# Development of Power train System for Inline 3-Cylinder Race-Spec Engine

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*ABSTRACT* **~Powertrain is a system of Intake Manifold, Engine, Exhaust manifold and Engine Cooling System that allows to extract maximum power and torque figures with minimum backpressure and overheating of the engine. In wider scene, the powertrain includes all its components used to transform stored chemical energy, kinetic energy, potential energy etc. into kinetic energy for a running purpose. A Powertrain system must serve a purpose which includes reaching the maximum power and torque level from the engine selected. It is responsible for the Intake, Exhaust and Cooling system of the vehicle so that maximum power and torque can extracted from the engine during its manoeuvre. It serves the dual purpose of providing stability to the vehicle while providing a comfortable ride quality to the occupants. This report proposes a design of effective Intake and Exhaust system for FSAE vehicle by performing a simulation on Riccardo wave software. In order to study the effect of dynamic characteristics of the powertrain system, a simulation study has been done in this work. A car powertrain model with Daytona 675R engine is modelled in Solidworks. It is then imported and simulated using Riccardo Wave software.**

**Keywords- Intake, Riccardo Wave, Exhaust System, FSAE, Muffler, Throttle body.**

## I. INTRODUCTION

Formula Student is the biggest student competition in the world, around 1000 universities around the world boast of a functional formula student team. FS competitions are held across the globe, which attract a host of students from various domains such as Mechanical, Electrical, Electronics and Production. To compete in formula student competitions students must develop a small Formula-style, prototype race car that must be an open-wheeled race car with the prospect target buyers being an average weekend racer. Each student team must follow a strict series of rules to encourage fair competition as well as promote astute problem solving skills. This competition prepares university-level engineering students for the automotive industry by exposing and involving the students in research, design, manufacturing, testing, developing, marketing, team management, and financial management. Students involved in this competition are able to actually implement the textbook theories and principles learned in class to real hands-on projects. During the competition, each team is judged on their design as well as the performance of the overall vehicle. Moreover, the team's business structure and organization is judged.

The anticipation of Team Stallion Motorsport was to frame a formula student race car with high dynamic performance by upholding reliability. The most important Feature of a race car is to get the maximum power and torque figures over a study range of rpm by conceding to the rules of Formula Student World. Until last year, the team was using a single cylinder 390cc engine which could produce a maximum power of 33bhp and a Maximum torque of 22Nm. This year the team has decided to use an inline 3 cylinder engine which has led to various complications like:Designing an intake system to get maximum power without choking, to get maximum Power and Torque with minimum Back Pressure, to get maximum performance from the engine without overheating, Manufacturing rigid as well as light weight components to sustain the endurance.

### *A. Constraints:*

If more than one engine is used, the air for all engines must pass through a single air intake.In order to limit the power capability from the engine, a single circular restrictor must be placed in the intake system and all engine airflow must pass through the restrictor. The only allowed sequence of components is the following:

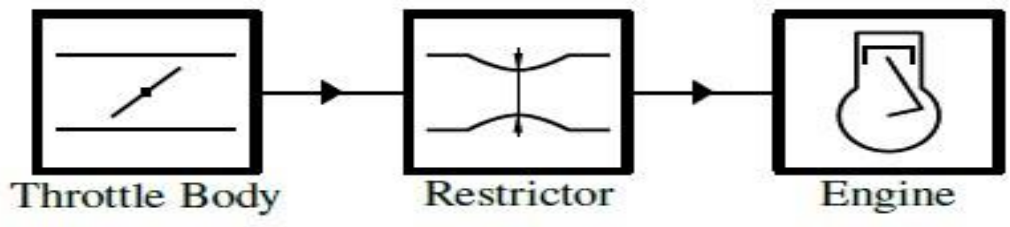


Fig.1 Sequence of Comonents

For naturally aspirated engines, the sequence must be: throttle body, restrictor and engine throttle body and engine . The maximum venturi diameters which must be respected at all times during the competition are:

- Gasoline fueled vehicles -20mm
- E-85fueled vehicles -19mm

The restrictor must be located to facilitate measurement during the inspection process. The circular restricting cross section may not be removable or flexible in any way, e.g. The restrictor must not be the part of movable portion of barrel throttle body. The maximum sound level test speed for a given engine will be the engine speed that corresponds to an average piston speed of 15.25m/s. The calculated speed will be rounded to the nearest 500rpm. The maximum permitted sound level up to this calculated speed is 110dB(C), fast weighting. The idle test speed for a given engine will be upto the team and determined by their calibrated idle speed. If the idle speed varies then the vehicle will be tested across the range of idle speeds determined by the team. At idle the maximum permitted sound level is 103dB(C), fast weighting.

