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Implementation of Rapid Prototyping for Optimisation of Intake System in a Powertrain of Formula Student Vehicle

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Abstract:
The Air intake system For a Formula Student car is done for cutting edge performance of car with satisfying all Rules set by FSAE for the competition. The intake system designed for high torque figures and stable torque plateau. Designing of any intake system requires great applicative knowledge in engineering. For designing intake lot of parameters were considered to setup Engine simulation model and according to that Validations are done. Different intakes were designed in Solidworks and were introduced in Ricardo wave and outputs were checked. ANSYS Fluent feature provides you the Boundary layers and Mass flow through the intake. When the simulation results were satisfying the material selection is done on the basis of ANSYS static structural.

Keywords: *Intake, Throttle Body, Restrictor, Plenum, Ricardo Wave, Ansys, Solidworks***.**

1. Introduction

The function of the air intake system is to allow air to reach car engine. Oxygen in the air is one of the necessary ingredients for the engine combustion process. A good air intake system allows for clean and laminar air into the engine, thereby achieving more power for car. The air intake system has following main parts: air filter, custom throttle body, De-Laval (restrictor), Plenum, Runner and lower throttle body. The powertrain of the Formula student vehicle islocated behind the main hoop.To attain utmost 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 best possible air flow uniformly through the cylinder while keeping maximum airflow possible to the engine. Also, the intake system must have best possible air flow with least pressure losses achievable. Without a high performing engine, the rest of design optimizations for the car will not have a chance to be utilized.

A. *Constraint:*

The air for all cylinders must pass through a single air intake. In order to limit the power ability of the engine, a single circular restrictor of cross section area of 20mm must be located in the intake system and all engine airflow must go by through the restrictor. The only line of action to be followed is supposed to be like below:

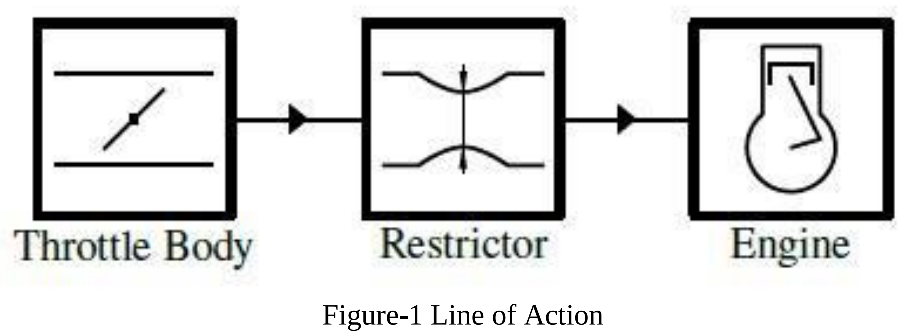

Figure-1 Line of Action

B. *Methodology:* -Softwares used for the purpose are Ricardo wave, Ansys, Solidworks. Various Geometries are created in the Solidworks software. Later these geometries will be inserted into the Ansys software where the parameters such aspressure and velocity are obtained. After satisfying

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the values, the geometries are inserted into the Ricardo Model. Engine simulation model is created on the Ricardo Wave. The detailed descriptions of the softwares used are mentioned below:

1. *Ansys:* ANSYS's Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyse problems that involve fluid flows. This computer simulation product provides finite elements to model behaviour, and supports material models and equation solvers for a wide range of design problems. This software provides many important parameters which help to meet the targets. Ansys analyses the design and gives Parameters like mass flow rate, pressure difference, type of flow and much more important parameters.

2. *Solidworks:* It is a designing software whose purpose is to create various geometries, understanding 3D views of any part, applying different material to the object and obtaining the estimation weight.

3. *Ricardo Wave:* The Ricardo software is used to create an engine simulation model. The advantage of using a simulation program like WAVE is that many design iterations of a component can be performed without physically building and testing them. WAVE saved a significantamount of time, money and materials by optimizing the system design before dynamometer testingWAVE is an extremely powerful tool capable of producing results so accurate that major manufacturers all over the worlduse it to design engines and related systems before they ever build one. This accuracy is solely dependent on the accuracy ofthe computer model in relation to the actual engine.

