Design And Fabrication of Air Intake For FSAE Race Car

S S Sawant[1], P N Gurav[1], P S Nivalkar[2], P M Sawant[3] ,Dr. S N Waghmare[4]
[1, 2, 3] Dept of Mechanical Engineering
[4]Assistant Prof. & HOD, Dept of Mechanical Engineering
[1, 2, 3, 4] Ambav (Devrukh), Ratnagiri, Maharashtra, India

***Abstract**- This research paper aims to optimize a venturi type restrictor which is to be fitted in the intake manifold of a Formula SAE car engine. The main purpose of 20mm restrictor in intake manifold is to restrict mass flow passing to the engine thus reducing its maximum power. Analytical calculations are done based on standard results to get maximum mass flow rate and CFD tool is used to calculate minimum pressure drop across the restrictor buy varying converging and diverging angles of venturi. Objectives of this research is to optimize a venturi type design to allow maximum possible mass flow rate to the engine from 20 mm restrictor by reducing the difference in pressure across venturi at all speeds.*

Keywords- Runner, Plenum, Air Restrictor, Throttle Body.

I. INTRODUCTION

The purpose of this project to design intake manifold for a Formula SAE race car. Formula SAE is a student design competition organized by Society of Automotive Engineers International.

The FSAE rules committee imposed a rule that power of any four-stroke engine used in the competition should be limited by a 20 mm intake restrictor. The Engines used in FSAE are limited to 610 cc engines having an output of 120 horsepower with 15000 revolutions.

After including the 20 mm restrictor the engine revolutions are controlled from 10000 RPM to 7500 RPM. At such high speed, engine requires large amount of air for combustion. Thus, the mass flow rate should increase the air has to pass with very high velocity to fulfill the engine with required quantity of air. According to studies, mass flow rate is a fixed parameter for 20 mm restrictor used for the calculations in further optimization. Thus, the objective is to allow maximum possible mass flow with minimum pressure drop across the venture type restrictor.

II. LITERATURE REVIEW

Design and Fabrication of Air Intake for FSAE Race Car we referred various papers:

Singhal, A., &Parveen, M. (2013) It found that optimal solution to achieve the maximum mass flow with minimal pull from the engine. From the data gathered through the numerous simulations in Solid Works Flow Simulation, optimized values for converging angle & diverging angle of the Ventures.

Ryan Ilardo, Christopher B. Williams (2012) In this paper performed the analysis based on fused deposition modeling is used to create geometry of the intake system and use of composite material. It is found that Geometric flexibility in the design of manifold, sufficient strength and heat resistivity to survive operating environment.

Shinde, P. A. (2014) In this paper performed analytical calculations based on standard results to get minimum air flow rate and CFD tool is used to calculate minimum pressure drop across the restrictor by varying converging and diverging angles of venture.

Logan M. Shelagowski and Thomas A. Mahanak. In this paper Computational fluid dynamics (CFD) flow modeling software used analyze and visualize fluid flow to Reached maximum flow, higher volume flow rate (4.8 CFM on average), will create a more robust low- to mid-range torque, to optimize engine performance

Rahul Puri et.al (2016) This studied the design process of the air intake and exhaust system of the SAE Supra Race Car. Flow analysis for individual components are carried out, and verified against performance simulations of the entire engine system, followed by physical testing of several of the components using a flow bench. They achieved the purpose of compensating the pressure losses because of restrictor of 20 mm according to SAE rulebook and ultimately the power losses of engine.

Sachin N Waghmare et.al (2016) In this paper optimize the venture type of restrictor included in the intake system as imposed in the FSAE rule.

The fluid flow through the intake was analyzed using CFD flow modeling software. The optimum solution is to achieve the maximum mass flow rate of air through the flow restriction device. Venture serves the best design for this objective. It allows a maximum flow rate of 0.0703 kg /sec of air flow to the engine. From the above research, it is found that converging angle of 12 degree and diverging angle 6 degree gives minimum pressure drop at the exit of expansion cone.