*B. Parameters of Powertrain System:*

1. *Intake Manifold*: The intake manifold directs air-fuel mixture from the throttle body to the plenum. The plenum, in turn, feeds the mixture into lines leading to each of the engine's cylinders. The even distribution of combustion mixture to each cylinder head ensures that the engine's capacities are maximized.
2. *Throttle body*: Throttle is a device that controls the engine RPM by directly controlling the amount of air going in. More Air means more fuel and more Powerful and quickly will be the blast, so the RPM of engine increase & vice versa. Throttle in Petrol/Gasoline engine is connected with a Butterfly Valve in the Carburettor (between Air Filter pipe and Intake manifold) through Accelerator Cable. When we twist the accelerator valve opens and allows more air to flow in cable.
3. *Exhaust Manifold*: An exhaust manifold collects the exhaust gasesfrom multiple cylindersinto one pipe. The goal of performance exhaust headers is mainly to decrease flow resistance (back pressure), and to increase the volumetric efficiency of an engine, resulting in a gain in power output. The processes occurring can be explained by the gas laws, specifically the ideal gas law and the combined gas law.
4. *Muffler:* Internal combustion engines are typically equipped with an exhaust muffler to suppress the acoustic pulse generated by the combustion process. A high intensity pressure wave generated by combustion in the engine cylinder propagates along the exhaust pipe and radiates from the exhaust pipe termination.
5. *ECU*: It controls a series of actuatorson an internal combustion engineto ensure optimal engine performance. It does this by reading values from a multitude of sensorswithin the engine bay, interpreting the data using multidimensional performance maps (called lookup tables), and adjusting the engine actuators. Before ECUs, air-fuel mixture, ignition timing, and idle speed were mechanically set and dynamically controlled by mechanical and pneumatic means.
6. *Engine Control Sensors*: Sensors monitor all the key functions necessary to manage ignition timing, fuel delivery, emission controls, transmission shifting, cruise control, engine torque reduction (if the vehicle has antilock brakes with traction control) and charging output of the alternator. On most late model vehicles the PCM also controls the throttle. There is no mechanical linkage or cable between the gas pedal and throttle. Reliable sensor inputs are an absolute must if the whole system is to operate smoothly.
7. *Control Actuators*: An actuator requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure, or even human power. Its main energy source may be an electric current, hydraulic fluid pressure or pneumatic pressure. When it receives a control signal, an actuator responds by converting the signal's energy into mechanical motion.
8. *Engine Diagnosis System*: The main purpose of the MIL lamp on an OBDII-equipped vehicle, therefore, is to alert motorists when their vehicles are polluting so they will get their emission problems fixed. But as we all know, motorist are very good at ignoring warning lamps, even when steam is belching from under the hood or the engine is making horrible noises. That is why regulators want to incorporate OBDII into existing and enhanced vehicle emissions inspection programs. If the MIL lamp is found to be on when a vehicle is tested, it does not pass even if its tailpipe emissions are within acceptable limits.

9. *Helmholtz Resonance:* Helmholtz resonator augments the amplitude of the vibratory motion of the enclosed air in a chamber by taking energy from sound waves passing in the surrounding air. In the other definition the sound waves are generated by a uniform stream of air flowing across the open top of an enclosed volume of air.
10. *Ricardo Wave*: WAVE is used throughout the engine design process - from early concept studies, right through to detailed investigations of production engines. Whether it is improving volumetric efficiency, designing complex boosting systems, improving transient response or extracting the maximum performance from a race engine, WAVE is the ideal tool.
11. *Data Acquisition System:* Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. The components of data acquisition systems include:
    - Sensors, to convert physical parameters to electrical signals.
    - Signal conditioning circuitry, to convert sensor signals into a form that can be converted to digital values.
    - Analog-to-digital converters, to convert conditioned sensor signals to digital values.

*C. Method:*

1. *Approach:* The approach enables to accomplish project efficiently, addressing both internal constraints and dynamic external situations in the interim. The approach was assumed to keep the project scope and goal stable till the project completion.
   The phases laid down are:
   - Project initiation and sponsor
   - Project planning and design
   - Project monitoring and control
   - Project execution
   - Project completion
   - Project testing
   - Project validation

2. *Designing of components and selection of materials:* After identifying the problems related to the projects, the project work was embarked by designing the parts, analyzing the forces acting on them. The plan was to pick the material with high rigidity, high strength to weight ratio, and with less cost.

3. *Manufacturing of components :* The manufacturing was done with accepted production targets such as :
   - Minimization of manufacturing errors
   - Optimum usage of material
   - To trivialize the cost of production.
   - To downplay the compliances.

4. *Assembly and validation*: The skill requirement and knowledge required for this unit are:
   - Ease in assembly and disassembly.
   - High quality fixture.
   - Inspecting and checking the final assembly for conformance to specification.
   - Analyze components life and quality.

5. *Organization of Dissertation*: To enhance the performance of car in the dynamic field by diminishing the previous fault was the reason for the selection of project in the area of powertrain system. To satisfy this aim, intense study in the dynamic arena and regarding up gradation of suspension geometry were accomplished. The scrutiny was done regarding the problems faced by FSAE teams. The cross examination was carried out with the help of mentors. Immense testing of components were carried out to know practically problem faced in assembly. Data Acquisition System was used to validate the static results and tune the engine parameters to obtain maximum juice.

## II. DESIGN, CALCULATIONS AND SIMULATION

*A. Intake Manifold:*

To achieve maximum air flow in the engine , process begins in the Intake system .The aim of the Powertrain department is to design an Intake system that will provide optimal air flow equally through the cylinder while keeping maximum air flow possible to the engine . Also, the intake system must have optimal air flow with minimal pressure losses achievable. Without a high performing engine, the rest of design optimizations for the car will not have a chance to be utilized.

*B. Shroud:*

In S4.0 we had a chosen a standard cylindrical duct as the mouth of our intake system. In S5.0 we have decided to explore a new option for the mouth of our intake system. We have made a shroud from the main hoop to the throttle body in order to increase the ram air effect.

*Constraints:* The whole intake system must be inside the safety envelope.
*Materials used*: Poly lactic acid

*C. Engine Selection:*

*1. Rule*: The engine used to power the vehicle must be piston engine using a four-stroke primary heat cycle with a displacement not exceeding 710cc .We were using a KTM 390 engine up till now and were quite satisfied with the results. However, this year we thought that it was about time that we should upgrade to a better and more powerful engine. We had shortlisted 4 engines.