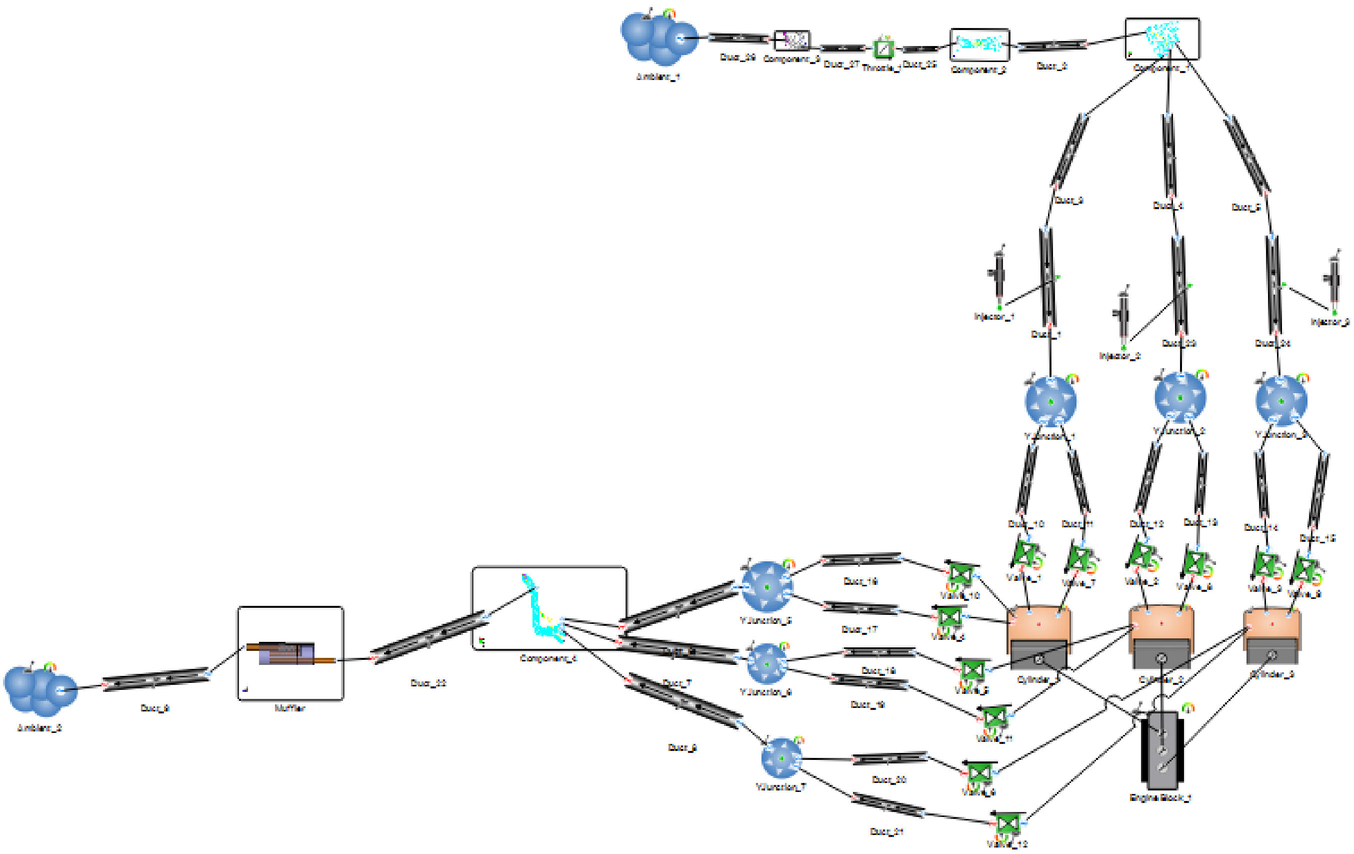

Figure 2- Ricardo Wave Simulation Model

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II. Design and Simulations

The main components of the Intake system for a formula student vehicle include Throttle body, Restrictor, Plenum and Runners.

A. *Throttle Body:*

It is a component that controls the engine RPM by directly controlling the amount of air supplied to engine. Itconsists of a Butterfly Valvewhich is actuated using accelerator pedal at the will of the driver. The throttle body can be of any size or design. The design of throttle body must be very accurate so that the Throttle Position Sensor should be accurately mounted so that it will not give any false reading to the ECU. In the designing process the throttle body, it was observed that by reducing the diameter more drivability was increased. With the stock throttle body, the mass flow rate was saturated much earlier than the modified throttle body. As the diameter of the throttle body is decreased velocity increases and the pressure of air decreases.

