVE RESONANCE

valve as the valve opens, it's drawn into the engine. The bouncing pressure wave of air and also the correct time of arrival at the valve creates a variety of supercharging.

for attaining this supercharging, the variables would need to be to be aligned such that the pressure wave arrives at the valve exactly at the required time. hence resonant conditionn is achieved.

PRINCIPLE

An intake system works with the principle of resonance superccharging, that is, high pressure wave to measure wont to charge the cylinder, so as to attain higher volumetric efficiency. The piston moves downward within the cylinder, in the direction of bottom dead center (BDC). It creates a high pressure wave.

This nonaggressive wave propagates itself although the resonance pipe to the opposite

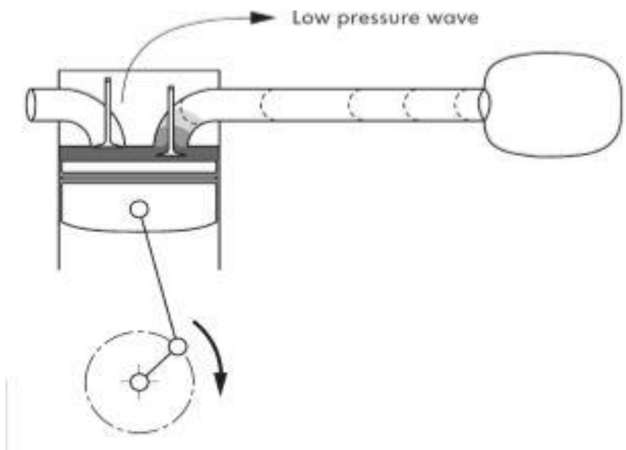


Figure 2.2: START OF RESONANCE

finish, that protrudes into a collector. The nonaggressive wave at the tip of the pipe acts on the amount of air gift within the collector.

The pressure of the amount of air within the collector is close to adequate close at-

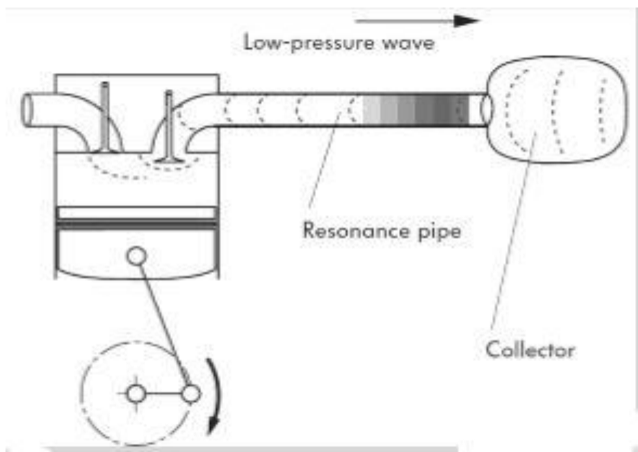


Figure 2.3: RESONANCE SUPERCHARGING

mospheric pressure. this is often considerably more than the atmospheric pressure at the open finish of the resonance pipe. The air mass currently gift at the tip of the pipe pulls on the atmospheric state gift here. They force themselves at the same time into the resonance pipe in order that wherever the nonaggressive wave was, associate degree equally giant hard-hitting wave develops, that propagates itself towards the water valve. This result is known as as Ram-supercharging. The air wave is mirrored at the open

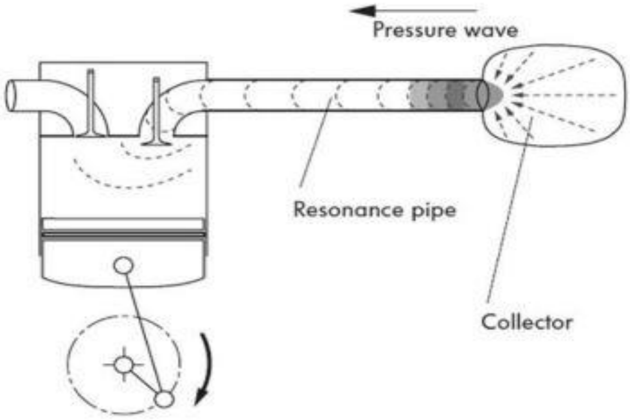


Figure 2.4: DEVELOPMENT OF HIGH PRESSURE WAVE

finish of the pipe within the collector. As a result, once the water valve closes, flowing of the ram-effect charging into the intake pipe is prevented. The time t (in milliseconds) needed by the low and hard-hitting waves to hide the gap S from the water valve to the collector and back is often constant as a result of they move at the speed of sound, v.
But the fundamental measure throughout that the water valve is opened relies on engine speed. As engine speed will increase, the amount of your time throughout that the water valve is open and air will flow into the cylinder decreases. A hard-hitting wave returning through a resonance pipe designed for low engine speeds can run into associate degree water valve that has already closed, âĂIJRam-effectâĂİ charging cannot come about. it's clear that resonance pipes of various lengths square measure needed for optimum charging at each engine speed.The problem, however begins when the engine operates at outside the narrow speed range. The intake manifold designed to work at a particular rpm would still be timing the air flow at the same speed, but the intake valves are now opening at a different time, hence creating a negative impact. Various manufacturers like BMW, Toyota Ferrari, etc. had different solution to this problem and some of them are still being developed further with technological complexities increasing.

The problem, however begins when the engine operates at outside the narrow speed range. The intake manifold designed to work at a particular rpm would still be timing the air flow at the same speed, but the intake valves are now opening at a different time, hence creating a negative impact. Various manufacturers like BMW, Toyota Ferrari, etc. had different solution to this problem and some of them are still being developed further with technological complexities increasing.

This thesis is written in a bid to help move forward with the research of variable length intake manifold. Our solution was different than what the manufacturers had already done and yet offered the simplicity in design and construction. The other notable thing is, while all the manufacturers had tried to incorporate variable length manifold only in multi-cylinder engines of higher capacity coupled with turbocharger, our solution was unique to single cylinder small engines. We converted a carburetted engine to fuel injected engine so as to obtain the air pressure in the intake and study the throttle percentage required to achieve a particular speed. The fuel injected engine was tuned to stoichiometric working conditions. ECOTRONS EFI kit was used as the fuel injection kit. The fuel injection kit was first coupled with standard stock intake and the air pressure values were observed. Later the same kit was coupled with the new variable length intake manifold and the volumetric efficiency and air pressure values were observed. The result of the comparison is mentioned in further chapters.

The intake is designed taking into account the acoustics of air in the runner to maximise volumetric efficiency. An intake based on the RAM effect or Resonance supercharging has been developed. The intake is tuned using Helmholtz Resonance theory so as to dictate when the torque peak of the engine should occur. A well designed resonator system can improve the volumetric efficiency of the engine at desired speed. Design of the intake is based on a particular RPM and it will only be effective in a narrow range of the set RPM. The tuning of the intake can be broadly divided into tuning for high engine speed and low engine speed. The intake runner length, runner diameter and the resonator volume are the parameters that control the torque peak of the engine. The difference between a conventional stock intake and RAM supercharged Intake can be noticed using the flow simulation software like ANSYS. A basic comparison of stock intake with RAM intake with throttle in a position where 3000rpm is achieved at no load condition is given below.

Intake runner

When engine's intake valve opens, air gets sucked into the engine, so the air moving rapidly towards the cylinder. When the intake valve closes suddenly, this air slams to a stop and stacks up on itself, forming an area of high pressure. This high-pressure wave makes its way up the intake runner away from the cylinder. If the intake runner is designed for the right length, the pressure wave will arrive back at the intake valve just as it opens for the next cycle. This extra pressure helps cram more air-fuel mixture into the cylinder effectively acting like a supercharger. The time for which the intake valve is open is used to determine the length of the runner required. Usually the length that is obtained is pretty long and as such it is difficult to realise it practically.

The design, thereof the length for all the other working rpms was calculated similarly using the same set of formulas. The length varying would be dependent on the rpm and it was observed theoretically that as the speed increases, the intake length reduces. Now, to achieve the peak torque before the manufacturerâĂŹs specified speed the intake length would increase and it can be found from previous sections that the maximum length in case here is 479mm. the diameter is kept constant at 32.29mm. The length of intake is limited to a minimum of 350mm. this gives us a range of 2500 rpm to 6500 rpm, which is the operating range in most of the small engines.

3D PRINTING

3D Printing refers to processes during which material is joined or solid below pc management to make a 3 dimensional object, with material being extra along (such as liquid molecules or powder grains being consolidated together). 3D printing is employed in each speedy prototyping and additive producing (AM). Objects are often of just about associate degreey form or pure mathematics and usually area unit made victimization digital model knowledge from a 3D model or another electronic knowledge supply like an Additive producing File (AMF) file (usually in ordered layers). There area unit many various technologies, like stereo Lithography (STL) or consolidated Deposit Modelling (FDM). Thus, not like material far from a stock within the typical machining method, 3D printing or AM builds a three-dimensional object from software package (CAD) model or AMF file, typically by in turn adding material layer by layer.

The term "3D printing" originally mentioned a method that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. additional recently, the term

is getting used in widespread vernacular to embrace a wider style of additive producing techniques. us and international technical standards use the official term additive producing for this broader sense, since the ultimate goal of additive producing is to realize mass-production, that greatly differs from 3D printing for speedy prototyping.
The desire to 3D print the whole Inlet Manifold was not possible, however because of the high cost of the process and because of unavailability of expertise for using the machine at the institute. A 3D printed model would be light in weight and provide perfect tolerances compared to the other methods. For a two-wheeler commuter, it is very important that something like an intake does not weigh much and occupies little space. Both of these objectives can be met by using the modern manufacturing techniques of 3D Printing or Rapid Prototyping. A complex structure of spiral which occupies very less space and at the same time the length need not be compromised, can be easily manufactured using the plastic ABS material and would not weigh much at all. The profile of the intake form the inside would also be smooth as per the requirement.

Manufacturers generally employ a more conventional and cheaper casting method

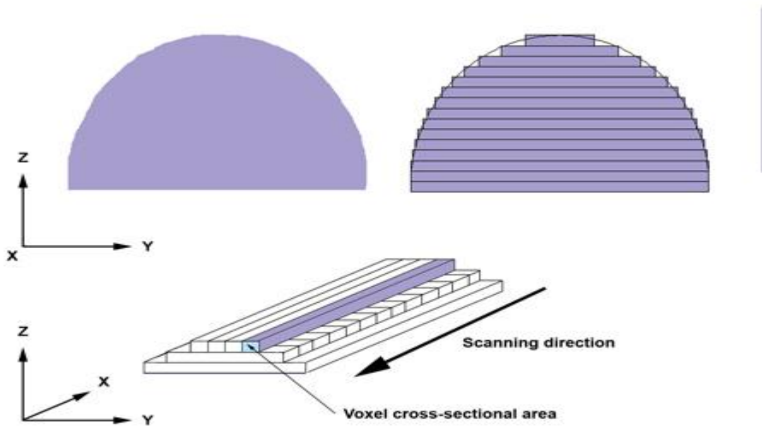


Figure 2.5: 3D RPINTING TECHNIQUE

compared to the modern manufacturing techniques. The problem with casting is that for longer lengths it is expensive and though complex shapes can be made but the moulds would be expensive and would need to be precise, which would further increase the fabrication costs. The other downside is that, the weight of the part would be too much and additional supports would be required.

DYNAMOMETER

A dynamometer, or "dyno" for short, is a gadget for estimating power, snapshot of power (torque), or power. For instance, the power delivered by a motor, engine or other pivoting prime mover can be ascertained by at the same time estimating torque and rotational speed (rpm).

A dynamometer can likewise be utilized to decide the torque and power required to work a determined machine, for example, a pump. All things considered, a motoring or driving dynamometer is utilized. A dynamometer that is intended to be driven is called an assimilation or aloof dynamometer. A dynamometer that can either drive or retain is known as an all-inclusive or dynamic dynamometer.

Notwithstanding being utilized to decide the torque or power attributes of a machine under test (MUT), dynamometers are utilized in various different parts. In standard emanations testing cycles, for example, those characterized by the US Environmental Protection Agency (US EPA), dynamometers are utilized to give mimicked street stacking of either the motor (utilizing a motor dynamometer) or full powertrain (utilizing a suspension dynamometer). Truth be told, past straightforward power and torque estimations, dynamometers can be utilized as a component of a testbed for an assortment of motor improvement exercises, for example, the alignment of motor administration controllers, point by point examinations concerning burning conduct and tribology.

WORKING PRINCIPLE

The basic parts of a rope brake dynamometer are as follows:

1. ropes
2. pulley
3. dead weight
4. spring balance
5. frame

Construction of a Rope Brake Dynamometer

Rope

A rope is required which acts as the medium through which the load is transmitted to the engine output shaft. the the rope connects the dead weights, spring balance and the pulley drum attached to the output shaft. the rope generates high heat because of high amount of friction and thus requires cooling.

Pulley

A pulley is a wheel with a depression along its edge for holding a rope or link.the rope winds across the pulley. The extent of the power is decreased, yet it must act through a more extended separation. Thus, the measure of work vital for the lift to achieve a specific stature is the same as the measure of work required without the pulleys.

Dead Weight

It is a weight. Desired amount of weight or load is added to test the engine in the loaded conditions and not just at idle conditions.

Spring Balance

a spring balance is a measuring scale. It works by Hooke's Law, which expresses that the power expected to stretch out a spring is relative to the separation that spring is reached out from its rest position.

Working of a Rope Brake Dynamometer

Brake power of the engine can be estimated using the above shown dynamometer. It

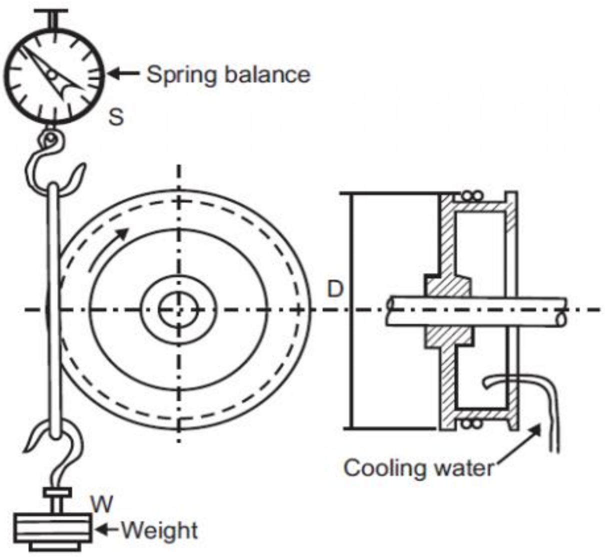


Figure 2.6: ROPE BRAKE DYNAMOMTER

comprises of a few turns of rope twisted around the pivoting drum connected to the yield shaft. One side of the rope is with a spring balance and the opposite side to the weights. The drum requires cooling because of the high frictional heat generated between rope and the drum.

CHAPTER 3

DESIGN AND DESIGN ANALYSIS

A model in Solidworks is formed for the same and flow analysis is checked. The orientation and shape of the resonant chamber is also a major design factor. The difference between conventional stock intake and the ram supercharged intake can be easily seen.

The above showed analysis report clearly shows the benefits of ram supercharging in

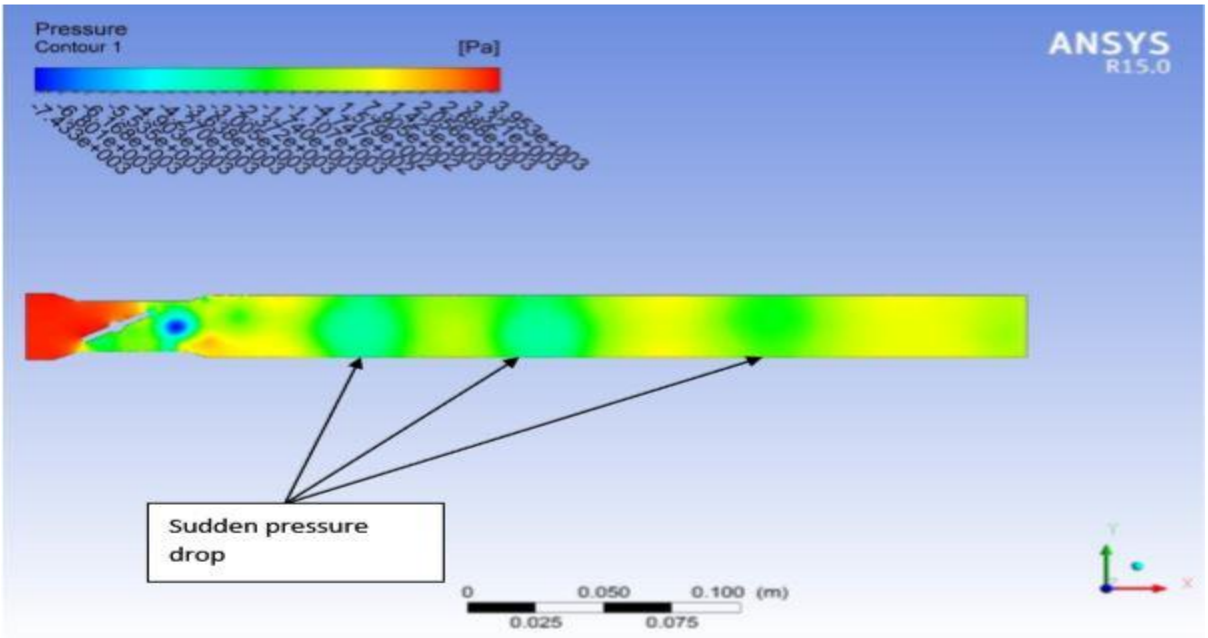


Figure 3.1: PRESSURE CONTOUR STOCK INTAKE

an intake manifold. The length and throttle valve for the test were kept as per 3000rpm. It can be noted that the pressure drop and the back pressure on the stock model is very high, while the orientation of the resonant chamber also showed drastic change in flow of charge through the manifold. The last two models show the pressure and velocity contours of the ram supercharged intake. The pressure drops are eliminated and there is no or very little back flow, which resists the flow of charge in to the combustion chamber. The results were obtained in 2D structure using the FLUENT tool in ANSYS simulation software.