- Suzuki GSXR
- Daytona 675r
- KTM 690
- Yamaha R6

TABLE I
Comparison Table of the above four engines

| Specification | Suzuki GSXR | Daytona 675r | KTM690 | Yamaha YZF R-6 |
|---|---|---|---|---|
| Power to weight Ratio(aprrox values) | 1.58 | 1.7 | 1.520 | 1.7 |
| Peak Torque(Nm) | 60.5 | 75 | 75 | 61.7 |
| Power(HP) | 103 | 128 | 73 | 116.8 |
| Budget(300000) | YES | YES | YES | NO |
| Availability of spares | Available | Available | Not available | Available |
| Repairing cost | high | high | high | High |

2. *Factors Considered For Selection*- After considering all these factors and studying all the shortlisted engines we unanimously finalised the Daytona 675r engine. The decision was also made by keeping in mind the 5 point rule which is:

- Need
- Availability
- Cost
- Reliability
- Assembly

*D. Throttle:*

Function of the throttle is a device that controls the engine RPM by directly controlling the amount of air going in . More Air means more fuel and more Powerful and quickly will be the blast, so the RPM of engine increase & vice versa. Throttle in Petrol/Gasoline engine is connected with a Butterfly Valve in the Carburettor (between Air Filter pipe and Intake manifold) through Accelerator Cable. When we twist the accelerator, valve opens and allows more air to flow in cable. The vehicle must be equipped with a throttle body. The throttle body may be of any size or design. The throttle must be actuated mechanically by a foot pedal, i.e. via a cable or a rod system. Throttle position is defined as percent of travel from fully closed to fully open where 0% is fully closed and 100% is fully open. The idle position is the average position of the throttle body while the engine is idling. The throttle system mechanism must be protected from debris ingress to prevent jamming.

*1. Requirement of diminution of Throttle*: As using stock throttle directly to our restricted engine we observed issue like after flipping of the butterfly flap by, our restricted engine, gains peak mass flow rate, and remaining throttle range (from $30^o$ to $90^o$) and remains of no use even after opening the flap, due to the restrictor which is located after throttle body. There was no change in mass flow rate after $30^o$, which was reducing drivability. So, it was decided to manufacture a new throttle body in which there was a diminution in diameter, which made possible gradual increase in mass flow rate till $70^o$ i.e. full pedal press, thus making driver convenient to control throttle of car. And this manufactured throttle body helped driver to increase drivability.

*2. Material used*: Our objective is to have minimum weight for object that we manufacture as per our requirement so we used Aluminium 6061, and we reduced the weight by 2/3 that of stock throttle body.

It is commonly available in pre-tempered grades such as 6061-O (annealed), tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

Annealed 6061 (6061-O temper) has maximum tensile strength no more than 120 MPa (18,000 psi), and maximum yield strength no more than 55 MPa (8,000 psi). The material has elongation (stretch before ultimate failure) of 25–30%.

*3. Reason to take throttle of 32 mm in diameter :*

- Maximum possible mass flow rate is being achieved at nearly $70^o$ of throttle opening in case of throttle body with 32mm diameter whereas with throttle body of 44 mm diameter we are getting it at nearly $30^o$ flapper angle. It helps to increase drivability.
- As the diameter of throttle is decreased, velocity and pressure of air are maintained at optimum level.
- By placing new throttle body, unnecessary sensors are vanished.

*4. Arrangement for idling conditions:* The throttle plate is provided with the bleed holes whose flow area can be varied. The external idle air bypass consists of a parallel path for gas air mixture flow under closed throttle condition. The idle speed controller may consist of one or more, or a combination of these means.

To provide sufficient amount of air to engine at idling we installed a barrier (stopper) for the flapper shaft which stops the flapper at instead of bleed holes

*E. Restrictor:*

An air restrictor is a device installed at the intake of an engine to limit its power .Restrictor are devices installed between the throttle body and intake manifold that restrict the amount of air and fuel entering the engines combustion chamber. This device limits the power output of the motor and hence slows both the acceleration and the overall top speeds obtainable on the tracks. In automobile racing it is used to limit top speed and to provide equal level of competition. The Triumph Daytona 675R engine selected is a 674.8cc engine which gives a power output of 110 bhp at 9500 RPM. It has a 44mm of port opening for the air intake, but placing the restrictor reduces the area drastically from 44mm to 20mm diameter. At high RPM engine burns more fuel and also urges for more air, and restrictor plays a vital role here to restrict the air into the intake manifold resulting in reduction of power. Air restrictor that is being design is basically a obstruction .Since the aim is to optimize the mass flow rate, we can use various types of restrictors such as orifice, venturi and De-Laval.

*1. Orifice*: An orifice is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, the fluid is forced to converge to go through small converging section (hole in the plate) actually occurs at the so called vena-contracta point. As it does so, the velocity and the pressure changes. Beyond the vena-contracta the fluid expands and the velocity and pressure changes once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena- contracta and mass flow rates can be obtained from Bernoulli's equation.It generally has a coefficient of discharge around 0.65.

*2. Venturi*: The venturi is a tabular set up of varying pipe diameter through which the fluid flows. The venturi effect is a jet effect, as with a funnel, the velocity of fluid increases, as the cross-section area decreases, along with the static pressure correspondingly decreasing. An equation for the drop in pressure to the venturi effect is derived from combination of Bernoulli's principle and the continuity equation. Venturi has a coefficient of discharge of around 0.95.

*3. De- Laval*: A de Laval nozzle (or convergent-divergent nozzle, CD nozzle or con-di nozzle) is a tube that is pinched in the middle, making a carefully balanced, symmetric hour glass shape.