Oh Yide & Andre (2012) in this paper create a foundation of knowledge on which to build the next generation of air intake systems. Computational Fluid Dynamics software, aid the design process through virtual simulations, including data acquisition and analysis of design variations for better information on the effects without cycling through the manufacturing and assembly processes

Shubham Raj et.al (2016) It purposed that venturi type design to allow maximum possible rate to the engine from 20 mm restrictor buy difference in pressure across venturi Analytical calculations are done based on to get maximum mass flow rate and CFD calculate minimum pressure drop across the varying converging and diverging angles of be observed from CFD results that for diverging angle of 14 degrees and 6 degrees minimum pressure drop can be achieved.

Kaushal Kishor (2015) The author approached for designing, analyzing and manufacturing of air intake and exhaust system is discussed for prototype model of a Formula style car with the locally available resources in hand as per the rules specified by the two major student level events organized in India. Design was analyzed in CAD software (SOLIDWORKS) It also gives a brief introduction to the flow simulation of the designed models.

HONG Han-chi et.al (2012) In this paper Computational fluid dynamics (CFD) flow modeling software used analyze and visualize fluid flow to Reached maximum flow, higher volume flow rate will create a more robust low- to mid-range torque, to optimize engine performance1-Dimensional software GT-Power was applied to simulate the engine performance. The parameters including the sphere style plenum diameter, the intake runner diameter, exhaust runner lengths and the position of retractor were optimized via a combination of the 1-Dimensional simulation and an orthogonal L9 (34) testing design.

III. STUDIESANDFINDINGS

The mixing of air flow and fuel is a turbulent phenomenon. Thus we have to apply turbulence flow on this model. Turbulence or turbulent flow is a flow regime in fluid dynamics characterized by chaotic changes in pressure and flow velocity. It is in contrast to a laminar flow regime, which occurs when a fluid flows in parallel layers, with no disruption between those layers.In CFD analysis, turbulence flow simulations are divided into various sections, but for our project two types of CFD analysis is considered “k-epsilon” and “k-omega”.

K-omega: -

This type of simulation is applied for high velocity objects such as planes, jet planes, etc. since the FSAE race cars doesn’t reach that much high speed we have to check an alternate method for this analysis.

K-epsilon:-

This type of analysis are used for moderate velocity objects such as cars, bikes, etc. since the FSAE race cars are ranged in this speed criteria we use this type of analysis. K-epsilon is further sub-divided but we use “K-epsilon resilience” for our model

To perform the CFD analysis for this model we use the “K-epsilon resilience type of CFD analysis.

Helmholtz Theory (S.N. Waghmare, et al, IJETMAS February 2016, Volume 4, Issue 2, ISSN 2349-4476)

Helmholtz theory addresses the fact that an Internal Combustion Engine creates pressure waves that propagate in the engines intake system. Air compressibility can be linked to a spring force introducing resonance in the intake manifold as the wave propagation takes place. A single cylinder and intake runner with its intake valve open constitutes a Helmholtz resonator. Tuning peak takes place when the natural frequency of cylinder and runner is about twice the piston frequency. 3) Design Constants and Variables: Since the aim is to optimized the intake restrictor, the mass flow rate calculation is to be done.

Maximum flow rate is: m = r*V*A
For an ideal compressible gas:

$$m_{max} = A * P_0 \sqrt{\frac{k}{RT_0}} \left(\frac{2}{k+1}\right)^{(k+1)/[2(k-1)]}$$

Where A = cross-sectional area at which the flow is sonic, P0 is the stagnation pressure, T0 is the stagnation temperature, R is the specific gas constant, and k = cp/cv is the specific heat ratio of the gas. The maximum flow rate can be expressed in terms of inlet temperature Ti and inlet pressure Pi by expressing the stagnation temperature and stagnation pressure as

$$T_0 = T_i + \frac{V_i^2}{2c_p}$$

$$P_0 = P_i \left(\frac{T_0}{Ti}\right)^{k/(k-1)}$$

Where Vi is the inlet velocity.

Mass flow rate is maximum when M = 1. At these conditions, flow is choked.