The first two images show the air flow inside a stock intake. The flow is very uneven

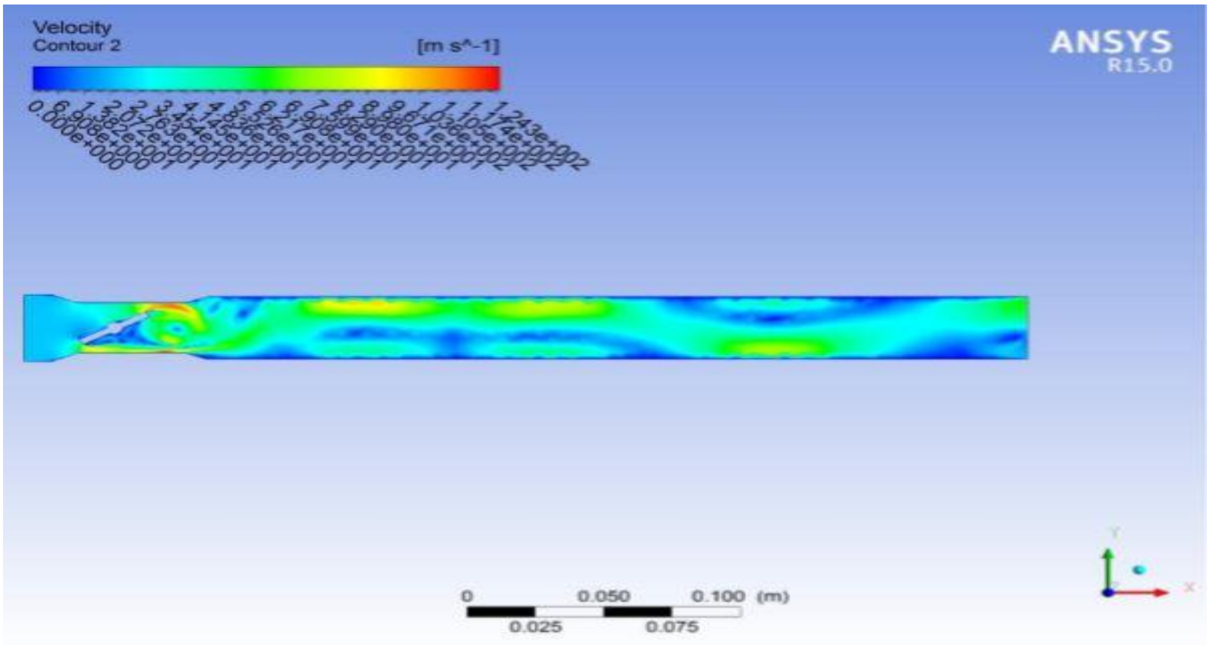


Figure 3.2: VELOCITY CONTOUR STOCK INTAKE

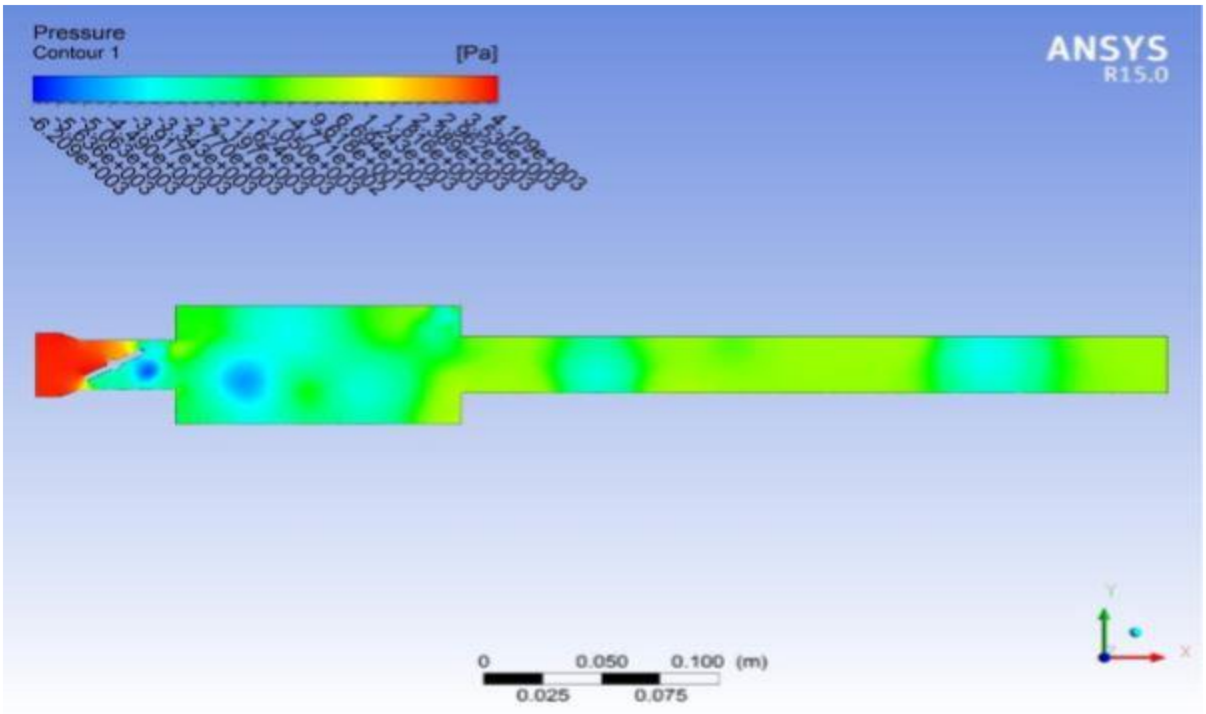


Figure 3.3: PRESSURE CONTOUR RESONANCE BOX PLACED LENGTH WISE

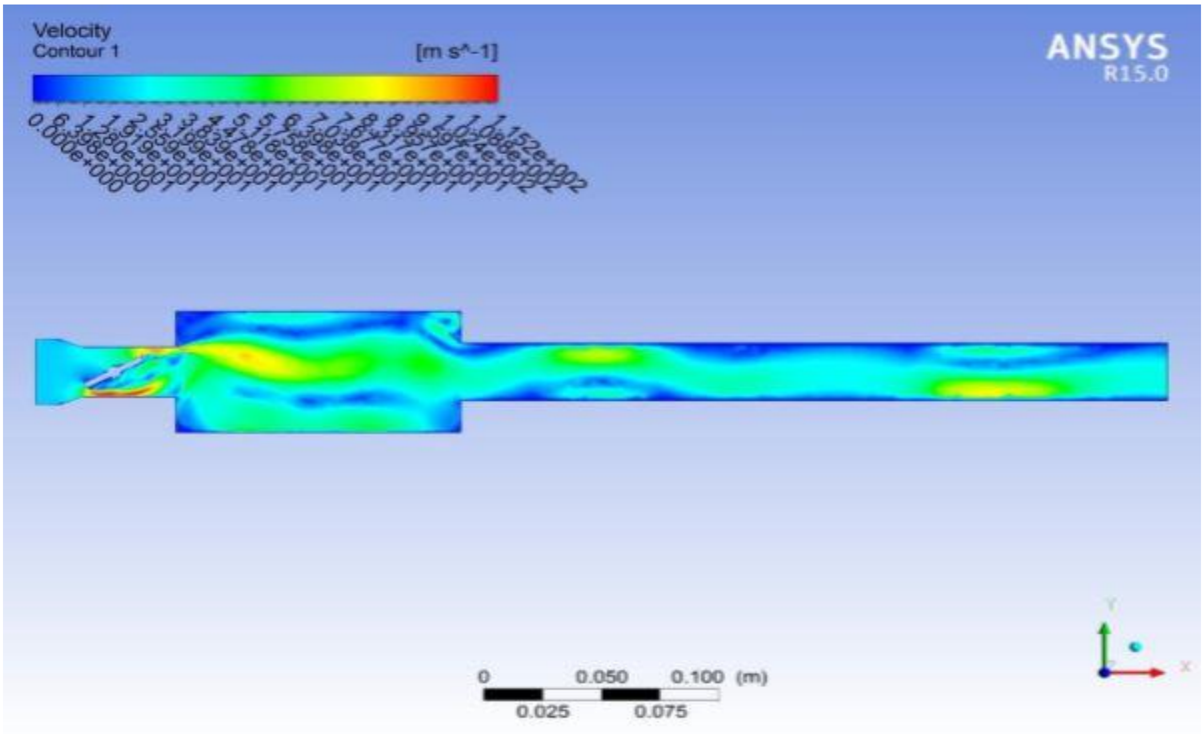


Figure 3.4: VELOCITY CONTOUR RESONANCE BOX PLACED LENGTH WISE

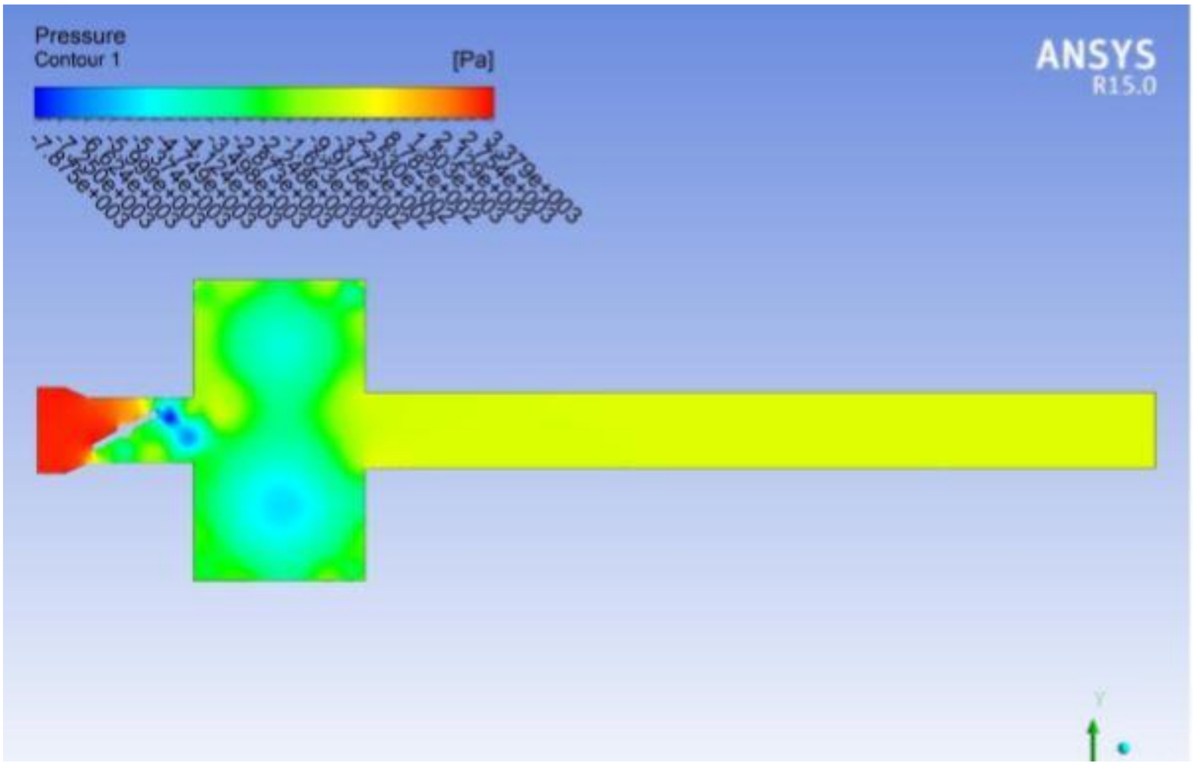


Figure 3.5: PRESSURE CONTOUR RESONANCE BOX PLACED WIDTH WISE

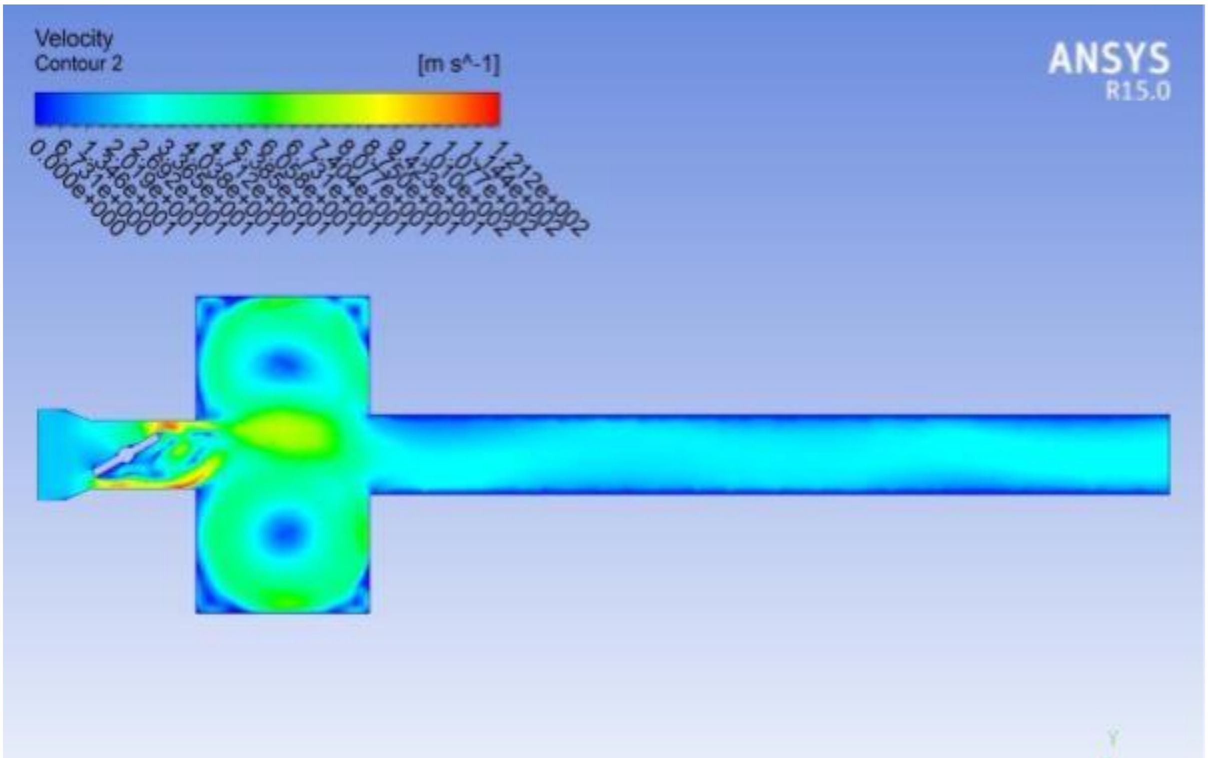


Figure 3.6: VELOCITY CONTOUR RESONANCE BOX PLACED WIDTH WISE

and not desired. Images three and four shows the air flow when the resonant chamber is placed other way around. The fifth and sixth image show the flow of air inside a ram supercharged intake. The flow is very neat with no back flow and pressure drops.

It can further be noted that the addition of a carefully designed and perfectly oriented resonant chamber at the inlet position itself can boost the intake flow. However, the volume of the chamber has to be carefully calculated and fabricated. The next step was to design the apparatus required in the software. The engine, EFI systems and the intake was designed in Solidworks. The engine rig had to be manufactured with the exact mounting points and therefore CAD model of the engine was crucial.

Design of the intake is based on a particular RPM and it will only be effective in a narrow range of the set RPM. The tuning of the intake can be broadly divided into tuning for high engine speed and low engine speed. The intake runner length, runner diameter and the resonator volume are the parameters that control the torque peak of the engine.

At the critical time of .0268 seconds, our wave travelled the target distance of 181" up and down the tube. Although our pressure wave arrived at the intake valve five times to find it was still shut, on the 6th bounce our wave arrived to find the valve open. The pressure wave entered the cylinder and we had ram induction!

Table 3.1: TIME FOR PRESSURE WAVE TO TRAVEL

TIME	BOUNCE
0.00446	1
0.00829	2
0.01838	3
0.1487	4

The example on top of has incontestible why ram induction works.