TABLE III
Coefficient of discharge of various restrictors

| Restrictor types | Coefficient of discharge |
|---|---|
| Orifice | 0.65 |
| Venture | 0.95 |
| De-Laval | 0.96 |

TABLE IIIII
De-Laval: Converging –diverging angle and Delta Pressure

| Converging angle | Diverging angle | Delta pressure |
|---|---|---|
| 12 | 4 | 4886.12pa |
| 14 | 4 | 4091.31pa |
| 16 | 4 | 3452.2pa |
| 12 | 6 | 7909.73pa |
| 14 | 6 | 8265.28pa |
| 16 | 6 | 9782.47pa |

TABLE IVV
Venturi Angles: Converging –diverging angle and Delta Pressure

| Converging angle | Diverging angle | Delta pressure |
|---|---|---|
| 12 | 4 | 3605.22pa |
| 14 | 4 | 4311.63pa |
| 16 | 4 | 4480.61pa |
| 12 | 6 | 10391.7pa |
| 14 | 6 | 9880.541pa |
| 16 | 6 | 10512.277pa |

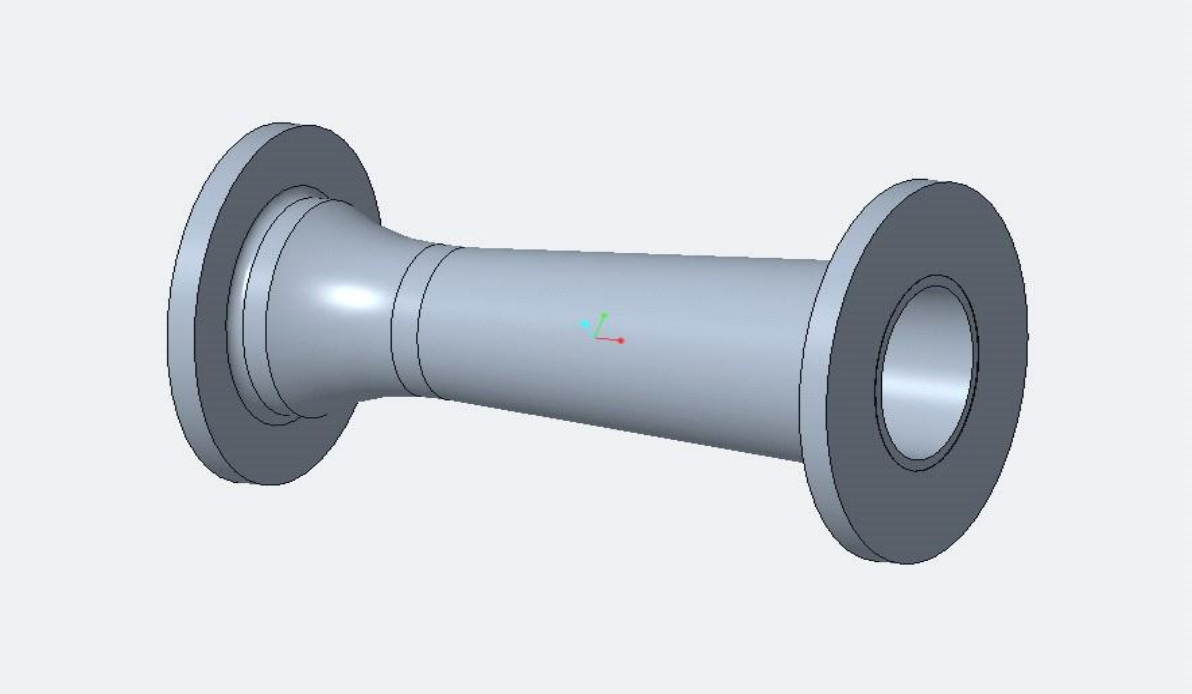

Fig.2: CAD Model of De-Laval

*Reasons of selecting De-Laval:*

By keeping in mind, the listed three restrictors we decided to use De-Laval because it satisfied our requirements. De-Laval assisted us to accomplish our goals, such as:

- Better laminar flow: This is a very major characteristic for the flow required by the engine.

- Packaging: De-Laval acquires a length of 12cm in the whole intake system, whereas other restrictors (such as orifice, venturi) takes much longer length (nearly 22-26cm) to attain the same results.
- Reduction in sudden losses: De-Laval provides a continuous converging cross-section, due to which sudden losses are decreased compared to the venturi and orifice where due to sharp convergence-divergence & obstruction respectively, sudden losses are more.

TABLE V
*Details of De-Laval:*

| **Parameters** | **Values** |
|---|---|
| Coefficient of discharge | 0.96 |
| Length | 12mm |
| Converging angle | 16º |
| Diverging angle | 4o |
| Throat position | 33.5mm (from inlet) |
| Inlet diameter | 32mm |
| Outlet diameter | 32mm |

*F. Plenum (prism):*

When a valve closes, the air outside of the valve compresses against it, creating a pocket of high pressure. This pressure equalizes with lower pressure in the plenum, which creates cycles, or pulses, of oscillation. This enables the plenum to operate at a high volumetric efficiency when equalizing air flow to the engine cylinder.

Since the intake stroke is only one of the four strokes in the cycle, air is only being drawn ¼ of the time, which results in large pressure pulses. If there are multiple cylinders operating this is not as much of an issue because the intake strokes are offset, creating a more uniform suction. The RC390 engine is a single cylinder, so these pulses are quite large. The purpose of the plenum is also to minimize the effects of the single cylinder pulses. Ricardo WAVE was used to find the effects of plenum's geometry and shape.