The mass flow rate from above equation is calculated using the following data values :

M = 1
A = 0.001256 m2 (20 mm restriction)
R = 0.286 KJ/Kg-K
ϒ = 1.4
P0= 101325 Pa
T = 300 K
Mass flow rate = 0.0703 kg/sec

The conical spline intake design is chosen because it haslowest loss of total pressure through the restrictor. The complete air intake system is design in Solidworks & analyze in Ansys Fluent Workbench with appropriate boundary conditions.

Air intake system is divided in 3 parts i.e., Restrictor, Plenum & Runner.

1. Restrictor

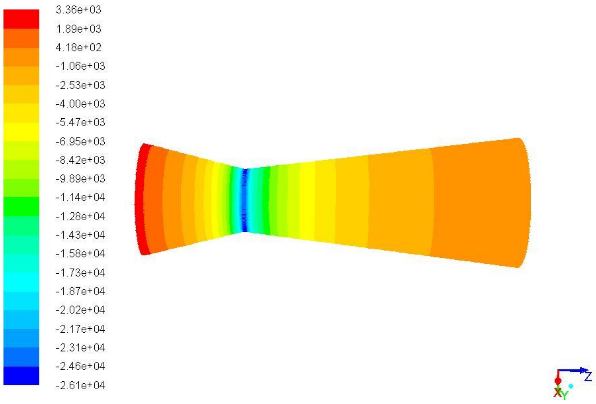
For the restrictor, we considered the design of convergent-divergent nozzle. Total length of restrictor is 145mm. For convergent section, both the end diameters are constrained (36mm of throttle body and20mm of the restrictor). For divergent section outlet diameter is 41.5mm.
Boundary Conditions:

Inlet : PRESSURE INLET = 1 Atmosphere
Outlet: MASS FLOW OUTLET = 0.0703KG/S

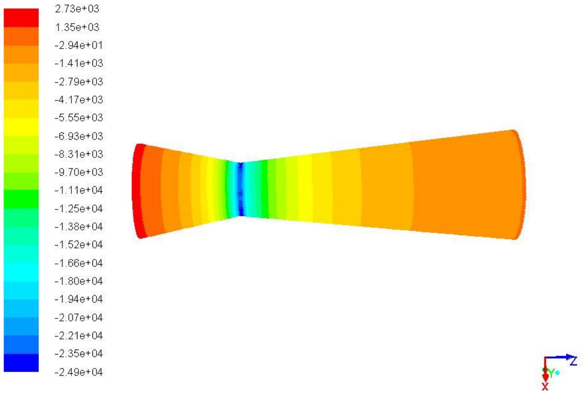
The results of iterations carried out at various converging and diverging angles are as follows:

Iteration no	Converging Angle (degree)	Diverging Angle (degree)	Pressure Difference (Pa)
1	14	7	2154.55
2	12	6	1894.48
3	10.5	6	1856.20

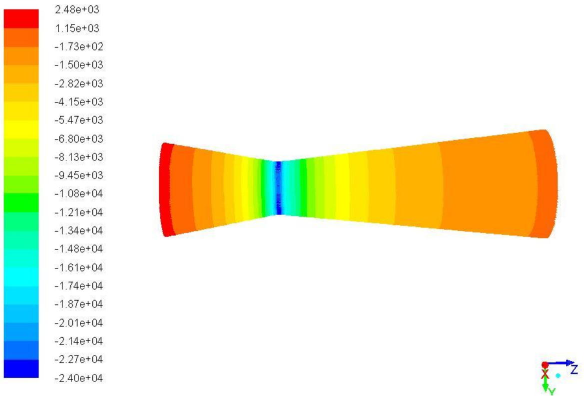
(Table no. 1)



(Fig.1.a) Contours of Pressure for Iteration 1(Pascal)



(Fig.1.b) Contours of Pressure for Iteration 2(Pascal)



(Fig.1.c)Contours of Pressure for Iteration 3(Pascal)

Convergent angle of 10.5° & Divergent angle of 6° are selected for restrictor because they gives minimum pressure loss through the restrictor.

2. Plenum

Spherical shape type plenum was considered. Performance of engine at higher speeds improves with increase in plenum volume. Volume of plenum is 1.2 liter, which is almost 3 times the engine displacement.