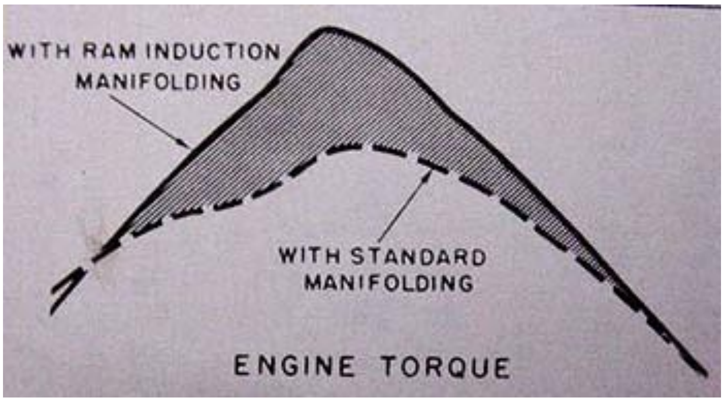


Figure 3.7: EFFECT OF RAM INDUCTION USING LONG RAMS

Now let's inspect the constraints of ram induction.
The following parameters have an effect on the arrival of our pressure wave at the intake valve:

1. Engine speed
2. The number of crank rotation degrees the intake valve is closed.
3. Length of the runner tube.

If these parameters don't seem to be balanced properly, ram induction does not work.
Let's bear the calculations once more with the engine rate modified to 1200 RPM:
The essential time issue calculates to .0528 seconds.
At .0528 seconds, our pressure wave has bounced around eleven.8 times.
In this state of affairs, the wave is just eightieth through the intake once the valve opens and the pressure wave arrives at the valve too late.

Change the rate to 3600.
The essential time issue decreases to .02084 seconds.

At .02084 seconds, our pressure wave is midway down the tube throughout its fourth bounce once the valve opens.

Once again, the pressure isn't synchronic to the open valve.

In the illustrations on top of, we tend to solely modified engine speed.

What would happen if you furthermore mght weakened the intake runner length and adjusted the cam timing?

You could another time synchronize the pressure wave to the valve gap

for 3600 rate and you'd have Short rams!

The runner length may be calculated from David Vizard's rule that states,

âĂIJYou ought to begin with a runner length of seventeen.8 cm for a ten,000 rate peak torsion location, from the intake gap to the plenum chamber. You add 4.3 cm to the runner length for each a thousand rate that you simply wish the height torsion to occur before the ten,000 rpm.âĂİ

So, as per our demand peak torsion ought to occur at three,000 rpm. Therefore, the whole runner length ought to be seventeen.8 + (7 x 4.3 cm)= 47.9 cm.

Runner Diameter:

Having a bigger runner diameter will increase the mass air rate however that's solely effective up to a limit. Increasing it on the far side the limit results a decrease in air speed that affects its turbulence and combination properties. the best diameter for AN intake is once the intake has twenty fifth additional cross-sectional space than the TB's bore cross-sectional space. The TB diameter dictates intake runner diameter. the world of TB bore = (ÏĂ/4) x diameter square. If we tend to calculate TB's space so multiply it by one.33, we tend to get the intake's space. Then, use this space to work out the intake runnerâĂŹs radius.

Diameter of throttle body = 28mm Cross-sectional space of the throttle body = (ÏĂ/4) x (28)2 = 615.75 mm2 Cross-sectional space of the intake runner = one.33 x cross-sectional space of TB = 818.95 mm2 Diameter of intake runner = SQRT

= 32.29 mm

Resonator Chamber:

The Resonance Chamber acts like a spring with the box connected on the end of spring. When the box compresses the spring, it builds or stores up energy and when it uncoils, the box is given energy because it travels far from the spring's compressed position. Just like the box and spring, the air resonates at a particular frequency within the plenum box. The air is then bounced back at the speed of sound in the Intake Manifold towards the valve once more.

The runner length and the diameter together will decide the volume of the resonator.

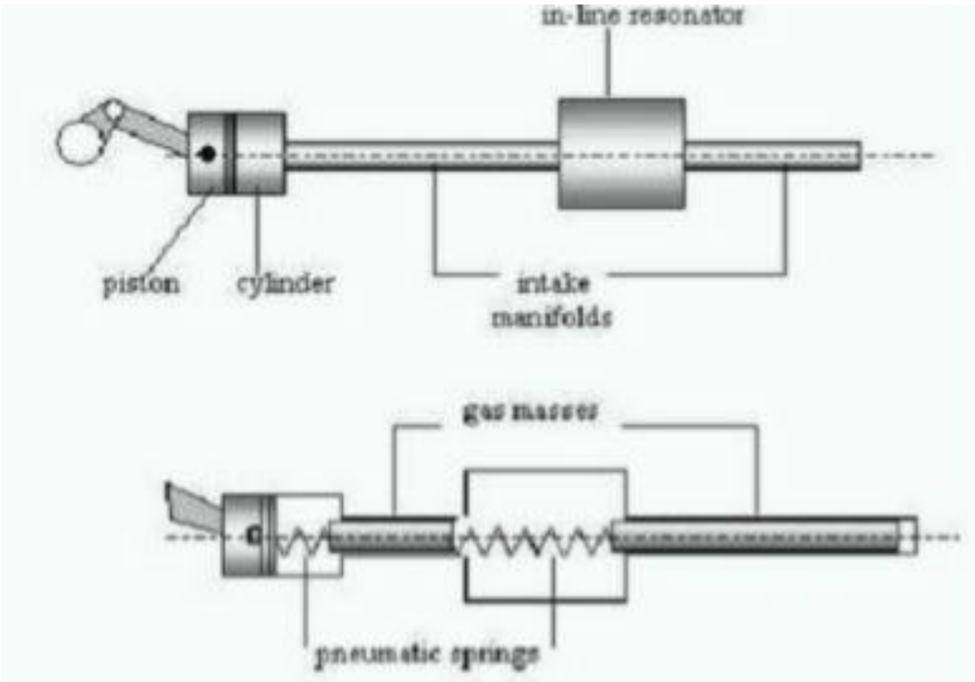


Figure 3.8: PRINCIPLE OF RAM SUPERCHARGING

Helmholtz resonance theory is used for this purpose. For tuning, the resonator frequency is kept almost double than that of the piston frequency.

FH = (c/2ÏĂ) x SQRT(S/L.V) Where, F = frequency, c = the speed of sound (340 m/sec), S = Runner Area, L = runner length, V = volume of the resonating chamber. (3000/60)x2 = (340000/2ÏĂ) x SQRT 854.865/ (500 x V) V =0.000501 m3

The most desired shape is of a Cube, as it is easy to fabricate. Therefore, the side of the Resonating Chamber = (V)1/3 = 7.9 m

For each rpm ranging from 3000 to 8000, the length was calculated using the same method as above. The diameter is kept constant and length is varied upon depending upon the rpm.

The table below shows the variation of length according to the rpm. As per the David ViardâĂŹs rule for an rpm of 10,000 the length should be 17.8cm and for every 1000 rpm increase the length should increase by a factor of 4.3cm.

Table 3.2: RPM WISE LENGTH IF INTAKE

LENGTH	RPM
17.8cm	10,000
26.4	8000
30.7	7000
35	6000
39.3	5000
43.6	4000
47.9	3000

The activa 110cc engine can reach up to 7500-8000 rpm at max. So the calculations were done for up to 8000 rpm. Though it is not the speed at which the scooter runs practically. On road conditions the engine is usually run from 3000 to 6000 rpm for most of the time. Whether in cruising conditions or during city driving conditions. So it was decided to vary the length of the intake manifold for the speed range 3000 to 6000. It is also a fact that the speed increases rapidly from standstill to 3000 rpm after which the speed increases a bit slowly, giving our system enough time to cope up and change the length.

The next part was to decide the mechanism for changing the length. A rack and pinion mechanism, where one pipe is sliding in to the other was chosen. The CAD model for the same was made in the in the design software Solidworks. The model is a rough draft of the actual design. The rack and pinion was not manufactured and a toy plastic rack and pinion is used instead. Since the project cost went too high.

RACK AND PINION

A rack and pinion is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move, thereby translating the rotational motion of the pinion into the linear motion of the rack. Shaft of DC motor is attached to rack and pinion assembly. The CAD model of rack and pinion is shown below.

The rack and pinion mechanism helps in adjusting the length of the manifold. The rack is attached to the slid able pipe and the pinion is attached to a DC motor. The DC motor will be fixed in its place and when the axle rotates the pinion would rotate resulting in movement of the rack, which is attached to the slid able pipe. The rack and pinion mechanism controlled by a DC motor is shown below.

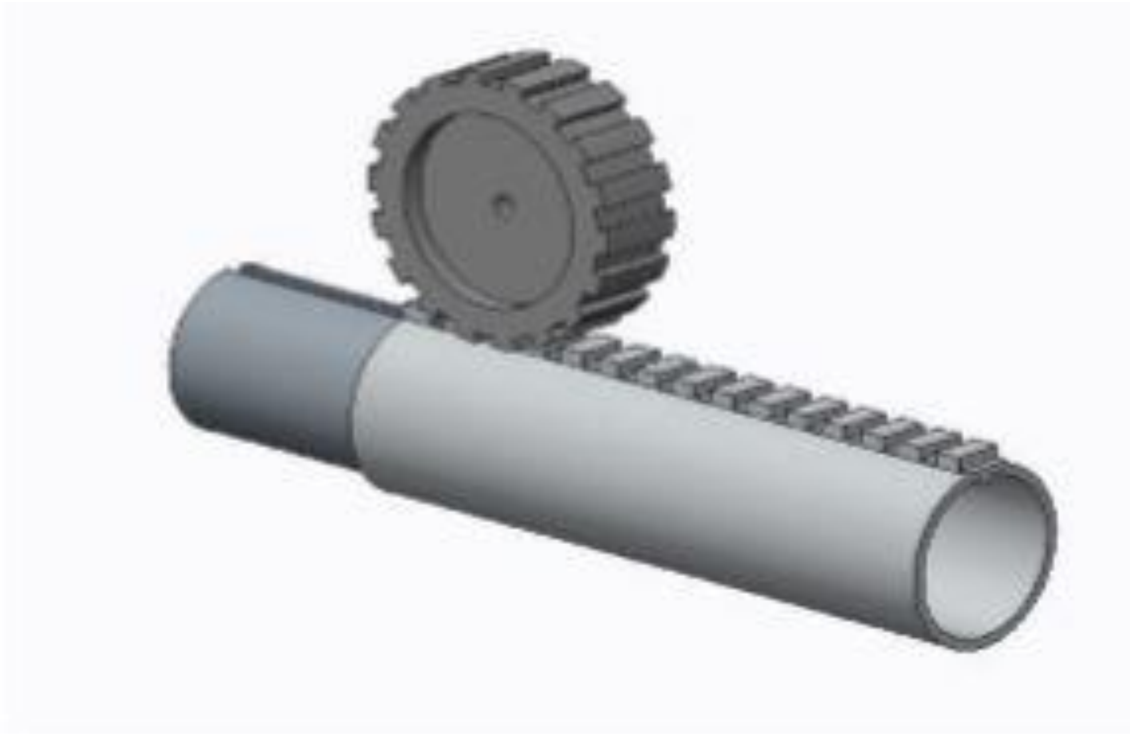


Figure 3.9: RACK AND PINION DESIGN

The DC motor is controlled using an Arduino. The Arduino uno is a microcontroller

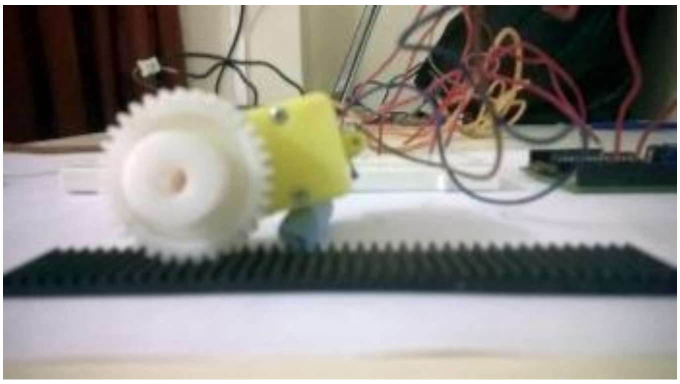


Figure 3.10: RACK AND PINION MECHANISM

board. It is an easy to use open source electronics platform based on easy-to use hardware and software. Arduino boards are able to read the inputs and convert the same into the working output.

First the stock intake is designed in the CAD so as to have an idea of the new design. The stock intake is designed with utmost perfection because the throttle body of the EFI system has to be coupled with the stock intake for which new parts had to be machined. CAD model of the stock intake is shown below, drawn in Solidworks.

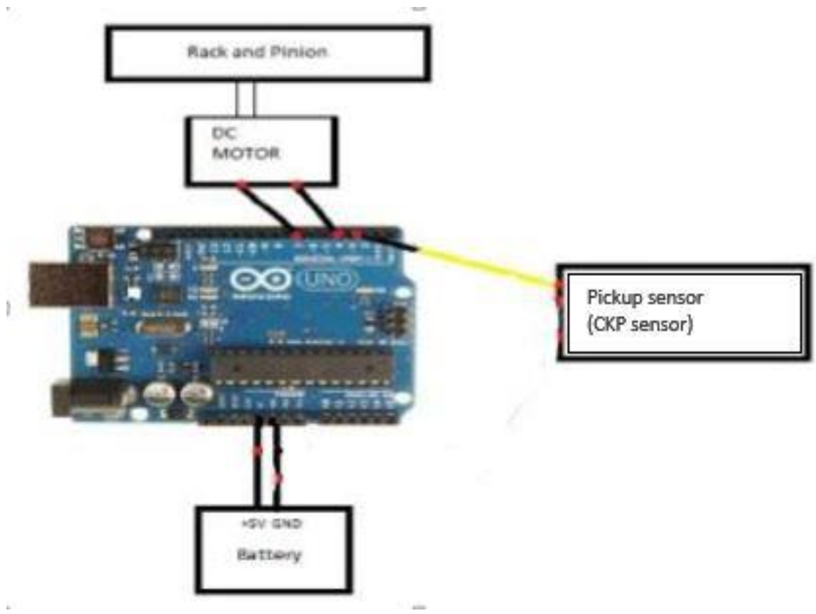


Figure 3.11: ELECTRONICS SCHEMATIC DIAGRGAM

The stock intake is made the same way as per the carburetted version. The manifold length is kept the same and the EFI is tune as per stoichiometry so as to minimise the advantage of fuel injection.

The new intake was now designed as per the calculation at 3000 rpm. The CAD model design is of maximum length so as to get the general idea of the length and compactness.

The initial design was more compact and designed keeping packaging on mind. The design was spiral and the and also turned out good during the flow analysis as well. The CAD model of the basic first design is shown below.

The design was very good in all aspects and turned out to be very compact as well, however because of the complex fabrication of this design and also because it involved a lot of welding and part bending the actual CFD flow would not be possible inside the manifold leading to obstructions all over the onside of the manifold, and also because the variable mechanism in a spiral design is very complicated the design was not used for any further considerations.

The spiral design can however be used if more modern manufacturing techniques are used instead of local outsourcing ways.

The second iteration of the design and the only other possibility was to make a straighter pipe and obtain the fabrication limit. The pipe was made with just two bends this time and flow analysis of the same was done before rushing into fabrication.

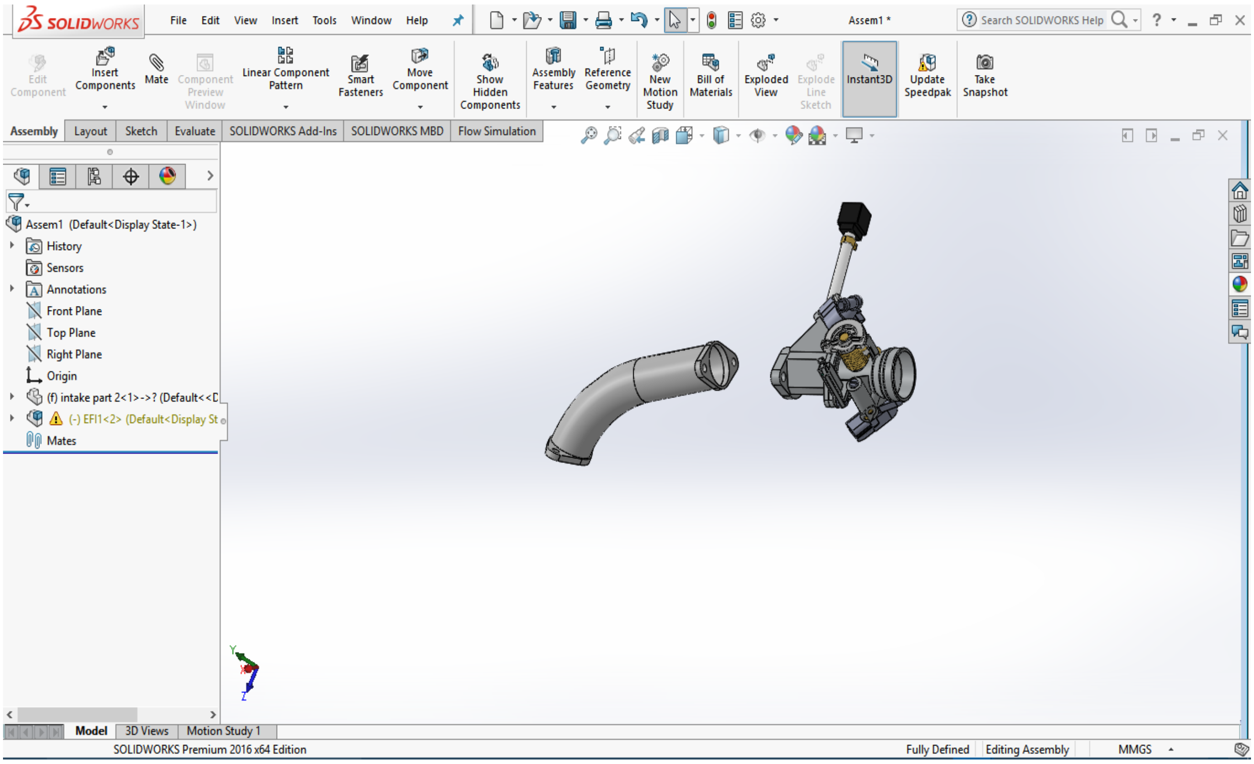


Figure 3.12: STOCK INTAKE DESIGN

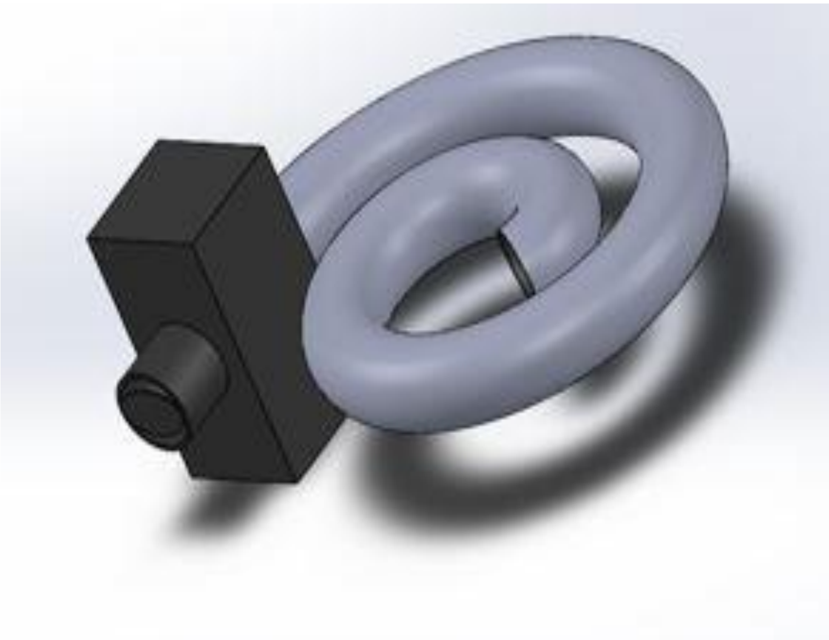


Figure 3.13: NEW DESIGN 1ST ITERATION

The CAD model of the second iteration and the actual part is shown below. The model