1. *Iterations:* Keeping in mind our aim, we designed multiple geometries. Also, we varied the volumes of these geometries from 2X to 3X with intervals of 0.5X. All the geometries with varying volumes were simulated on ANSYS software to check the flow of air through them and the magnitude and effect of turbulence. While ANSYS gave an idea about the better geometries and sizes, the final decision was taken based on the simulations we ran on Ricardo WAVE.The simulations and experiments ran on WAVE gave us incredible data to work on. Comparisons were made based on parameters like –

- Mass flow rate
- Peak torque
- Peak power
- Pressure and velocity at different cross-sections

After making complete and comprehensive comparisons Prism 2.5X plenum was finalized.

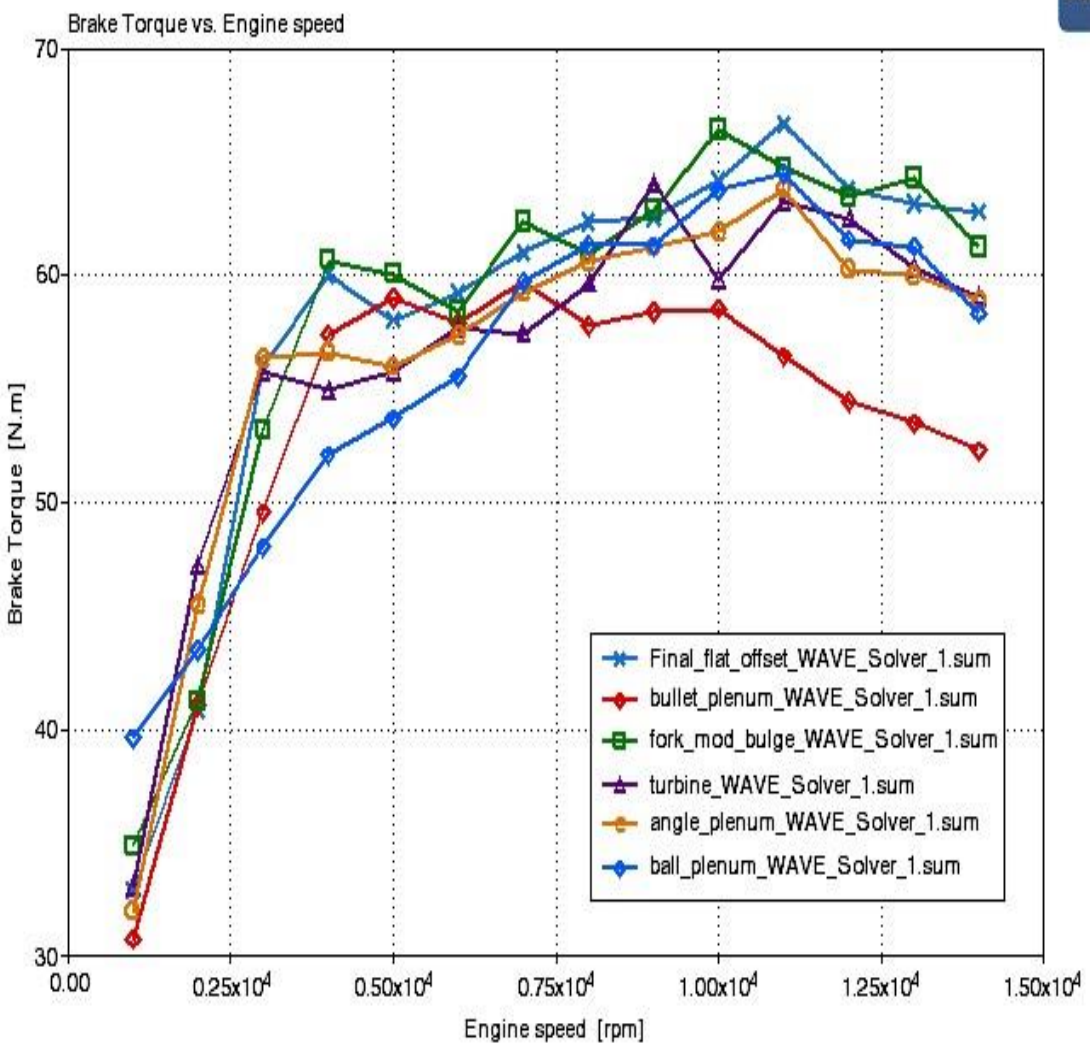


Fig.3. Brake Torque Vs Engine Speed

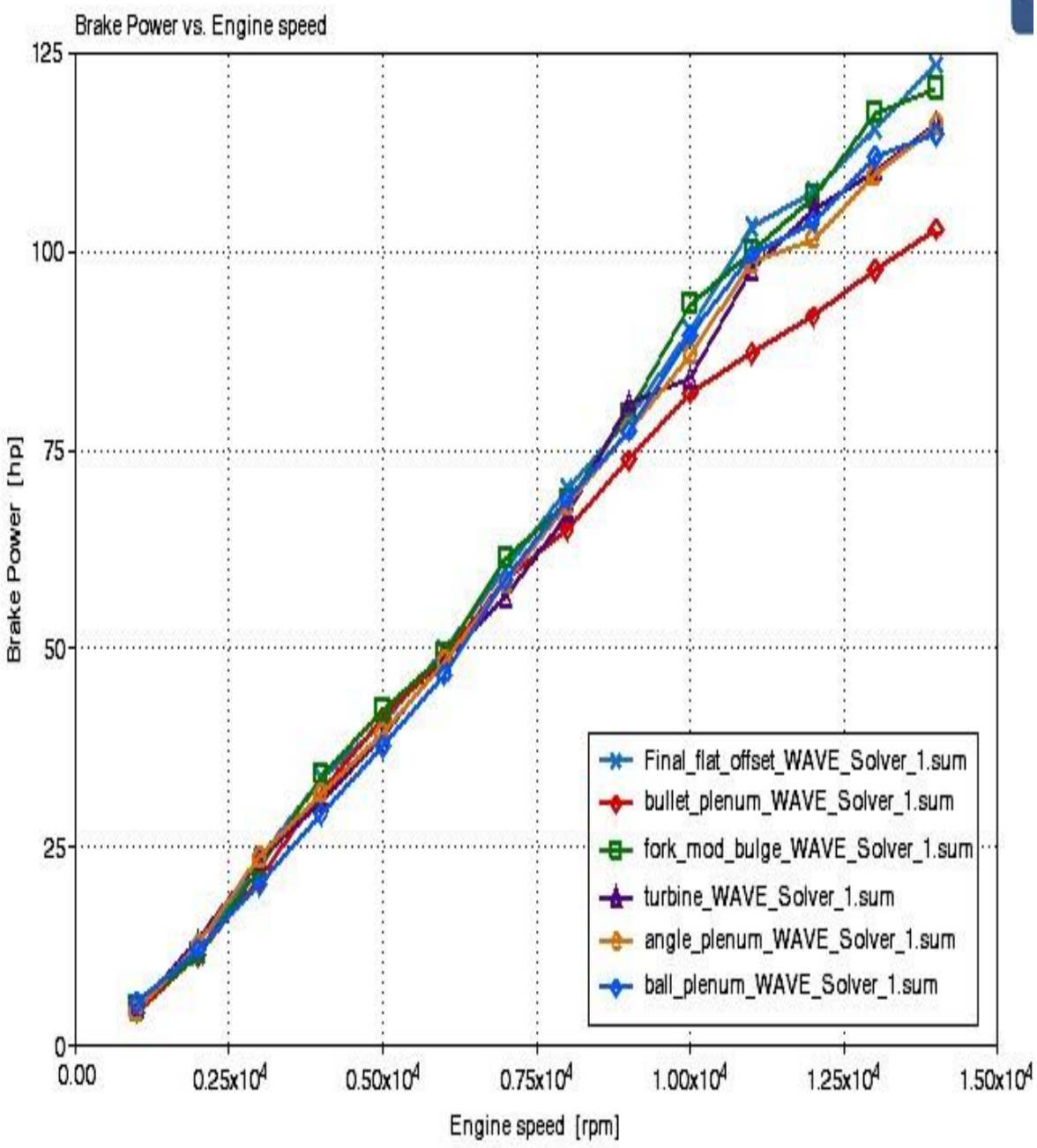


Fig.4. Brake power Vs Engine Speed.