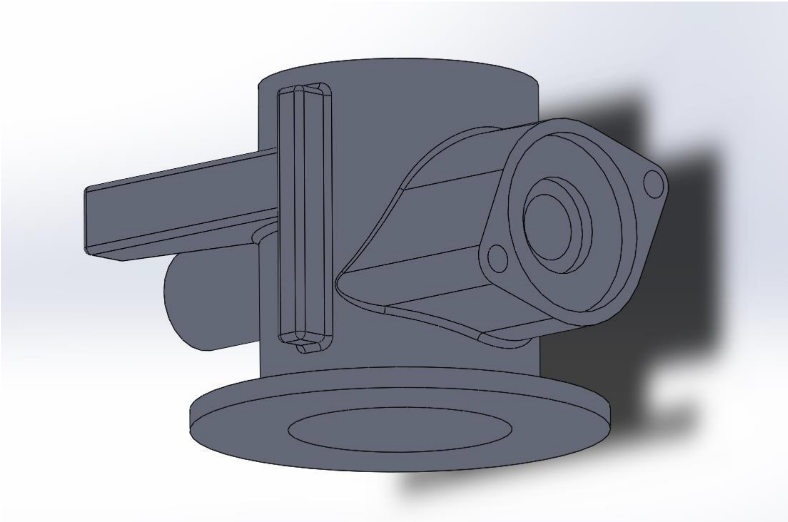

Figure 3- Solidworks CAD model of Throttle Body

B. *Restrictor:*

An air restrictor is a component placed in the intake of an engine to limit the air-flow to the combustion chamber. It is assembled in between throttle body and plenum. This component limits the power output of the engine and hence slows both the acceleration and overall speed of the car. The 3 main types of restrictorsdesigns which were taken into account are Orifice, Venturi and a D-Laval. The coefficients of discharge of the three are 0.65, 0.95 and 0.96 respectively.

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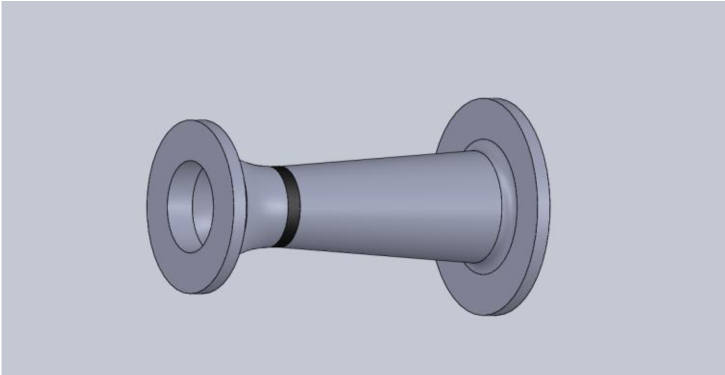