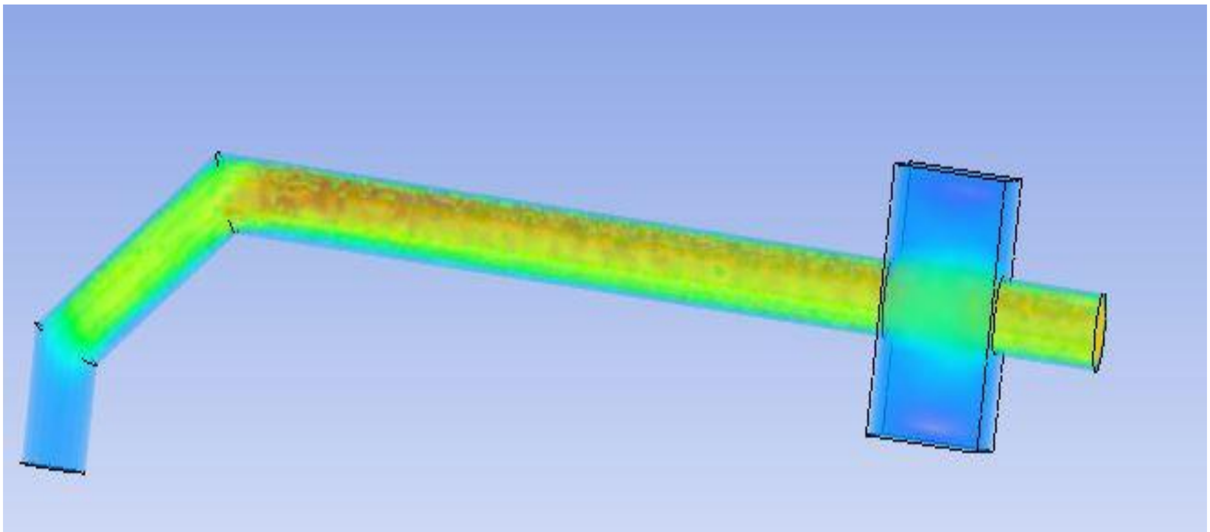


Figure 3.14: NEW DESIGN 2ND ITERATION

was drawn in design tool Solidworks.

The model is made simply with just two bends and the resonator box at the end. The model is designed as per the maximum length.

Flow analysis results showing the difference between flow of air in the stock intake pipe and the RAM supercharged intake pipe has already been shown in the previous chapters. Therefore, a benchmarking of the results that needs to be obtained had been obtained.

Flow analysis of the above model for velocity and pressure flow was done using the ANSYS tool.

The results of the air flow through the new intake manifold is shown below.

Velocity of the flow is checked using the CFD analysis. The analysis shows increment in flow velocity. There is no back velocity and the waves are smooth. Though if the curves can be a bit a more fillet instead of sharp bends the flow could be even more linear.

The parameters or the constraints of the analysis are all well considered before the analysis. Since the density variation would be very less therefore the density is considered to be constant. The inlet velocity of the air during intake stroke is considered to be one-thirtieth to one-tenth of the speed of sound or Mach speed. So the speed or intake air velocity usually varies from 9m/s to 34m/s. the intake temperature and pressure are considered to be at NTP.

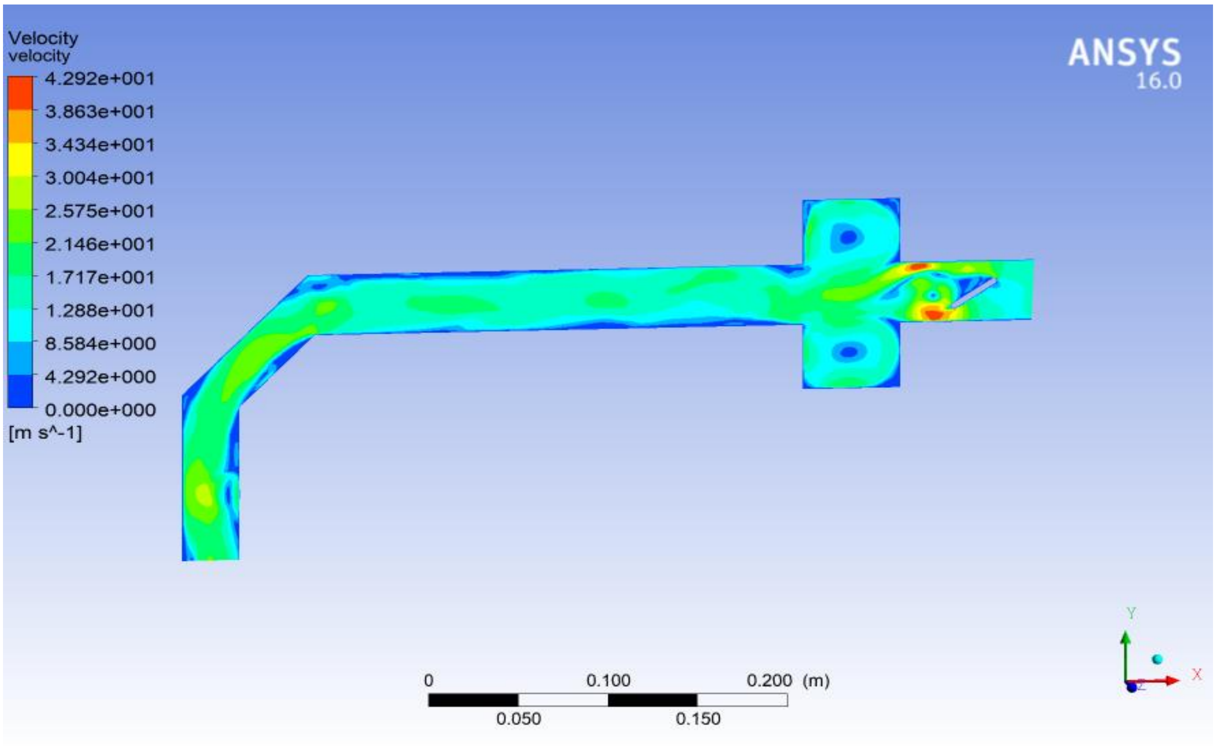


Figure 3.15: VELOCITY CONTOUR FINAL DESIGN

As there wonâĂŹt be any change in the temperature and pressure of the atmospheric air entering the system. The air that is going in the atmosphere would be at normal atmospheric conditions and no change in the same was done.

Now, the engine would always require only a certain maximum volume of air. In this case the engine would require 0.0001092 cubic metre of volume as the engine is 109.2cc. This means the engine, when undergoing suction stroke, that is when vacuum is obtained after the end exhaust stroke, would be requiring a 109.2 cubic centimetre of air. That is the maximum it can take up. So that was another constraint set as per the clear logic suggestions.

The velocity contour above suggests that had there been a more filleted curve rather than a sharp edge the flow would have been even more linear. The flow is very neat with no back velocity and the outlet flow is of higher speed than that of inlet.

The above shown figure shows the pressure contour of the intake design. The pressure drop is drastically reduced and the outlet is more organised than that on the stock intake. The case is again that of having a filleted edge rather than sharp edge, a factor which was taken care of during fabrication. Instead of fabricating a sharp edged profile a more curvy profile was fabricated. The analysis was not done because it takes approximately

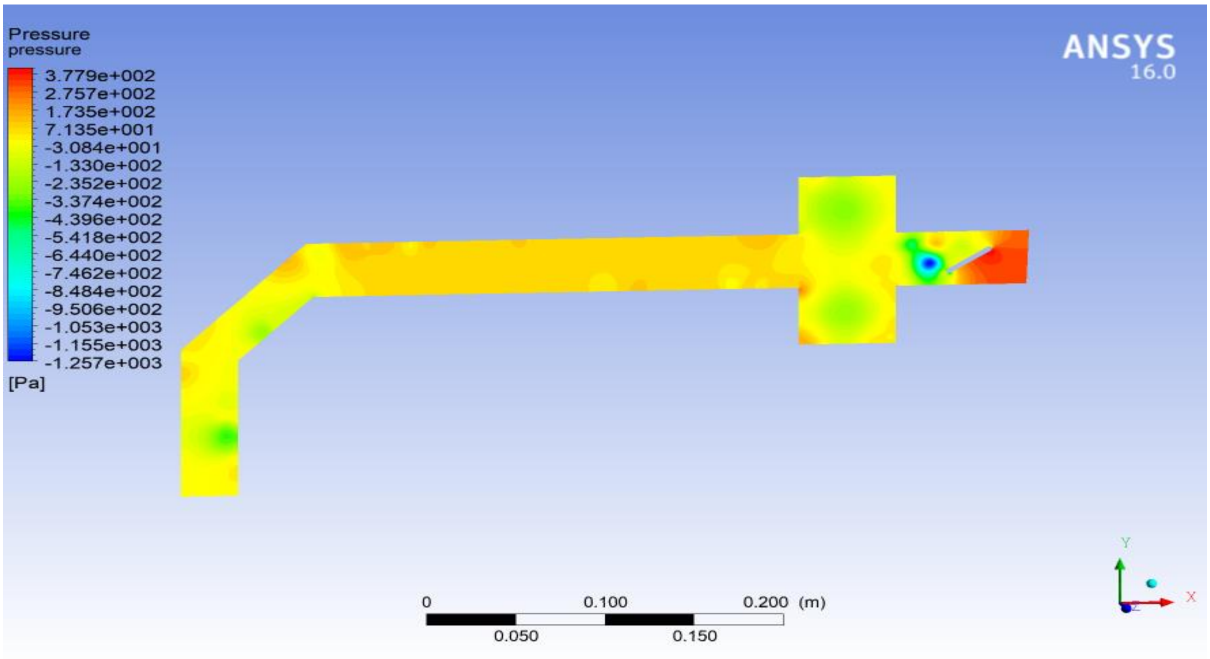


Figure 3.16: PRESSURE CONTOUR FINAL DESIGN

three hours for each iteration to be analysed.

The part therefore was carefully calculated, designed and analysed before fabricating. All the parameters were double checked before-hand and no stones were left unturned. The carefully assessment of the model before fabrication is always a sign of good engineering and all those processes were amply followed throughout the design phase of the project. The project was therefore left for only manufacturing and practical testing. For practical validation the Electronic Fuel Injection (EFI) system had to be up and running and a two wheeler dynamometer was required. The EFI system was running well with the engine reaching stoichiometric ratio. However, the two wheeler dynamometer was difficult to obtain. The university has a two wheeler dynamometer, which is used for teaching but cannot be used for conducting experiments. The reason is the dyno does not work. The dyno is used for teaching incorrectly and all the experiments are very carefully manipulated by the lab coordinators and lab assistants during the experiments. At a later stage when the setup was ready to be tested in two wheeler dyno it was found that testing in dyno cannot be done. This is where the idea of developing a rope brake dynamometer for testing purposes evolved and technicalities of rope brake dynamometer were studied.

CHAPTER 4

EXPERIMENTAL SETUP

Whenever a component is designed the constraints had to be noted. The two key things while designing a component is keeping constraints in the loop and remaining parts according to the constraints. It is basically an act of obtaining a perfect balance between the constraints and new part. The parameters before designing a component had to be well known and always be kept in mind. this case we had full liberty in deciding the constraints and designing the part accordingly.

The most likeable scooter in the Indian market right now is the Honda Activa. It

Figure 4.1: ACTIVA 110CC

is also one of the most optimised and clean engine. Honda Activa 110cc engine was therefore chosen as the biggest constraint of the project. Since it is one of the highest selling scooters across the country, procuring an Activa 110cc engine is also very easy. The 109.2 cc engine though has one problem considering this thesis, it is a carburetted engine and for the experimental setup we needed the system to be more controllable and derivable, hence an electronically controlled fuel injected system was required. The Honda engine was therefore chosen for its easy availability, easy working parameters and because there is no other scooter in the market with fuel injection.

The Honda Activa 110cc engine had to be converted in to a fuel injected engine from

Figure 4.2: ENGINE 110CC

the carburetted functioning it has. For the same, many fuel injection kits available in the market in some of the high end motorcycles were tried upon, however none of them were compatible with the small scooter engine and the data could not be simply derived from them without an open ECU. The internet is a vast place and this is where a simple google search led us to the many after-market fuel injection kits available for the small scooter engines.

Ecotrons EFI (Electronic Fuel Injection) kit was chosen as they provide a wide range of options to work with and the values to be obtained were easily derivable using the computer laptop. The EFI kit had already been discussed upon in the previous chapters. The more important thing to be noted here is that though the fuel injection kit allows to tune the engine leaner and richer as per requirement, the engine was allowed to run in the stoichiometry condition. This was done in order to minimise the changes in the stock setup and the ram setup made for the completion of the thesis. The engine was run till the breakdown period as an instruction given along with the fuel injection kit.

A jig is the stand for keeping the engine up in air and still keep it running so, Jigs were the next important thing. For doing any testing or before manufacturing any parts the jigs or the rigs had to be designed and manufactured with utmost perfection as the perfection of the component depends upon the quality of jigs design and fabrication. The engine jig was designed keeping a lot of thing in mind. The jig had to be in such a way that the engine can be removed and fixed back easily, engine can be refilled without needing to take the engine out of the jig and more importantly keeping the position of the engine exactly the same as that in the scooter, as changing the angle of the engine makes a huge difference in lubrication of the engine and that may lead to catastrophic results. Therefore keeping all these things in mind, the engine jig had to be designed. For designing the engine jig in CAD tool Solidworks the engine had to be designed first. The engine was designed in Solidworks with each mounting points at the same distance and the same angle as in the real.