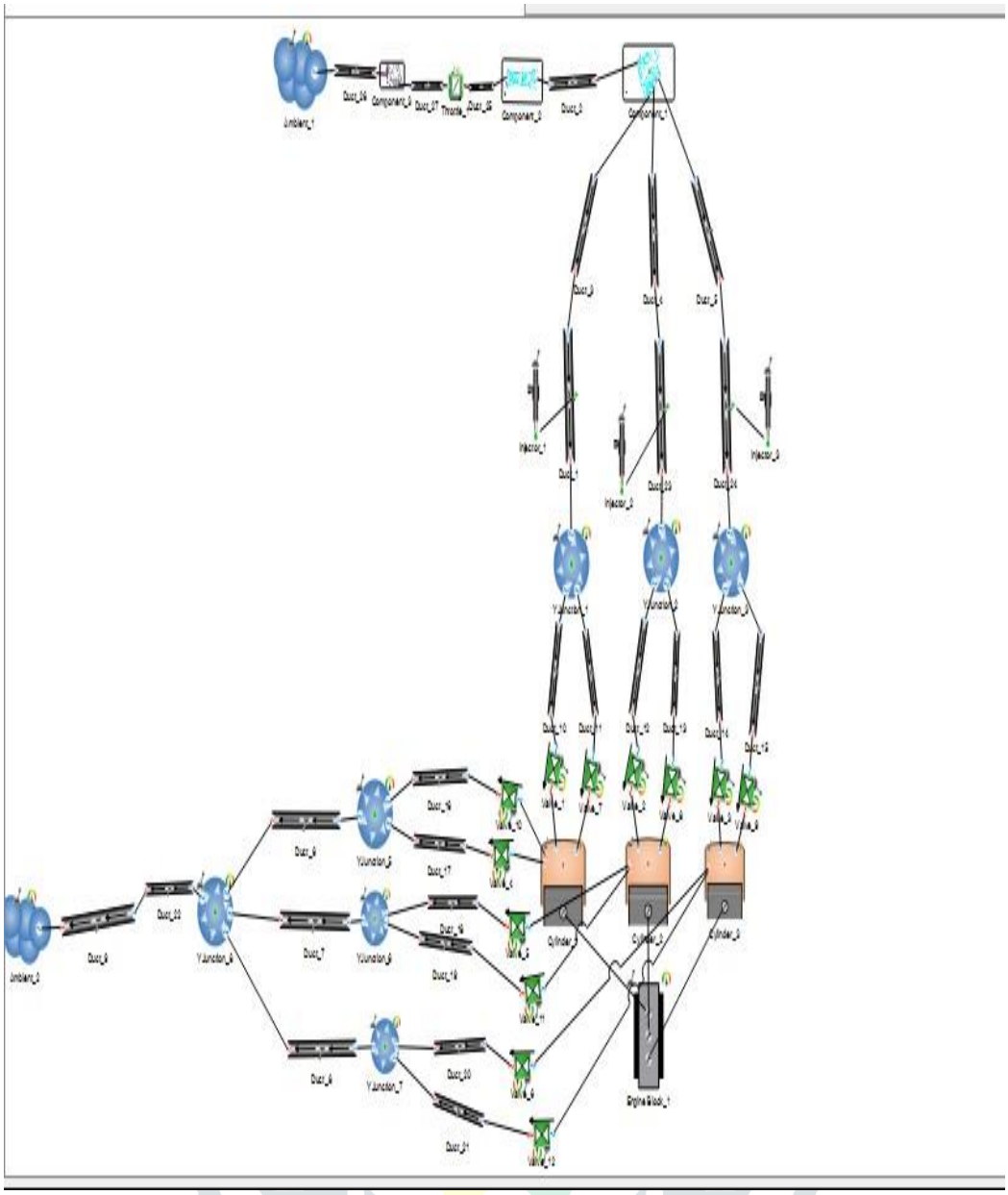

Fig.5. Ricardo Wave Canvas

*Prism 2.5X:* As the name indicates, it is a 'Prism' shaped plenum. The air enters through the 'head' and exits the plenum through the bottom section at a bend.

TABLE VV
The specifications of PRISM 2.5

| | |
|---|---|
| Volume | 1687 |
| Inlet diameter | 32 mm |
| Outlet diameter | 44 mm |

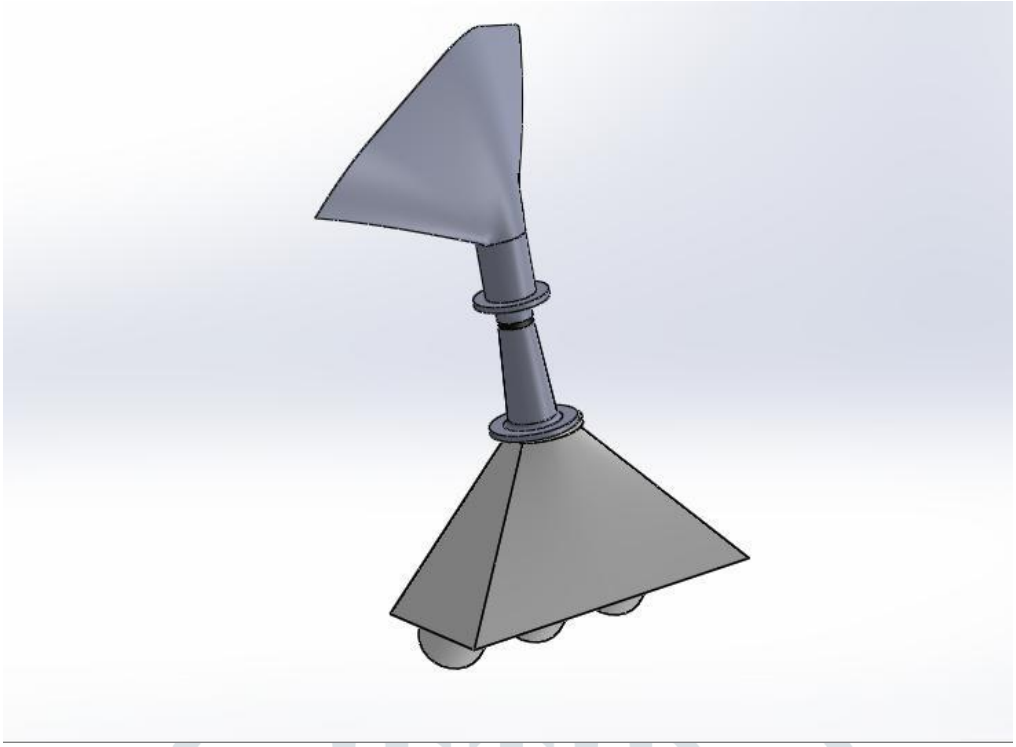

Fig.6. Cad model of Prism *2.5X*

*G. RUNNER:*

Engines have been around for a long time -- longer than some of the sciences that explain how they actually work. In the early days, figuring out the size, shape and design of things like intake manifold runners was mostly a matter of trial and error. Modern understanding of software's such as ANSYS and RICARDO WAVE have solved some of the puzzles of yore, and allowed us to start tuning engines to be the best that they can be. Air pressure going into the engine through the runners bounces back off the head's intake valves when they close like a spring. The pressure waves shoot back up to the end of the runner, and come back down; each of these bounce cycles is known as a "harmonic." If you open the intake valve at just the right time, you can catch the pressure wave on the way back down; the pressure waves shoves air through the valve, much like a supercharger. But this supercharging effect only works in a certain rpm range, and the pressure waves can bounce back and forth two or three times before the valve opens again. The length of the runner determines how long the harmonic takes to get back to the intake valve. For this reason, long runners will "supercharge" the engine at low rpm, and very short runners will do it at high rpm. The height, width and volume of the runner determine how much air can go through, which dictates top-end horsepower.

1. *Helmholtz Resonance*: It works on the theory of harmony. As the air (or any gas) tries to ram into the resonator through its neck, the pressure inside the cavity increases and the air bounces out, but while bouncing out quickly due to inertia, it creates a partial vacuum near the neck of the resonator and the air is again sucked in. The process continues like the phenomena of a ping-pong ball hitting the ground. The resonator acts like a shock absorber for the pressure waves. This theory gives relation between IC engine volumetric efficiency and resonators in air intake system. The volumetric efficiency of an IC engine can be increased by using the resonator.