Figure 4- CAD model of Restrictor

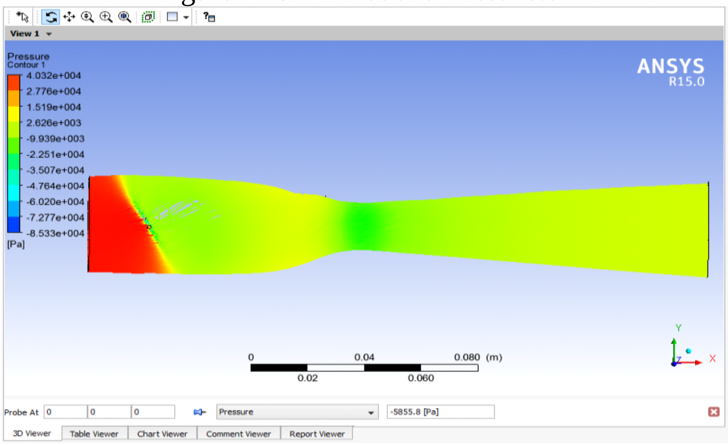

Figure 5- Pressure Analysis

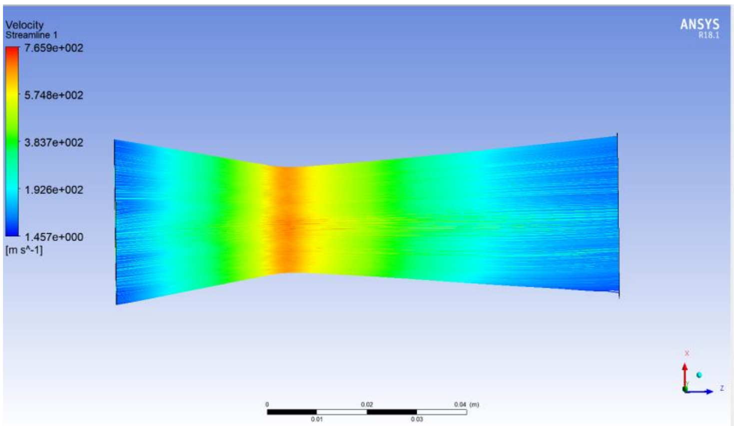

Figure 6- Velocity Analysis

The optimum results were observed when the D-Laval's length is 12mm at converging angle of 16^{o} and diverging angle of 4^{o} .

C. *Plenum:*

Due to the 20mm venturi the engine starves at a high rpm and due to this there is a significant loss in the power and torque. In order to maintain a high pressure and to provide adequate air to the engine an air box or a plenum is integrated in the intake manifold.When a valve closes, the air outside of the valve compresses against it, due to which high pressure is created into the plenum. During this action the pulses are created of oscillation. If these pulses are matched then high torque, power and volumetric efficiency can be achieved. Hence to match these pulses, optimum designing of the geometry is necessary.

Following are the graphs achieved from the Ricardo Simulation Model:

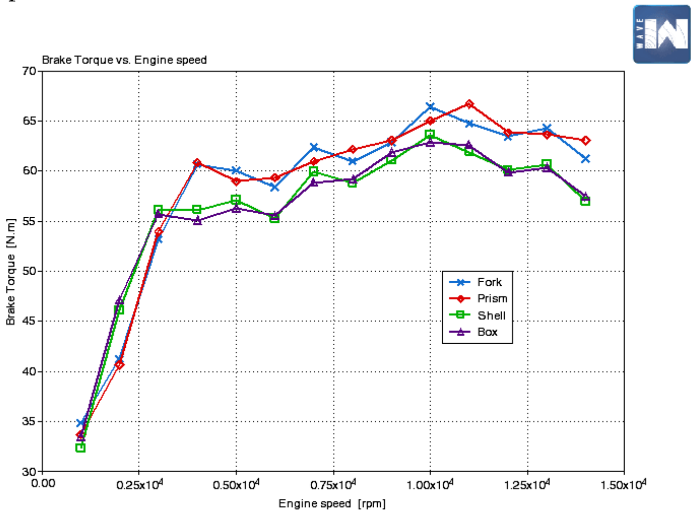

Figure 7- Torque vs RPM

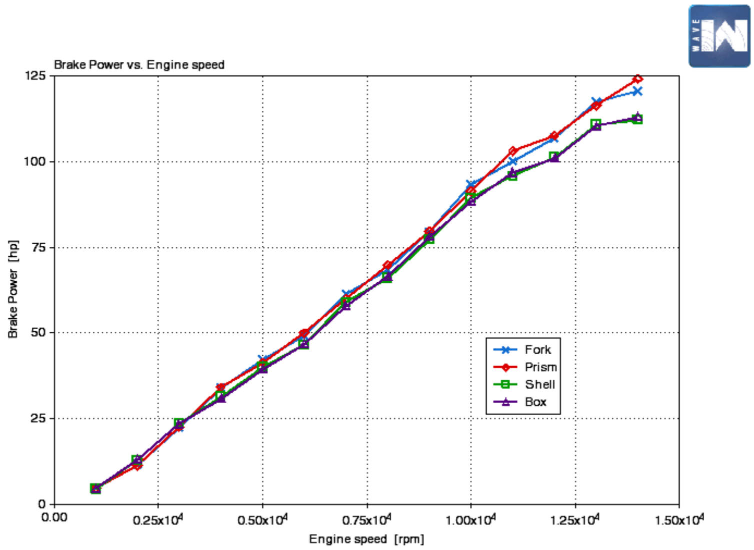

Figure 8- BHP vs RPM

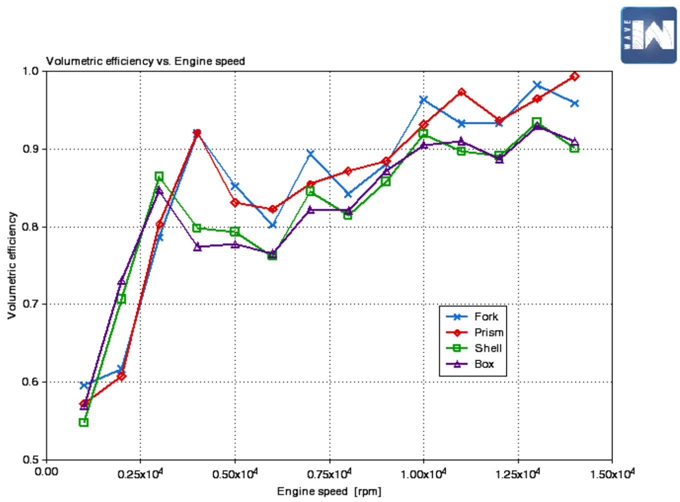

Figure 9- Volumetric efficiency vs RPM

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When we compared these parameters the graphs we unanimously selected the Prism plenum.

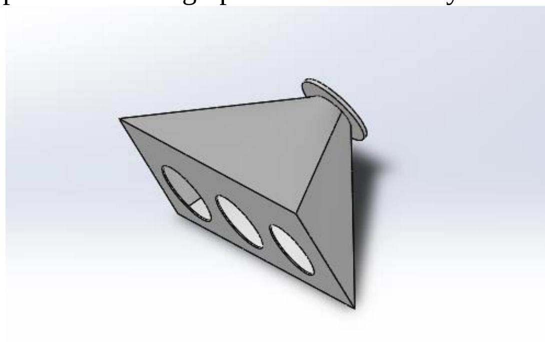

Figure 10- CAD model of Prism Plenum

D. *Runners:*

Intake runner is the duct linking intake valve and the plenum exit. This length is accountable for the resonance effects. The length, inside diameter, volume and shape of the runners are absolutely critical in terms of power output, and where in the rpm range the engine makes that power. Therefore the long runners will give more power at low rpm and short runner will do it at high rpm range. There are many theories such as Helmholtz Resonance Theory, Ram Air Theory and David Vizard's Rule which explains the importance of runner length, volume and its shape. Simulations were performed on Ricardo wave by changing the runner length and optimum length was achieved.

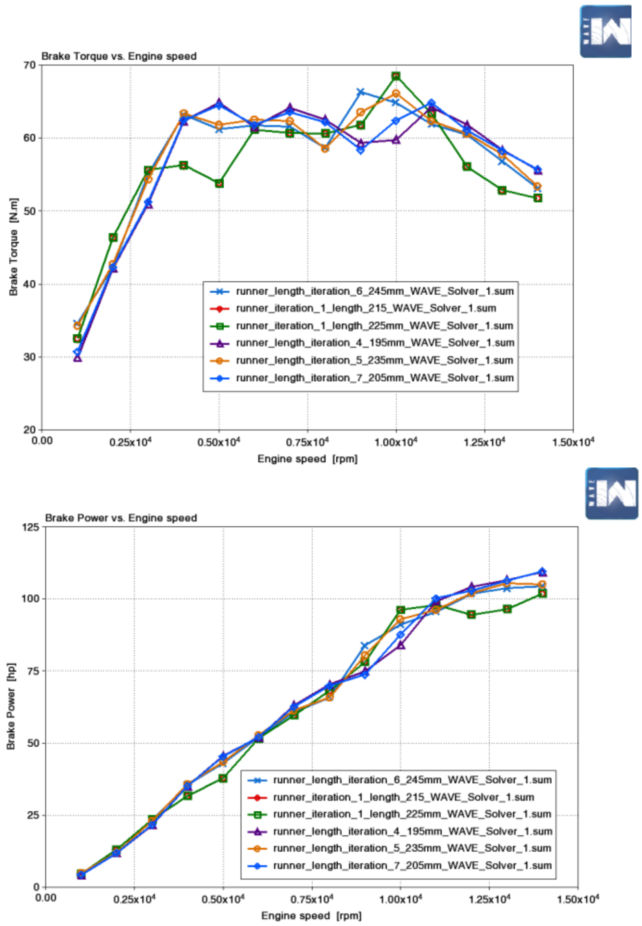

Figure 11- Torque vs RPM (left) and BHP vs RPM (right)

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Hence from the above graphs, the final length of runners was finalized to 235mm (yellow line from the graph) and the shape was straight to minimize the bend loses. Since there are total 6 injectors (3 Primary & 3 Secondary) each runner will have 2 injectors each with a spray angle of 15 degrees.