The jig for the engine was designed using the above CAD model. Again, as the

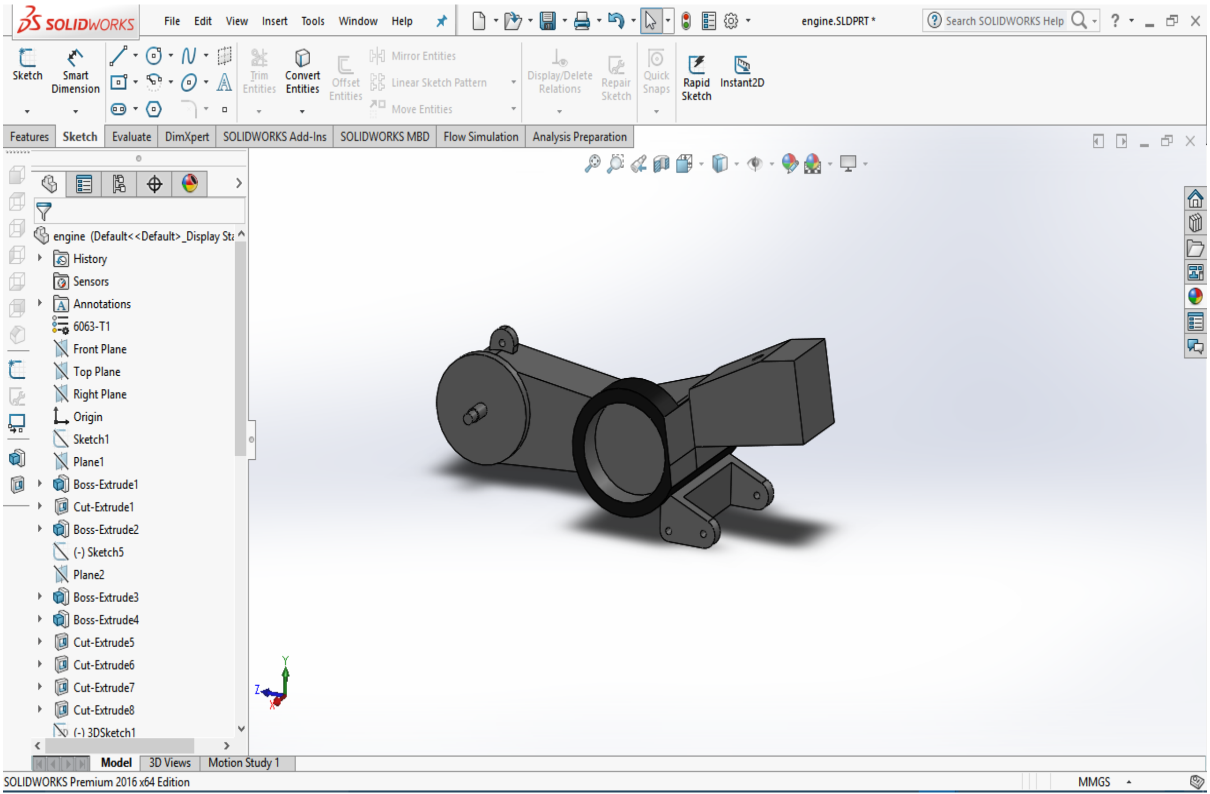


Figure 4.3: ENGINE CAD MODEL

designing began the first thing to be noted was the constraints and the constraints in this case is the mounting points and the structure or shape of the engine. Neither the mounting mounts can be changed to elsewhere nor can the shape be altered with. The engine jig was therefore started with three mounting brackets and the members were added afterwards. This helped us in maintaining the same angle of the engine as well as keeping the engine running.

The engine was supposed to take up the load of the running engine and therefore had to be a bit bulky and the members were made out of thick mild steel tubes. The Intake

Figure 4.4: ENGINE JIG DESIGN CAD MODEL

was desired to be made by using the newer methods like 3D-printing using the ABS (Acrylonitrile Butadiene Styrene) material.

The alternative solution was to find a pipe of the suitable diameter and bend it as per the design. The pipe can be either aluminium or made of any other plastic material. The aluminium pipe is easy to bend and can also welded. The plastic pipe would be difficult to bend but would be light in weight. The procurement of materials could only be done if they are available in the market and hence a market search was conducted to explore the material that can be used for the intake.

CHAPTER 5

FABRICATION

Fabrication is the art of copying the design in reality. If the part is manufactured exactly like the design that means all the processes has been followed properly. The fabrication or manufacturing of a part perfectly requires three steps to be followed.

- Design for manufacturing.
- Identifying the machining required.
- Designing the jig according to the process of machining done.
- Manufacturing the jig using cheap materials but with great accuracy and proper tolerances.
- Using the jig to manufacture the part.
- Comparing the fabricated part with the design after every stage.

The project involved manufacturing of a lot of parts. The first part was engine jig. The engine jig members are made out of mild steel and cutting and notching of the members were all done in-house with the university not helping even a little with the manufacturing of the jig. Once the members were notched, it was ready for welding. TIG (Tungsten Inert Gas) type welding was used for the welding of the members. The welding was also done by the members of the group and no outsourcing was done.

The parts of stock intake were machined using milling machine. The part had internal taper and was machined out in two days in the milling machine.

While all the parts were manufactured the engine was being converted in to a fuel injected one. The fuel injection conversion from carburettor required heavy wiring skills and high level of precision along with safety.

The jigs were therefore manufactured with all the process steps followed properly and in the end a very precise jig was made.

The manufactured part had to be now assembled with the engine. The engine had three mounting points, two at the front below the head and one in the back of the engine

Figure 5.1: ENGIEN AND JIG AND INTAKE ASSEMBLY

above the output shaft. The two front mounts used M10 bolts while the one in the rear had to be fixed using a M8 bolt.

The mounts were also stuffed with rubber bushings so as to reduce the vibrational losses and unwanted noise.

The EFI kit installation was the tricky stuff and required heavy knowledge on wiring and safety. The following steps were followed to install the EFI kit in place of carburettor.

- Carburettor was removed from the motorcycle.
- New throttle body was installed at the same location of the carburettor. A new adapter was needed to connect the throttle body as there is no such after-market manifold that can fit.
- Connecting the throttle body inlet to the air hose from the air filter.
- Bolt-on the new intake manifold to the inlet of the engine, with the heat insulator in between.
- Install the existing throttle cable to the throttle body.
- MAP sensor is connected to the intake manifold with the small pipe (4mm diameter).

MAP sensor needed to be connected with the intake manifold and had to be sealed and air tight. The MAP value should read vacuum. The wiring harness had the connectors for other sensors well marked and highlighted.

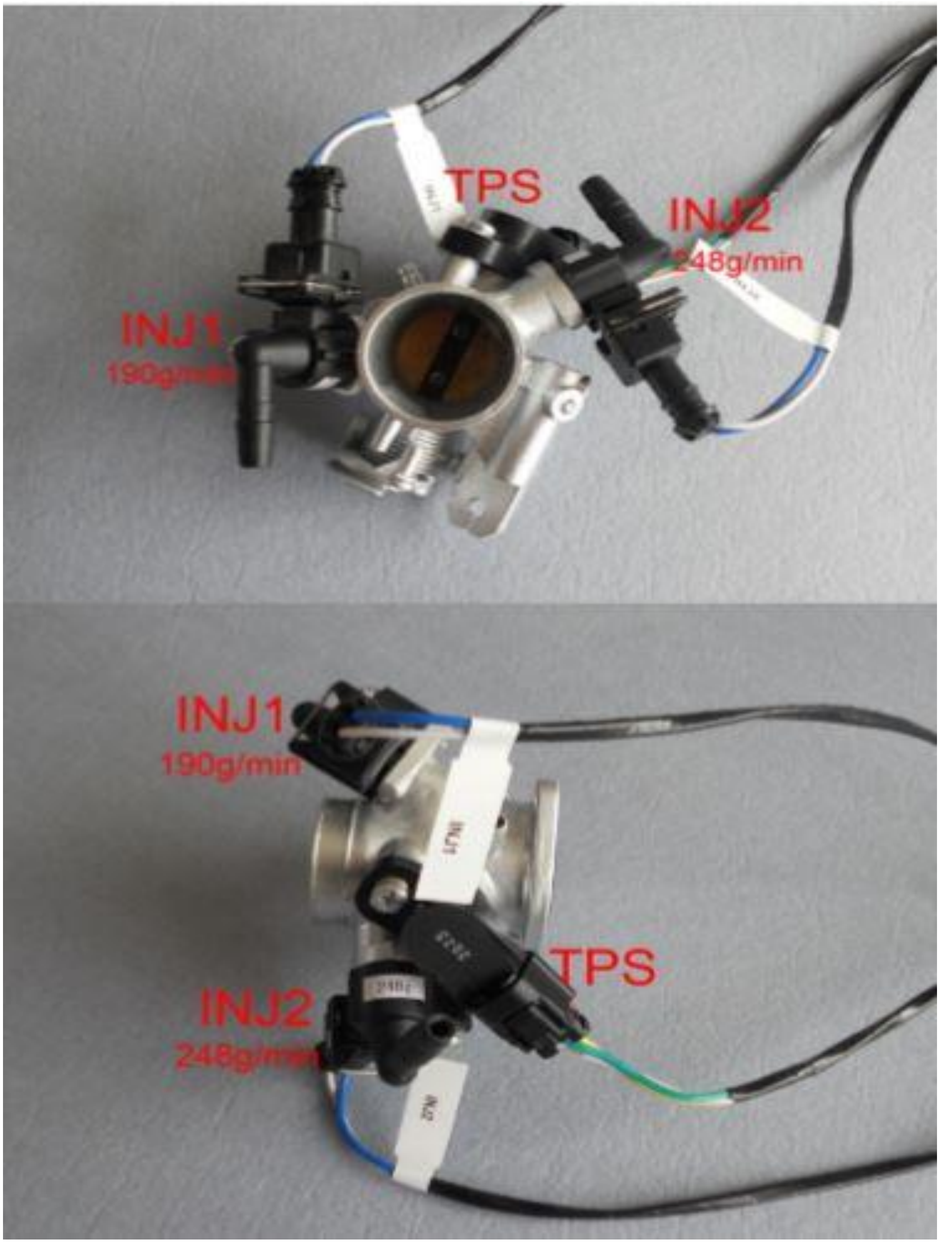


Figure 5.2: THROTTLE BODY AND SENSORS

The above figure shows the connections of the respective sensors with the wiring harness. The wiring harness itself is a big lay out of a cluster of wires wound around with all the wires ultimately culminating at the ECU.

The diagram below shows the wiring harness laid out in a table. The EFI wiring harness had to be coupled with the starter motor harness. The wiring as can be seen is highly complex and required a lot of time to set up.

The wiring was completed and the engine was run on the fuel injection successfully.

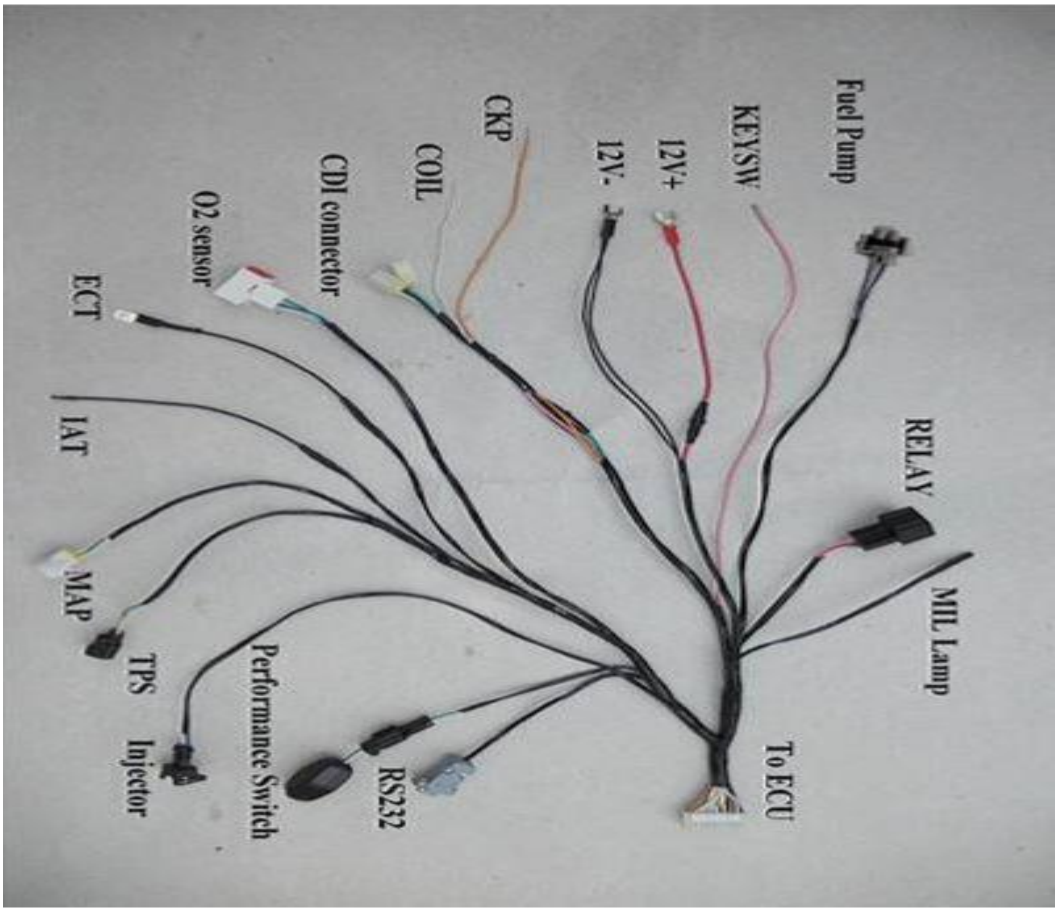


Figure 5.3: WIRING HARNESS EFI KIT

Some early values were noted down.

The final working picture of the EFI run Activa engine with stock intake is shown in the above diagram. Some of the stock intake parts were still used, while a small adapter had to be machined for connecting the throttle body. Volumetric efficiency of the stock intake was inferred using the software ProCAL. The following results of volumetric efficiency were obtained.

The results of volumetric efficiency reach a maximum of 82percentage at around 5000

Figure 5.4: EFI WORKING

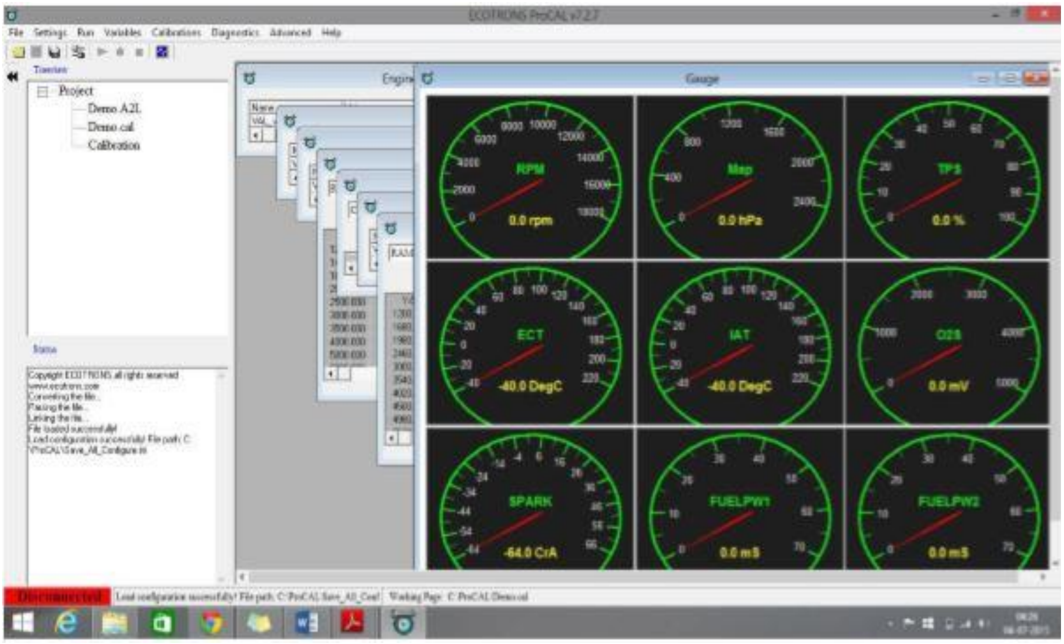


Figure 5.5: SAMPLE DISPLAY EFI SOFTWARE

rpm. When on the run, it is noted that the air pressure readings attained by the MAP (Mass Air Pressure) sensor is around 550 to 750 hPa. The value varies with altitude and in the testing place currently at Chennai, the above results were obtained. Air temperature and pressure also plays a major part in MAP sensor readings.

With the readings of stock intake taken and documented. It was time for comparing the volumetric efficiencies of the stock intake with the variable length intake manifold. For doing the same, the variable length intake had to be manufactured. The fabrication of intake took some thinking as the material and manufacturing processes were not on our side. Therefore, market research for a suitable ligh t weight material which could be bended easily was done. On completion of the market research it was found that there is a translucent polyvinyl pipe which can be bended under the influence of heat. The diameter calculated was also available and finally the material search was completed.

The above shown pipe is the intake primary pipe with a PVC pipe sliding along on

Figure 5.6: INTAKE PIPE MATERIAL

the periphery as the secondary pipe. The PVC pipe was chosen because it can be easily meshed with the plastic rack and pinion and at the same time is light weight which is better for faster movement.

However the pipes could be very unreliable and break off easily if the engine back fires on a regular basis. This is one of the problems we had to face and therefore a number of intake of parts got damaged because of the same. Having said that, the 3D printed model would have also faced the same fate. The engine tuned by the OEMs are very reliable these days and do not tend to back fire or knock as much as the fuel injected Honda engine that we converted.

The next part of the project was to test the model under closer to real conditions. For testing the major equipment required was a two-wheeler chassis dynamometer, which, even after being available in the university lab facilities could not be used because of the condition of the dynamometer. This meant that the intake could not be tested for its purpose, and the torque figures could not checked for real improvements apart from theoretical suggestions. A solution was found for the same and has been discussed in detail in the upcoming chapters.

For manufacturing the intake itself a lot of materials were pondered over with. First model was made out of aluminium.

The pipe was smooth from inside, bends could be easily made and it was also cheap

Figure 5.7: ALUMINIUM INTAKE

to procure and two different parts could be welded together. This looked ideal up until the time of installation of the intake on the engine. The intake length was a bit too long and because of that the variable part or the end part of the intake collapsed of its own weight.

This lead to the testing phase getting delayed and the requirement of manufacturing of new intake with the same design but which is much lighter than this. This is when a market survey helped us find a plastic pipe which could be sealed properly with the help of O-rings and araldite and could act as the intake pipe.