3. Runner

Calculation of Runner Length:

Speed of pressure wave = 1116.44 feet/second
Effective Cam Duration (ECD) = 226°
EVCD = Effective Valve Closed Duration
= 720-(ECD) = (720-226) + 20
= 514°

5000 rev/minute divided by 60 seconds/minute
= 83.33 rev/second
83.33 rev/second X 360°/rev = 30,000°/second
514° / 30,000° per second = 0.0171 seconds.
At 5000 RPM, 514° = 0.0171 seconds

This 0.0171 seconds is the critical time factor. During this 0.0171 seconds that the intake valve is closed, the pressure wave is moving at 1116.44 feet/second and travels 19.12 feet.

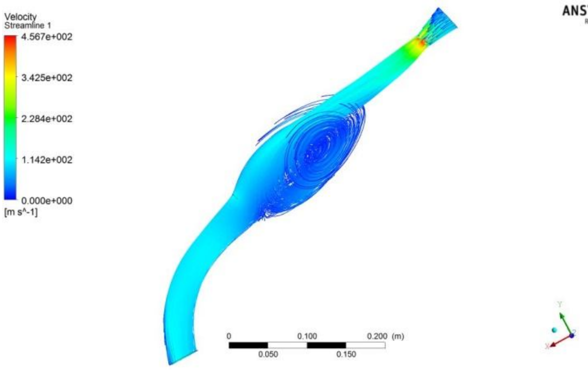
At resonant conditions, the pressure wave has to travel 19.12 feet to arrive at the intake valve when it is open. Since the pressure wave spends this time going up the runner AND going back down the runner, the runner length is actually only half of 19.12 feet, or 9.56 feet, which is equal to 114.77 inches.

But, here we can’t use such long runner, so we divide it (by 7) as suitable.

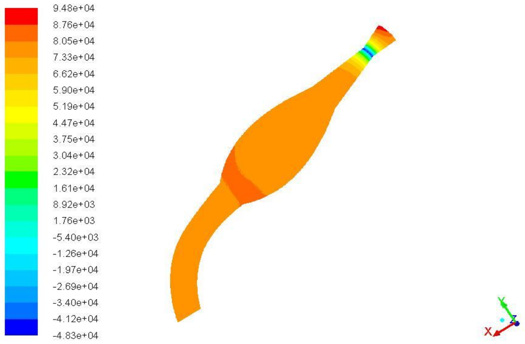
Runner Length = $\frac{114.77}{7} =$ 16.39 inches = 416 mm

According to RAM Theory, intake system was tuned at 5000 RPM, resulting in total runner length of 416mm.

The CFD of whole air intake system is also done at the end in Ansys Fluent by applying appropriate boundary conditions.



(Fig. 2.a) Velocity Streamline



(Fig. 2.b) Contours of Pressure (Pascal)

Also to mount the intake system to the engine, especially design mounting is used. This is fixed mechanically to engine by using 3 countersunk bolts. The mounting is made of Duraform PA Plastic material & manufactured by SLS 3D printing method.

Properties of Duraform PA Plastic:
Heat Deflection Temperature = 184°c
Tensile Strength = 44MPa

The whole air intake system is also made of ABS Plastic material by 3D printing method.
Properties of ABS Plastic:
Heat Deflection Temperature = 105°c
Tensile Strength = 46MPa

(Fig. 3) Air Intake Assembly

IV. CONCLUSION

The flow analysis using Computational fluid dynamics (CFD) helps to analyze the flow in the intake manifold. The entire intake system should be optimized to reduce pressure loss and improve engine performance. Convergent angle of 10.5° & Divergent angle of 6° are selected for restrictor because they gives minimum pressure loss through the restrictor.

V. ACKNOWLEDGMENT

We would like to express my sincere thanks to our friend Yogesh Desai who helped us out in performing the Computational Fluid Dynamics accurately, after a lot of practice and hours put into it. Our sincere thanks to Prof. S. N. Waghmare of Mechanical Department for giving us the opportunity to take up this paper, for his guidance and supervision in all respects of this paper.

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