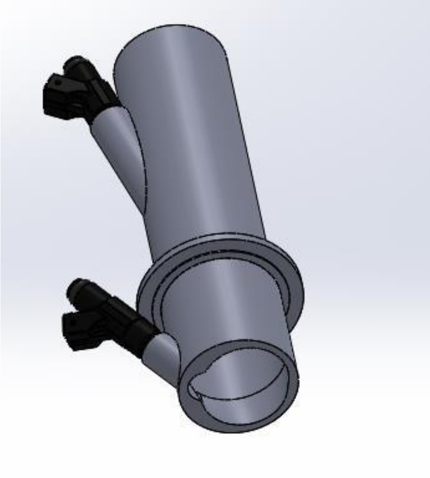

Figure 12- Runner with injector ports

E. *Final Intake Geometry:*

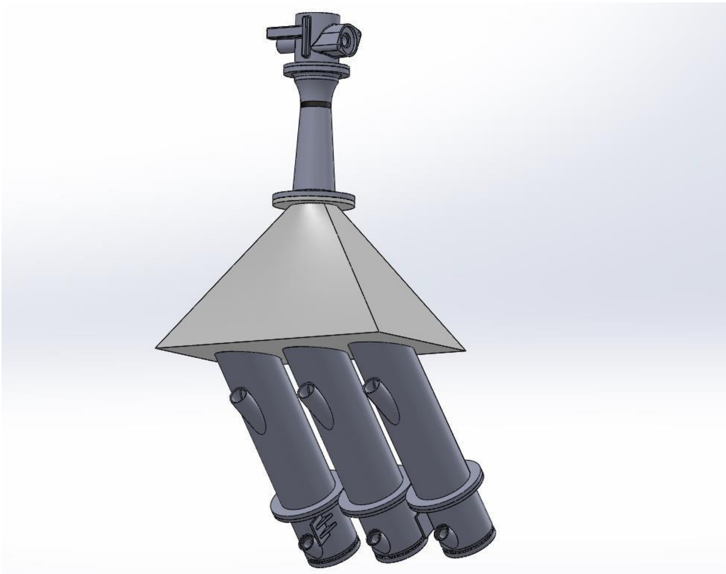

Figure 13- Intake geometry

III. Rapid Prototyping

IV. Conclusion

The Intake system was designed from the ground up with the needs of research in mind. All components are designed to be light weight and high performance. The knowledge of all the research papers are to be incorporated within the prototype. All the pros are to be put to maximum use and initial simulation tests. This will show a high performance behaviour of the vehicle with stable torque plateau with weight reduction of intake manifold.

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REFERENCES

[1] J.B.Heywood, International Combustion Engine Fundamentals, McGraw hill series.1988. 930p.

[2] J.L.Lumley, Engines,CambridgeUniversity Press, New York, 2009. 245p.

[3] R. Bosch, Gasoline engine management, Wiley Blackwell; 3rd Edition. 2009.364p.

[4] Paper presented by University of Florence, By Giovanni Vichi, Luca Romani, Lorenzo Ferrari, Giovanni Ferrara.

[5] ArifKurniawan, Ricardo WAVE Simulation on the Effect of Exhaust Header Geometry to the Power and Torque of the UGM's FSAE Engine, 2004.

[6] "HowStuffWorks "How Car Engines Work"" HowStuffWorks "Learn How Everything Works! "Web. 2 Feb. 2015. <http://www.howstuffworks.com/engine.htm>.

[7] "WAVE." Engine Simulation Program.Web. 03 May 2016.

[8] "Compression Ratio Tech."Popular Hot Rodding.Web. March. 2012. <http://www.popularhotrodding.com/tech/0311_phr_compression_ratio_tech/>.

[9] Rulebook, Formula Student Germany,2018

ISSN: 2233-7857 IJFGCN