The intake manifold was finally ready. The schematic diagram of the manifold is

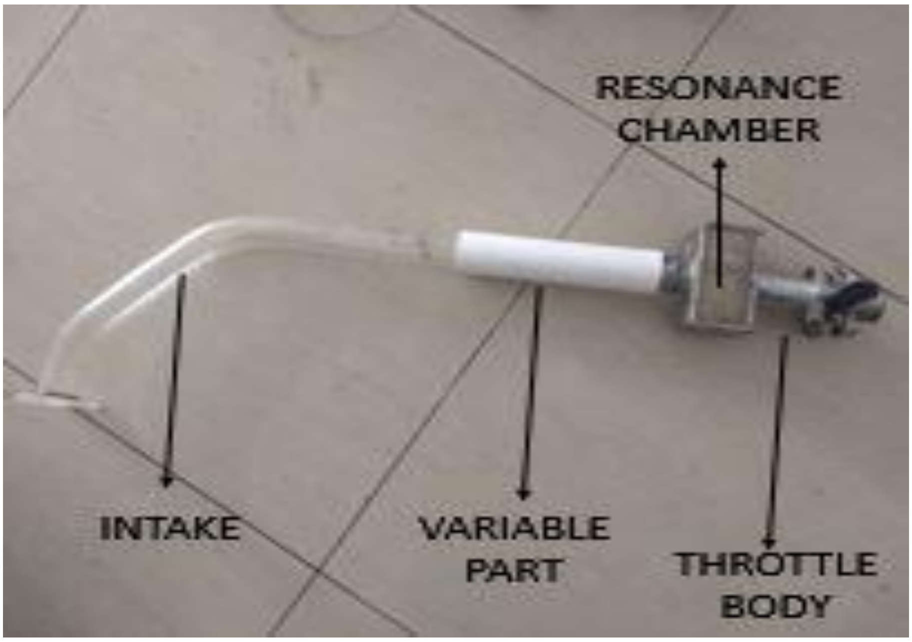


Figure 5.8: MANIFOLD FIRST LOOK

shown above. The fixed part of the intake is attached to the engine intake port using flange on the manifold end. The flange is attached to the manifold using O-ring and araldite. The variable part is a straight pipe whose ID is just big enough to slide outside of the fixed pipeâĂŹs OD. The resonant chamber is sealed and fixed unmovable to the variable part of the manifold. As the box structure is difficult t manufacture from the polyvinyl material. The throttle body is attached to the intake runner using bolts and has flanged connection at the end of the variable part of the manifold.
For the next part of the manufacturing included varying the length using rack and pinion.

The pinion was supposed to be controlled with the help of a motor, which in turn is controlled with the help of Arduino. Input for Arduino is the waves of signal obtained from the CKP or Crankshaft Pickup Sensor in the engine. The CKP sensor delivers the value of engine rpm which is the main and only input which decides in the length of the intake. Therefore the design needed to be efficiently transformed in to the working reality.
The initial control design is shown above. The control of the motor was planned to be carried out in a certain manner. However it was later noticed that there was requirement of a module or relay which would help in switching the polarity of the motor and

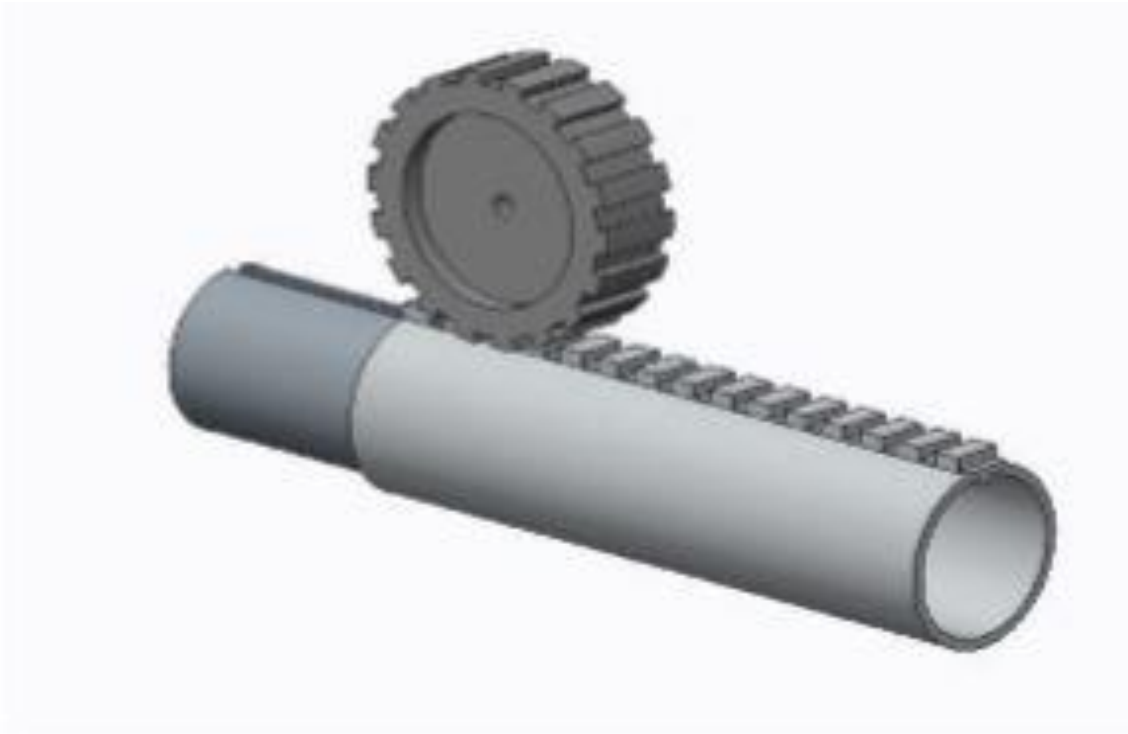


Figure 5.9: RACK AND PINION DESIGN

hence would help in retracting thee length during deceleration. The manufactured part is shown below.

The rack and pinion along with the electrical control of the system is shown above.

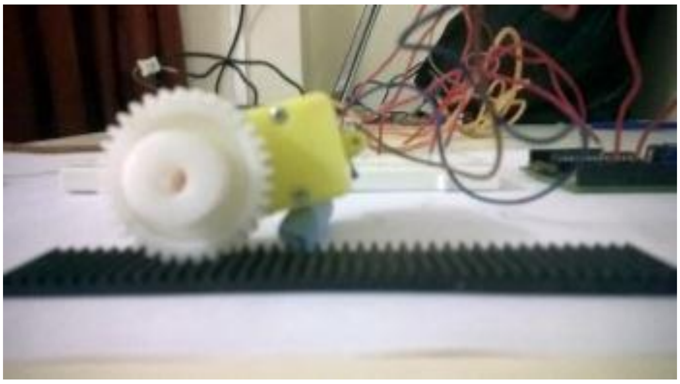


Figure 5.10: RACK AND PINION MECHANISM

The rack and pinion were tested and calculated beforehand. The rack and pinion had to be incorporated in to the manifold now.

The rack and pinion was successfully installed in the manifold. The small changes that were required to be made from the initial design are, in the design a shift module is claimed, while we used the relay instead. This was done siting the need for a

Figure 5.11: INTAKE MANIFOLD FINAL ASSEMBLY

much bigger motor in the actual application in which case a shift module would not work. The other change made from the design was the use of Arduino Nano instead of Arduino uno. Both the Arduinos would work just fine and it would barely make any difference, infact the added advantage of using Arduino nano is that its more compact and the system as a whole can get smaller.

CHAPTER 6

TESTING AND VALIDATION

The testing and validation of the engine to generate the required power and torque graphs are tested using a rope brake dynamometer which has been self-fabricated. Rope brake dynamometers are generally not too accurate to be honest. But the development of a rope brake dynamometer turned out to be of vast help during the course of the project in helping us achieve a flatter torque curve as was the objective. In order to do built a rope brake dyno, we had to convey some research and literature survey needed to be done.

Ifs and buts of the dyno had to be studied extensively. Various different types of dynamometer were studied and rope brake dyno was chosen. There are a few reasons for the rope brake dyno to be chosen, firstly they are easy to manufacture. The manufacturing of rope brake dyno is easy. Secondly, they take less time to couple with the engine unlike a gear pump dyno.

Spring balance readings was developed. The same model was again developed using the previous philosophy of obtaining a CAD drawing of the component and then modifying the design for the manufacturing. The CAD model of the rope brake dynamometer is shown below. The model is developed in the design tool Solidworks.

The Dyno basically has two gauges or spring balances, which hang on the top next to each other at the top cross member. The spring balance in this case acts as weight and spring balance readings respectively. The spring balance on the left acts as weight. When the nut on the top is tightened more weight is added.

The spring balance on the right is kept untouched and deflection is observed and noted as the weight is added. The drum or the pulley is coupled with the engine using splines and lock nut, all of which was manufactured using hobbing. Both the spring balances are linked to each other using a rope creating a loop and the loop going through the drum or pulley which in turn is connected to the engine.

The problem with this design is that not more than 50 kg of load can be applied. The rope tends to get very hot due to very high friction between the rope and rotating drum

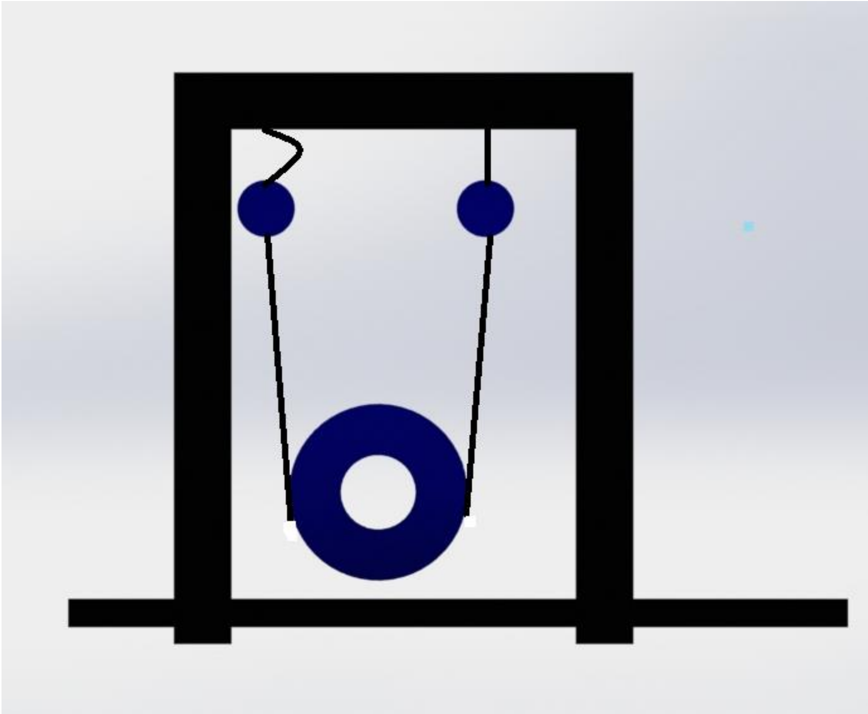


Figure 6.1: ROPE BRAKE DYNAMOMETER CAD MODEL

or pulley. Especially at high speeds the rope tends to slip a lot sometimes even burning the rope.

Rope dynamometers are usually used for testing small engines or low rpm engines. Honda 109.2 cc CVT engine is considered to be a high rpm engine compared to the type of dyno used for testing.

The advantages of the rope dynamometer however overweighs the disadvantages in our case and hence the fabrication was done. Before the fabrication began suitable size Mild Steel tubes were ordered and purchased. Suitable lengths of the members were obtained from the CAD design and were cut and notched.

The notching process is shown in the above picture. The fabrication processes involved lot of dangerous cutting and fabrication and hence all safety measures were carefully followed.

The members were marked with numbers as per the CAD design, and TIG welding method was used to weld the members together. The dials were then connected with the help of nut tightened V-hook.

The above showed picture is the final manufactured product. The dynamometer is successfully fabricated. A flat belt and normal rope both were used for testing and comparing with the actual values. It noted that the values obtained with stock intake using

Figure 6.2: DYNAMOMETER

the dyno made varies by 20 percentage. However, when the suitable torque curve is drawn the trend of the curve is noted to be similar to that of the actual torque curve. Rope brake dynamometers are shoddy and can be developed rapidly yet brake control can't be estimated precisely in view of progress in the grating coefficient of the rope with an adjustment in temperature. The brake control is given by the formula

Brake Power (bp) = ÏĂ DN (W âĹŠ S)

Where D is the brake drum diameter,
W is the weight of the load and
S is the spring balance reading.
r= r1+r2
Braking Torque= Tb=(W-S) x r
Power absorbed by engine= 2ÏĂN(W-S)/(60*1000)(KW)
The following test has been derived from the dynamometer readings by placing weights and the respective dead weight on the other spring balance.

Table 6.1: OBSERVATION TABLE AT 1000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	2.117	2.833	0.807
2	10	7.109	2.893	0.810
3	15	12.150	2.850	0.798
4	20	17.113	2.997	0.803
5	25	22.318	2.682	0.817
				Mean = 0.807

Table 6.2: OBSERVATION TABLE AT 2000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	0.714	3.013	1.200
2	10	6.025	3.975	1.113
3	15	11.068	3.956	1.101
4	20	16.504	3.496	0.979
5	25	22.238	2.762	1.172
				Mean = 1.113

With the help of the spring balance

A suitable torque vs rpm curve was hence plotted with the above inferred values. The graph looked something like this, as shown below. It can be noted that the peak torque obtained from the dyno reads 6.894Nm. However Honda claim the peak torque to around 8.7-8.889Nm.

Actual Torque curve for the Activa engine was plotted for obtaining the curve and comparing it with the dyno obtained torque curve. The below shown graph of torque vs rpm represents the actual torque curve of the Honda 110cc engine.

A more realistic and actual torque value can be seen in the above curve. The torque values are linearly increasing and the peak torque of 8.7Nm is achieved at around 5500rpm. Though the actual peak torque value is 8.889Nm but the torque curve given by Honda denotes the peak torque is achieved at 5500 rpm and the value is slightly less.

Table 6.3: OBSERVATION TABLE AT 3000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	0.564	4.465	2.341
2	10	5.782	4.265	2.258
3	15	10.123	4.987	2.017
4	20	15.465	4.213	1.913
5	25	20.456	4.587	2.796
				Mean = 2.265

Table 6.4: OBSERVATION TABLE AT 4000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	0.456	4.598	4.579
2	10	5.013	4.987	4.501
3	15	9.356	5.658	4.328
4	20	14.598	5.325	3.928
5	25	19.795	5.239	4.304
				Mean = 4.328

Table 6.5: OBSERVATION TABLE AT 5000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	0.402	4.598	6.895
2	10	4.126	5.894	6.314
3	15	9.100	5.900	6.528
4	20	13.984	6.132	5.438
5	25	19.521	5.498	6.270
				Mean = 6.289

Table 6.6: OBSERVATION TABLE AT 6000 RPM

S.NO	W in Kg	S in Kg	W-S	Tb =W-S x r
1	5	0.231	4.769	6.000
2	10	3.298	6.712	6.710
3	15	8.451	6.549	5.821
4	20	13.337	6.663	6.132
5	25	18.735	6.265	6.067
				Mean = 6.146