*2. Ram Air Theory*: Dry air is thought to behave like a compressible elastic fluid. However, instead of looking at fluid dynamics, mass air flow can also be looked at in terms of its acoustic behaviour or behaviour as a sound wave and it's frequencies. Sound waves travel as undulating pulsations up and down an Impulse Modulated (IM)runner. These pulses have a frequency or resonance and carry energy. It is surprising to discover that air isn't just sucked into the engine but also can be forced through the engine's intake valves even in naturally aspirated setups. Provided they are properly tuned. While tuning the system, the volume and the design of the inlet manifold also need to be considered because the air inside the intake manifold will also participate in resonance. The increased static pressure in the plenum chamber has a positive effect on engine power, both because of the pressure itself and the increased air density that this higher pressure gives.

*3.David Vizard's Rule*: The general rule is that you should begin with a runner length of 17.8 cm for a 10,000 rpm peak torque location, from the intake opening to the plenum chamber. You add 4.3 cm runner length for every 1000 rpm that you want the peak torque to occur before the 10,000 rpm. So, for instance, if peak torque should occur at rpm the total runner length should be

17.8cm + (6 x 4.3 cm) = 43.6cm

Vizard also suggests that you can calculate the ideal runner diameter by the equation:

SQRT [ (target rpm for peak torque x Displacement x VE)/ 3330]

Where,

SQRT =square root
VE = Volumetric Efficiency in %
Displacement in Litres

*H. Exhaust Manifold :*

Acoustic pulses are created due to the combustion process of the internal combustion engine. Hence to suppress these pulses the exhaust system is equipped with muffler. These acoustic pulses are of very high intensity. These waves' pass through the exhaust piping known as bend pipes or header. Large amount of heat is accompanied with those pulses. The pulse repeats the firing frequency of the engine which is defined by

F= (Engine rpm x Number of cylinders)/120

The above formula is applicable for a four stroke engine.

Very high frequency waves are propagated through the bend pipes which create loud rough noise. Unwanted noise cancellation is achieved by creating destructive interference pattern which is 180° out-of-phase. This destructive pattern is achieved with the help of different muffler types. They are classified mainly into two types, Absorptive type and Reactive type. The Absorptive type of muffler uses sound absorbing material to take out the energy from the acoustic wave as it propagates through the muffler. The material commonly used for these types of mufflers is glass wool which is a type of fiber. The reactive mufflers are well known for the automotive purposes uses perforated tubes and baffle plates to create destructive interference. Different types of baffle plates are used in this type of muffler. For example, Delta shaped plates, swirl plates, circular plates, etc. This type of muffler is based on the principle of Helmholtz resonator theory and Acoustic transmission line theory. Our main aim is to reduce the engine noise emission which is classified as unwanted sound. Sound is basically the vibrations that travel through the air or other medium and can be heard by the living beings. The unit of sound is decibels (dB). The main objective of the system is to reduce the sound level below 110 dB. The maximum permitted sound level is 103 dB. This amount of sound level is bearable and healthy for the environment. Another main objective is that the exhaust outlets must not extent more that 450mm behind the centreline of the rear axle and shall be no more than 600mm above the ground.

The material used to make the bend pipes and muffler is mild steel and stainless steel. The baffle plates are made of mild steel and the walls are made of stainless steel.

*1. BEND PIPE:* The main function of bend pipe is to transfer the noise waves and exhaust gases from the ports to the muffler with minimum back pressure. For the smooth and constant continuity of the flow, all three bend pipes are made of around similar lengths but of different bends. Being a three-cylinder engine there is a 120° delay between the exhaust valve openings we decided to make equidistant bend pipe to minimize the back pressure.

Dimension of the bend pipe is 3 holes of 34mm diameter merging into forming one whole diameter of 78mm diameter.

Manufacturing process:

- Sheet bending
- Welding

These are the different bend pipe designs we designed to minimize the back pressure. We chose this design because it was creating the minimum back pressure and was able to fit in our CAD design.

*2. Muffler:* We are using a prototype of automotive muffler which is 60% Reactive muffle and 40% absorptive muffler. The Absorptive muffler is used to absorb the pressure waves with the help of glass wool fiber. Reactive type muffler is used to create the destructive interference. We have made customized baffle plates which effectively reduces the back pressure. The main aim is to maintain the noise level below 110 dB; hence we ended up by choosing 60% reactive and 40% absorptive. Therefore, we chose Combination muffler to get advantages of each type of muffler.

Dimensions of the muffler are 400mm length, 100mm height, 180mm width.

The following designs are chosen for iterations:

- Delta type baffle plates
- Semi-circular plates
- swirl plates

The manufacturing processes used to make a muffler are: Sheet bending and Welding.

## III.CONCLUSION

The team is designed a 3x intake plenum system to install on a race car. Various calculations and simulations on Ricardo Wave software have been done to attain maximum Power and Torque over a wide range of rpm. Ricardo Wave and various Exhaust Runner Length is tuned to get maximum Power and Torque with minimum Back Pressure. In this study, it can be concluded that the use of Ricardo WAVE software for designing the header exhaust system is very efficient because it can perform simulation with many variations, at no cost.

ACKNOWLEDGMENT

It gives us an immense pleasure to submit this project report on **'Development of Powertrain System for Inline 3Cylinder Race-Spec Engine'.** We have tried our level best to represent this topic in a precise manner briefing all the important points related to the topic.

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