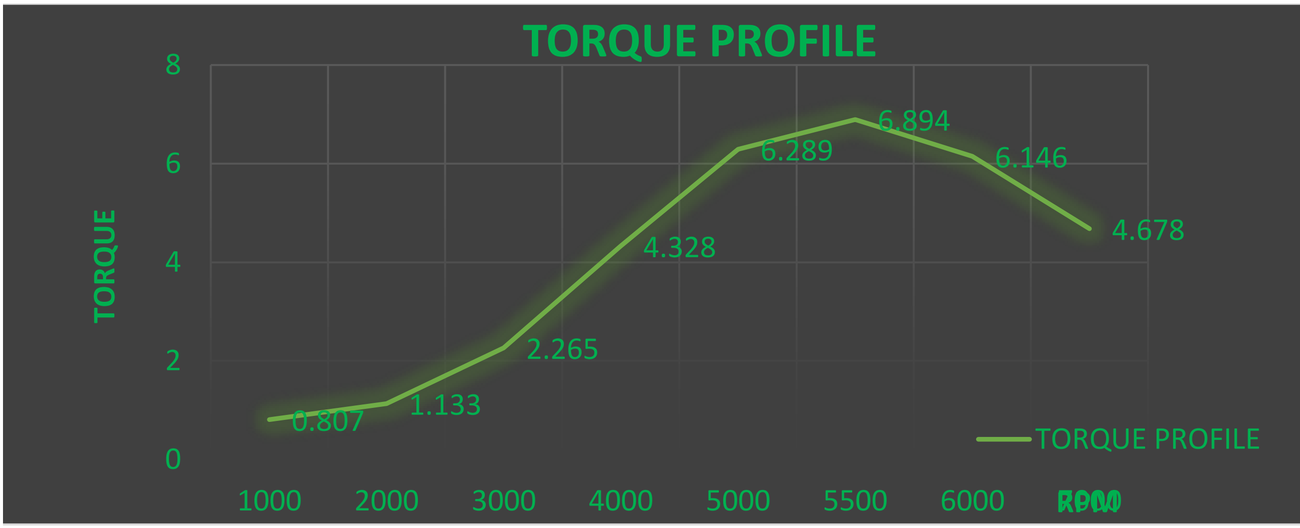


Figure 6.3: TORQUE CURVE FROM DYNO

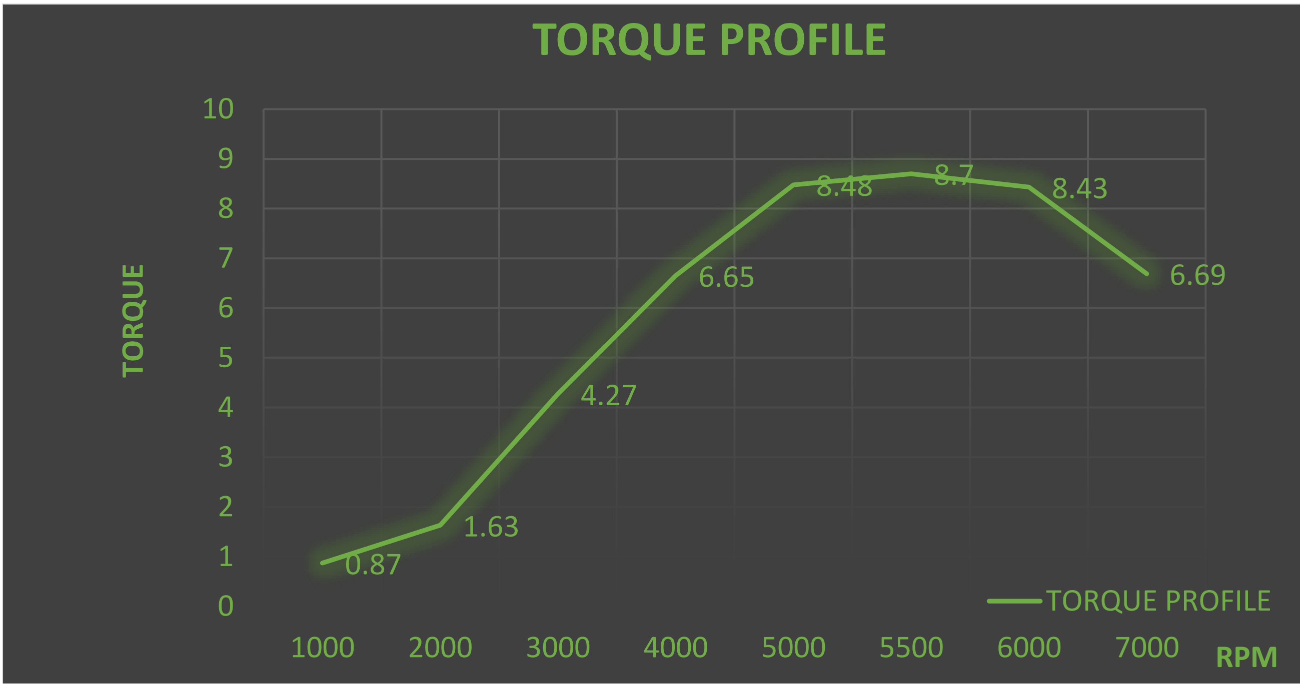


Figure 6.4: ACTUAL TORQUE CURVE

Once the dynamometer results for the stock intake was obtained, the test for the volumetric efficiency was conducted. To conduct the volumetric efficiency test, Ecotrons EFI system was needed to be connected with the engine and the engine needed to be run. Honda engine naturally ran on carburettor and the need for fuel injection rose because of the complexities involved around the experimental testing of the project. A two wheeler chassis dynamometer would have solved the problem, but because of instituteâĂŹs dyno not working properly, other alternatives like installing the fuel injection became a necessity.

Ecotrons EFI (Electronic Fuel Injection) kit is available to buy online through the site. The kit costs around fifty thousand rupees and import and customs charges would be an added extra. The advantage of the fuel injection kit however were tremendous. The kit offered self-tuning capabilities as well, which would prove to be a useful feature later on during the testing phase.

The stock intake was fitted first and testing was done on the stock intake first using dyno and then for the volumetric efficiency obtained through the kit.

The fuel injection was electronically controlled by the ECU (Electronic Control Unit). The kit offered full control over fuel, ignition and throttle. The lambda sensor provided in the kit would help in attaining auto-tune settings once the engine is warmed up. Once the engine is warmed up, the ECU starts running in closed loop condition. There are basically two conditions in which the engine primarily runs. Open loop and closed loop. By default, the O2 sensing element comes with associate Ecotrons EFI kit (if included) could be a narrowband O2 sensing element. It will solely indicate "rich" or "lean" conditions of the air fuel ratios. It cannot tell however you ways you the way made or how lean the mixture is. and so it cannot tell you ways far more or less fuel you must accommodates get to the AFR (Air-Fuel Ratio) you would like.

Ecotrons EFI kit doesn't embody a Wb O2, by default, as a result of it needs a special driver circuit, and since the Wb O2 is far costlier than the NB O2. what is more, many shoppers do not extremely do fine-tuning with a Wb O2 sensing element just in case the EFI kit has been tuned for his engine already. that is why the EFI kit doesn't associate with a band O2.

But if you are doing have to be compelled to tune your EFI for your engine, that is that the case if your engine has ne'er been regenerate with Ecotrons EFI kit before, or if you've got created plenty of client changes to your engines; and conjointly if you wish to grasp the period of time AFR and donâĂŹt mind to pay a handful of hundred a lot of dollars; you'll purchase a band kit beside the EFI. Then you'll be able to integrate the ALM and therefore the eu along seamlessly.

We need a maestro broadband O2 device and a broadband controller / or a lambda meter, as referred to as in automobile industries, to accurately live the lambda throughout a good choice, and feedback the amount of your time lambda to the eu.

The broadband O2 device forever desires some quite special driver circuit to manage it. The circuit itself is subtle. it's really utterly completely different than the circuit of narrowband O2 device. that identical eu that runs with a NB O2 cannot run the magnetic magnetic flux unit O2 with constant circuit. Meaning, the magnetic magnetic flux unit O2 is not compatible with a NB O2!

EcotronâĂŹs broadband controller, correct Lambda Meter, or ALM, is taking care of this issue. It controls the maestro LSU four.9 device and live the amount of your time accurately, and it converts that lambda to a linear analog voltage and send it to the eu. The eu will convert the voltage back to lambda (AFR) and management the fuel consequently.

For most EFI kits, there is a NB O2 device instrumentality on the eu harness, that the

Figure 6.5: A/F RATIO

engine can run in closed-loop management. And if we wish tune the fuel mapping, a broadband controller ALM is needed; it'll browse the amount of your time lambda. which we have a tendency to connect the ALM to eu via NB O2 device connector; we have a tendency to square measure ready to log the amount of your time lambda, and might conjointly keep the perform of performance switch, so we have a tendency to square measure ready to value more highly to use the ECO or moneyed mode.

This setup still uses the ALM linear izzard analog output as a result of the reading of lambda only. The eu jointly uses the ALM simulated NB O2 output as if there are associate NB O2 place in, so itwill run close-loop fuel controls whereas not associate actual NB O2. eu jointly logs the amount of your time lambda, but do nothing with this signal. it's useful simply just only have one O2 device bung on the exhaust (almost all people have only one bung), and so the bung is employed either NB O2, or WB O2.

This setup is helpful if wishwe would likewe wish to run close-loop fuel and jointly need to log the amount of your time lambda, then replay the logged info, see but smart our shut loop fuel is, and still be ready to manually regulate the fuel maps shortly.

Auto-Tuning means ALM and eu will work on and tune the AFR as per would love. In ECU, AFR is painted by Lambda (equivalent AFR). Lambda = one means AFR fourteen.7 for fuel.

The default target Lambda is one.0 across the board. One can define our own desired Lambda obsessed on the speed and TPS. Usually, a touch moneyed AFR at high rate / high TPS is preferred to have Associate in Nursing improved performance still as engine cooling impact. A typical desired Lambda table will be zero.85 at high rate and high TPS and one.0 everywhere else. the desired Lambda table got to be engine specific. Some engines hate fourteen.7 AFR at idle, and would possibly only be stable if it is a bit moneyed. in this case, one got to define the desired Lambda to match the engine characteristics.

With the Auto-Tuning feature, ECU will read the ALM's real-time lambda input, and

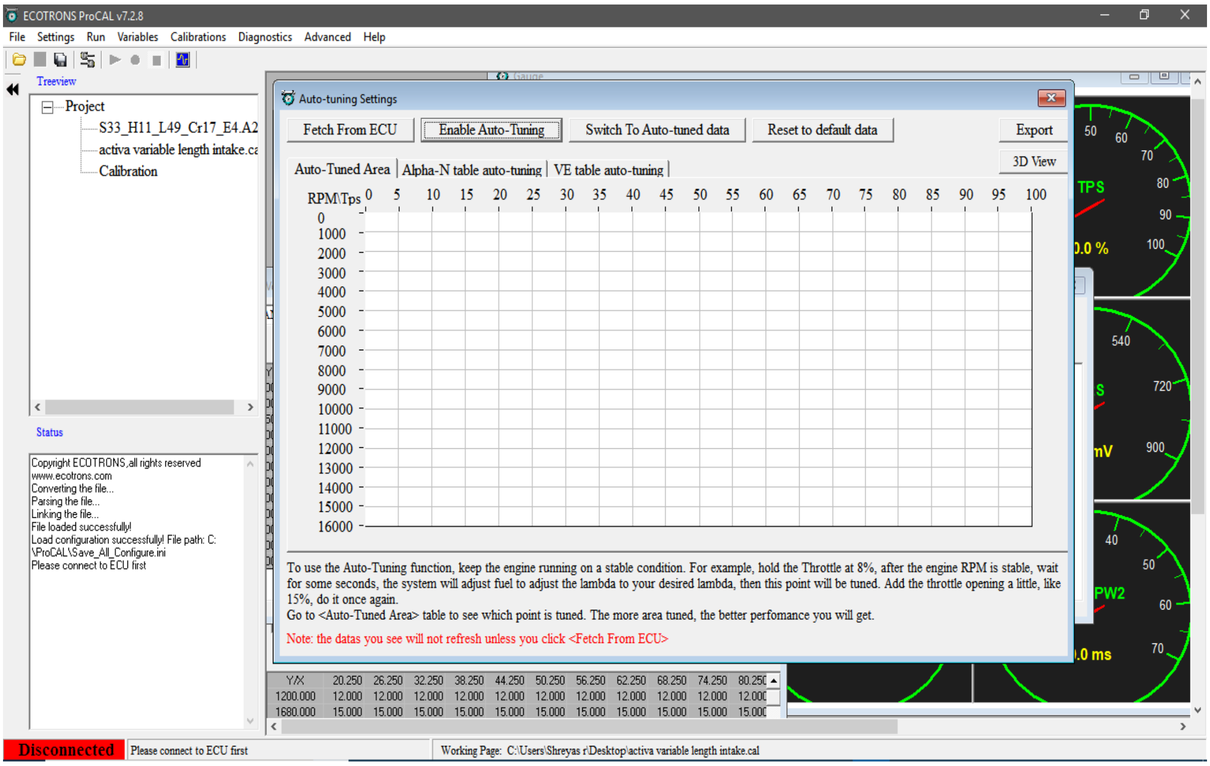


Figure 6.6: AUTO TUNING

automatically adjust the fuel towards the desired Lambda at that RPM and TPS status. ECU will store the learnt data in its own memory. After the engine is run at different operating conditions (RPM vs TPS) for a while; it will eventually learn most of operating points. And the engine is tuned then.

All that is needed to be done is drive the engine in different throttle positions and different RPM in âĂIJsteady state drivingâĂİ. (Steady state means holding throttle position at a certain RPM for about 10 seconds.) , ECU-ALM will take care of the rest.

The EFI will be able to log data in to the computer with the help of the software interface ProCAL or EcoCAL. The software interface is easy to use if one has some experience beforehand of using engine tuning softwares. However, it is not too hard to learn and can be easily learnt in a few weeksâĂŹ time. The software has to be preinstalled in computer and can sometimes cause glitches.

The ECU is connected to the computer using RS232 port. The RS232 port is connected to the USB port of the computer with the help of RS232 to USB port converter cable. The cable also sometimes tends to not work properly as RS232 is a very old way to connect systems with data logging. The data logging is done in csv format which is difficult to convert in excel form with lots of tables and columns having same notions. Therefore live data feedback was taken from the software interface during the testing of the engine. This helped in presenting in a more dynamic way as explaining an excel sheet is way more difficult and is also more pleasing to look at.

The software interface looks like the picture below. The dials representing various parameters are available and live values are shown as and when engine is connected and running. The control parameters include air system, fuel system, and ignition system. All the parameters that one could possibly think of can be changed, noted or logged as per the user requirement.

So the engine was run with stock intake first and the value of air pressure and volumetric efficiency was logged. The test was basically done to compare the air pressure and volumetric efficiency increase in the new intake from the stock intake. The software usually calculated the volumetric efficiency with the help of MAP (Manifold Air Pressure) sensor readings input to the ECU, varying with respect to the RPM of the engine. Engine rpm is taken with the help of pick-up sensor fitted at the crankshaft. It is basically a hall sensor, which senses the magnetic pole strip attached to the rotating crankshaft. It is called crankshaft pick-up sensor or CKP sensor commonly in the auto industry.

The volumetric efficiency readings of the stock intake are shown below. The table is basically a plot between MAP (Manifold Air Pressure) and RPM. On the X-axis MAP readings are given and on the Y-axis RPM is marked. When the engine is not running the Map reads atmospheric pressure that is 1013hPa. When the engine starts running it is noted and observed that the MAP readings vary from 450 to 700hPA.

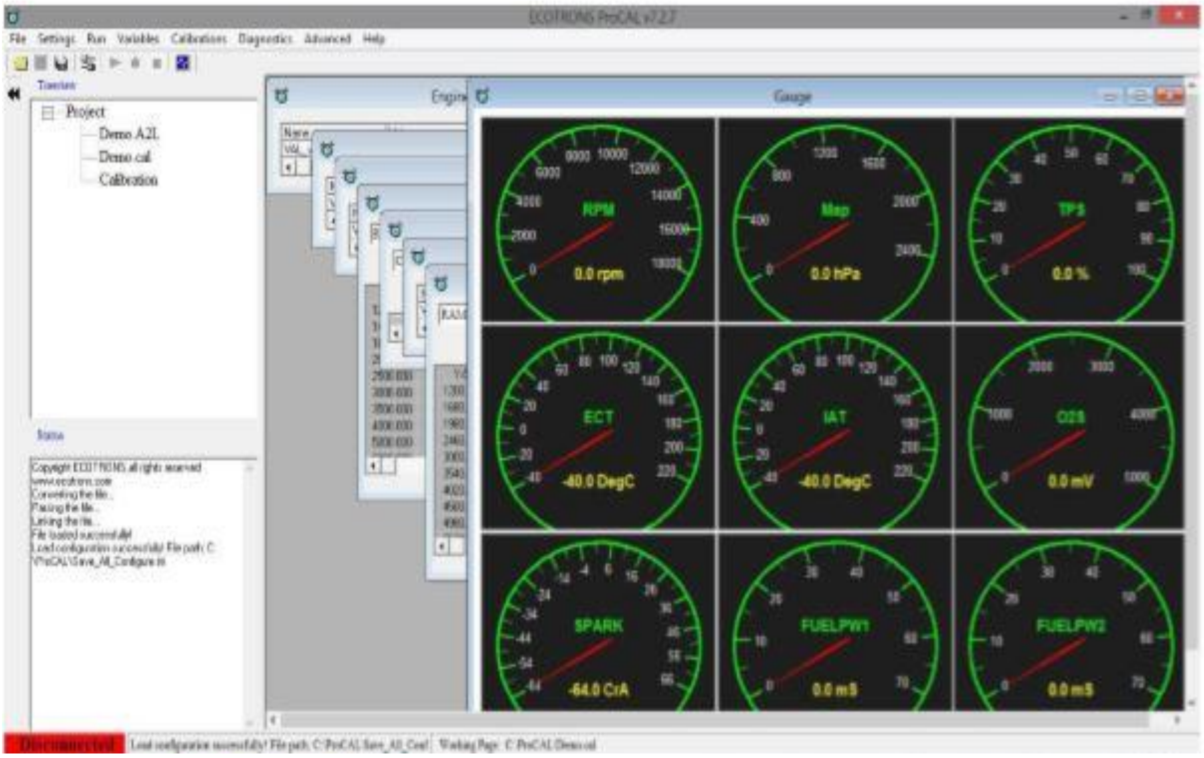
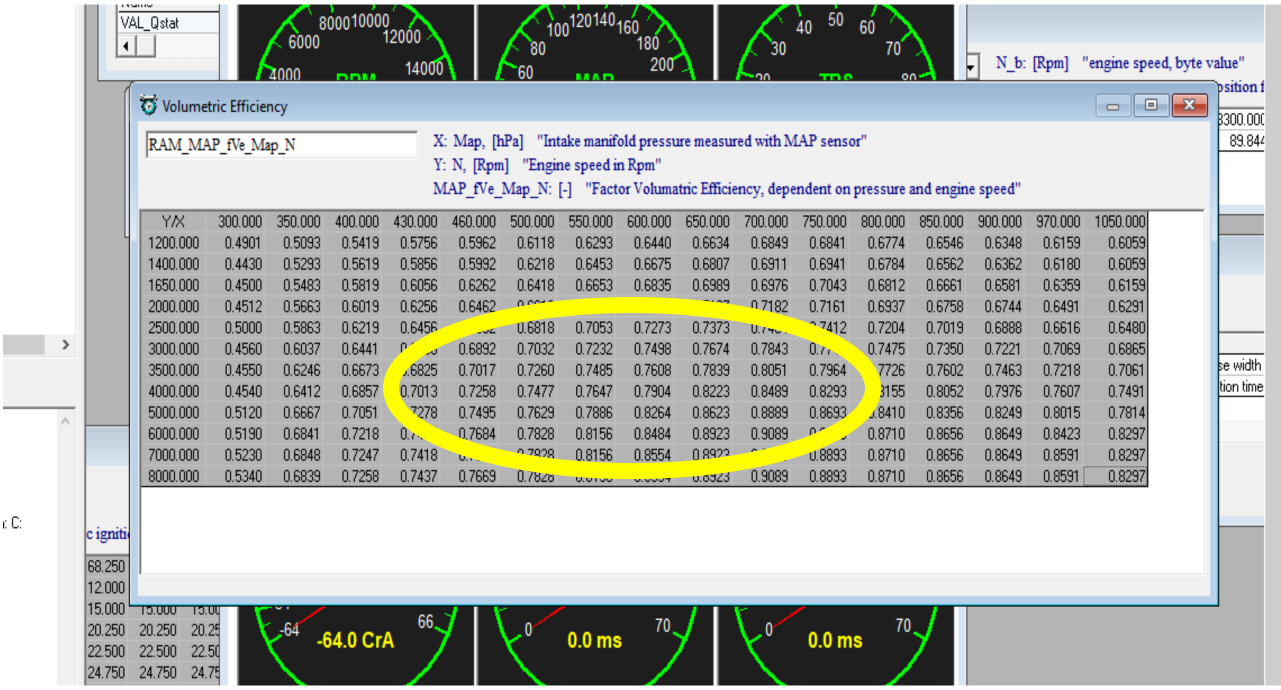


Figure 6.7: DATA LOGGING DISPLAY

It can be noted that from rpm range 3000 to 6000, which is the rpm of concern, at map reading ranging from 450 to 700hPa, the maximum volumetric efficiency obtained is 92 percentage. In theory it has been several time observed to obtain more than even 100 percent of volumetric efficiency at certain conditions. But with such values obtained with the stock intake the results were rather disappointing. This lead to the important question of efficiency improvement of the engine ass a whole. Not only does the fuel economy improve but an improvement in the above table will also lead to an improvement in the overall performance of the engine giving it a boost of approximately 15 percentage in the power and torque values.

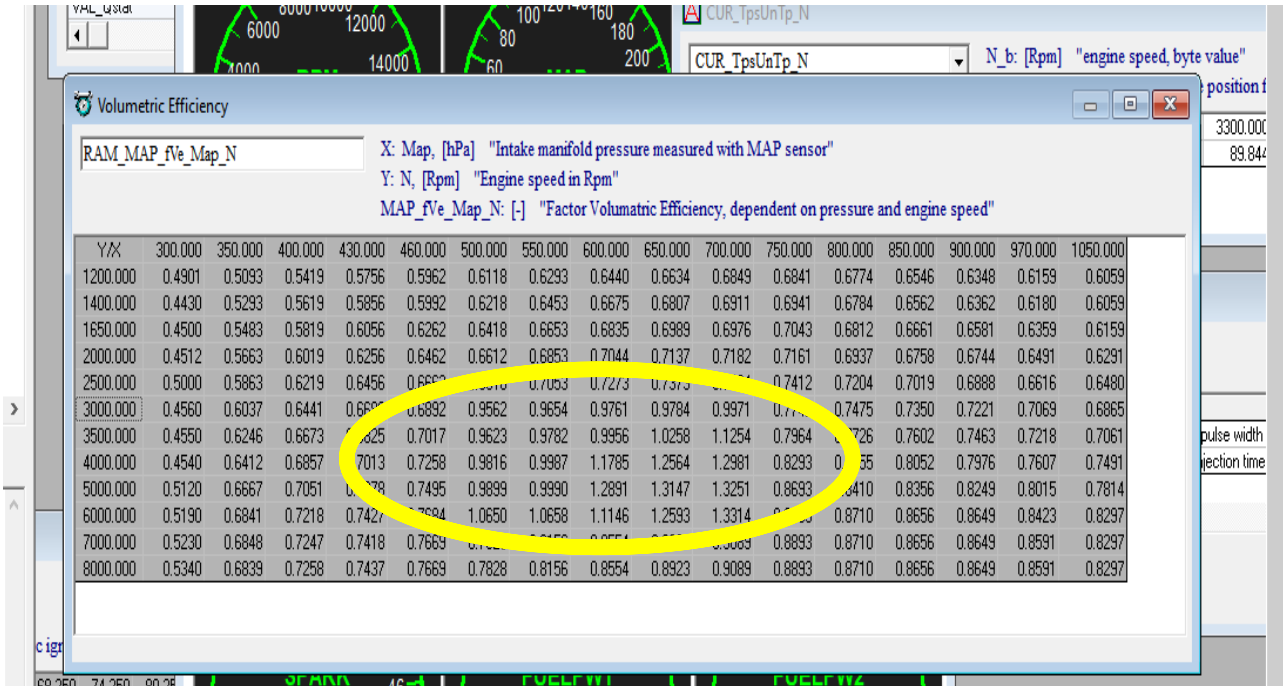
The result was enough to plot a curve comparing the volumetric efficiencies of the stock and new intake design. In the next segment, the volumetric efficiency of the new intake is discussed in detail.

The table shown represents the value of volumetric efficiency of the engine when run with the above shown intake. The length was varied manually for taking the readings. The sealing of the moving parts were done using O-ring inside the fixed pipe placed on the periphery using a groove. On the X-axis of the table is shown the MAP reading and on the Y-axis, rpm. When engine is running the map value jumps from 450 to 700hPa.



Y/X	300.000	350.000	400.000	430.000	460.000	500.000	550.000	600.000	650.000	700.000	750.000	800.000	850.000	900.000	970.000	1050.000
1200.000	0.4901	0.5093	0.5419	0.5756	0.5962	0.6118	0.6293	0.6440	0.6634	0.6849	0.6841	0.6774	0.6546	0.6348	0.6159	0.6059
1400.000	0.4430	0.5293	0.5619	0.5856	0.5992	0.6218	0.6453	0.6675	0.6807	0.6911	0.6941	0.6784	0.6562	0.6362	0.6180	0.6059
1650.000	0.4500	0.5483	0.5819	0.6056	0.6262	0.6418	0.6653	0.6835	0.6989	0.6976	0.7043	0.6812	0.6661	0.6581	0.6359	0.6159
2000.000	0.4512	0.5663	0.6019	0.6256	0.6462	[illegible]	[illegible]	[illegible]	[illegible]	0.7182	0.7161	0.6937	0.6758	0.6744	0.6491	0.6291
2500.000	0.5000	0.5863	0.6219	0.6456	[illegible]	0.6818	0.7053	0.7273	0.7373	[illegible]	[illegible]	0.7204	0.7019	0.6888	0.6616	0.6480
3000.000	0.4560	0.6037	0.6441	[illegible]	0.6892	0.7032	0.7232	0.7498	0.7674	0.7843	[illegible]	0.7475	0.7350	0.7221	0.7069	0.6865
3500.000	0.4550	0.6246	0.6673	[illegible]	0.7017	0.7260	0.7485	0.7608	0.7839	0.8051	0.7964	[illegible]	0.7602	0.7463	0.7218	0.7061
4000.000	0.4540	0.6412	0.6857	0.7013	0.7258	0.7477	0.7647	0.7904	0.8223	0.8489	0.8293	[illegible]	0.8052	0.7976	0.7607	0.7491
5000.000	0.5120	0.6667	0.7051	[illegible]	0.7495	0.7629	0.7886	0.8264	0.8623	0.8889	0.8693	[illegible]	0.8356	0.8249	0.8015	0.7814
6000.000	0.5190	0.6841	0.7218	[illegible]	0.7684	0.7828	0.8156	0.8484	0.8923	0.9089	[illegible]	0.8710	0.8656	0.8649	0.8423	0.8297
7000.000	0.5230	0.6848	0.7247	0.7418	[illegible]	[illegible]	0.8156	0.8554	[illegible]	[illegible]	0.8893	0.8710	0.8656	0.8649	0.8591	0.8297
8000.000	0.5340	0.6839	0.7258	0.7437	0.7669	[illegible]	[illegible]	[illegible]	[illegible]	0.9089	0.8893	0.8710	0.8656	0.8649	0.8591	0.8297

Figure 6.8: VOLUMETRIC EFFICIENCY STOCK INTAKE



Y/X	300.000	350.000	400.000	430.000	460.000	500.000	550.000	600.000	650.000	700.000	750.000	800.000	850.000	900.000	970.000	1050.000
1200.000	0.4901	0.5093	0.5419	0.5756	0.5962	0.6118	0.6293	0.6440	0.6634	0.6849	0.6841	0.6774	0.6546	0.6348	0.6159	0.6059
1400.000	0.4430	0.5293	0.5619	0.5856	0.5992	0.6218	0.6453	0.6675	0.6807	0.6911	0.6941	0.6784	0.6562	0.6362	0.6180	0.6059
1650.000	0.4500	0.5483	0.5819	0.6056	0.6262	0.6418	0.6653	0.6835	0.6989	0.6976	0.7043	0.6812	0.6661	0.6581	0.6359	0.6159
2000.000	0.4512	0.5663	0.6019	0.6256	0.6462	0.6612	0.6853	0.7044	0.7137	0.7182	0.7161	0.6937	0.6758	0.6744	0.6491	0.6291
2500.000	0.5000	0.5863	0.6219	0.6456	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.7412	0.7204	0.7019	0.6888	0.6616	0.6480
3000.000	0.4560	0.6037	0.6441	[illegible]	0.6892	0.9562	0.9654	0.9761	0.9784	0.9971	[illegible]	0.7475	0.7350	0.7221	0.7069	0.6865
3500.000	0.4550	0.6246	0.6673	[illegible]	0.7017	0.9623	0.9782	0.9956	1.0258	1.1254	0.7964	[illegible]	0.7602	0.7463	0.7218	0.7061
4000.000	0.4540	0.6412	0.6857	[illegible]	0.7258	0.9816	0.9987	1.1785	1.2564	1.2981	0.8293	[illegible]	0.8052	0.7976	0.7607	0.7491
5000.000	0.5120	0.6667	0.7051	[illegible]	0.7495	0.9899	0.9990	1.2891	1.3147	1.3251	0.8693	[illegible]	0.8356	0.8249	0.8015	0.7814
6000.000	0.5190	0.6841	0.7218	0.7427	[illegible]	1.0650	1.0658	1.1146	1.2593	1.3314	[illegible]	0.8710	0.8656	0.8649	0.8423	0.8297
7000.000	0.5230	0.6848	0.7247	0.7418	0.7669	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.8893	0.8710	0.8656	0.8649	0.8591	0.8297
8000.000	0.5340	0.6839	0.7258	0.7437	0.7669	0.7828	0.8156	0.8554	0.8923	0.9089	0.8893	0.8710	0.8656	0.8649	0.8591	0.8297

Figure 6.9: VOLUMETRIC EFFICIENCY NEW INTAKE

It can be seen that for the working range that is 3000 to 6000 rpm, at the jump value of map that is 450 to 700hPa, the volumetric efficiency is logged. The values are almost a jump of 16 percentage from the stock intake values. Where the maximum efficiency obtained with stock intake is just 92 percent, new intake pushes the value to beyond 100 and a maximum of 133 percent can be noted at the highest working rpm.

Overall volumetric efficiency in the working range is seen to increase by a factor of

Figure 6.10: VOLUMETRIC EFFICIENCY COMPARISON

around sixteen percentage. The target of the increase of volumetric efficiency at the beginning of the project was aimed to be ten percentage. With the above shown results it can be stated that the objective was met. The engine is now running much efficiently without the need to change any physical parameters and by just redesigning an existing part.

The rope brake dynamometer test for the variable intake was the next work to be done. The rope brake dynamometer testing proved to be the toughest part. The rope would often create so much friction on the drum that the spring balance reading would be very uneven. The dynamometer readings were very improper and plotting a curve was proving difficult. This coupled with the fact that the manifold is sensitive to temperature and rope-drum friction was creating a lot of heat near the manifold leading to cracking of the manifold on one of the occasions. Hence the dynamometer testing has to be aborted. An expectation of the torque curve, had the dynamometer working properly, is plotted. The torque graph is expected to peak at 3000 rpm and is expected to stay high till 6000rpm. The torque value is also expected to increase from its original value.

The torque curve is expected to follow a flatter trajectory. The trajectory is expected to

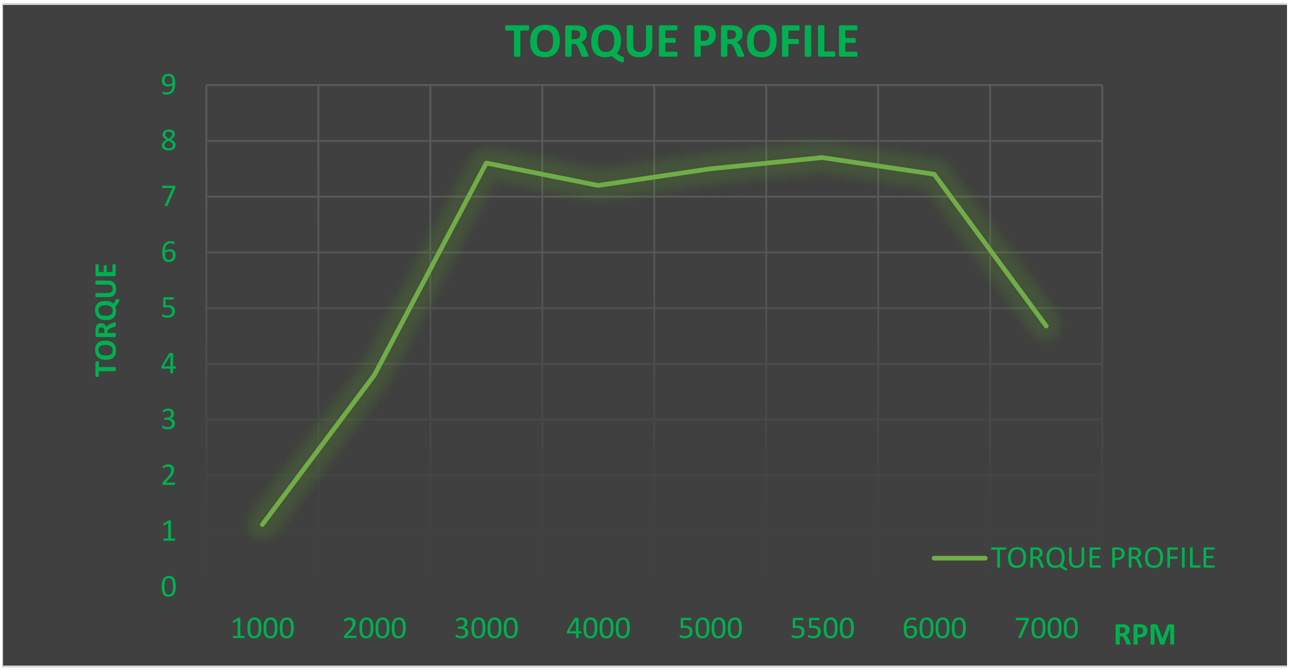


Figure 6.11: TORQUE CURVE FROM DYNO OF NEW INTAKE

continue till the rpm for which the intake is designed that is 6000rpm. The flatter torque curve obtained is also expected to peak higher than what the manufacturer has claimed. The torque value is expected to increase by 15 percentage and can be only tested for actual increment values using a two-wheeler chassis dynamometer.

A gear pump dynamometer may be able to solve the problem but there would be still question mark on the credibility of the values. Hence it is best if proper testing of the part can be done. The design has the ability to put forward some of the best test results and with the right testing apparatus the same can be proved.

A comparison between the stock torque curve and the new intake torque curve is shown. It can be noted that the torque figure is expected to slightly improve from the original value, peak early and keep peaking for a longer duration. Undoubtedly providing a boost in the performance of the engine.

Figure 6.12: TORQUE PROFILLE COMPARISON

CHAPTER 7

CONCLUSION

The project is turned out to be a successful one in terms of attaining the results. Previous chapter describes about the improvements made and suitable graphs were plotted. The project can be implemented in the real life application. There would be need of some improvements however. The manufacturing methods need to be improved. Better adaptation of the design could be done at the OEM level. Better manufacturing techniques like 3D printing would not only improve the quality but also help in reducing weight and creating complex shapes.

The objective of the project was to achieve an improvement of 5-10percent in volumetric efficiency, increase peak torque value by 5-10percent and to obtain a flatter torque curve. The objectives were met easily in the end. To test the improvement in volumetric efficiency, Ecotrons EFI kit was installed and using MAP sensor volumetric efficiency chart was plotted. An increase of approximately 16perccent in volumetric efficiency is observed.

For testing of the torque, a rope brake dynamometer was made. The dyno was used to plot torque curve of stock intake, so as to obtain inaccuracy in the dyno. Later new intake was tested and torque figures were plotted. It was observed that an 18 precent in peak torque value and a much more flat torque curve ranging from 3000-6000 rpm is being obtained.

The method could be adopted in the two-wheelers currently in the Indian market as implementing this could lead drastic to improvement in fuel efficiency, which is the need of the moment. This could also see the use of Fuel Injection being used in the two-wheeler sector of the Indian market. The cost of the vehicle might increase however but considering the advantage in reducing emissions and increment in fuel efficiency, the cost would not be a major impact factor.

CHAPTER 8

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