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Design, Analysis And Manufacturing Of An Air Intake System For Fsae Car

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Abstract

Air intake system for any automobile is one of the most crucial part of an automobile. The characteristics of air entering into the combustion chamber directly affect the power generation and performance of engine. The system is designed with a 20mm diameter restrictor which restricts the amount of air flowing in the engine.

Keywords-*component; Throttle body, Venturi, plenum, Runner*

I. Introduction

The main function of an air intake system is to supply the engine with clean air and in correctamount to burn theinjected fuel in the combustion chamber. The intake system of the engine hasthree main functions. Its first and usually most identifiable function is to provide a method offiltering the air to ensure that the engine receives clean air free of debris. Two othercharacteristics that are of importance to the engineers are designing the intake system are its flowand acoustic performance. The flow efficiency of the intake system has a direct impact on thepower the engine is able to deliver. The acoustic performance is important becausegovernment regulations dictate the maximum air mass flow level that vehicles can makeduring a pass-by test. The speed of air generated by the intake system can be significantcontributor to this pass-by filter and separated flow.

II. DESIGN OF AIR INTAKE SYSTEM

1. Throttle body

The previous air intake system used a stock throttle body of KTM Duke 390 bike which was a butterfly type with a bore of 46 mm. The team faced a lot of problem regarding the throttle response which showed a sudden increase of rpm within 50% of throttle travel. The 20 mm restrictor got saturated with air within 50% throttle opening. To overcome this issue the team decided to downsize the throttle bore to 36 mm. A butterfly type single blade shaft throttle body was used to decrease air resistance. Velocity stack was added before the throttle plate to get a continuous mass flow rate at low engine speeds.

The observed result was a predictable throttle response at any engine speed keeping only the restrictor as the limiting factor.

Calculations:

$$\emptyset TB = \frac{\sqrt{(121.43)(No.of\ cylinders)(Stroke)(RPM)(Bore)^2}}{67547.4}$$

ØTB = 31.33 mm

A correction factor of 15% is added to compensate losses due to throttle valve and shaft.

ØTB = 35.98 mm.

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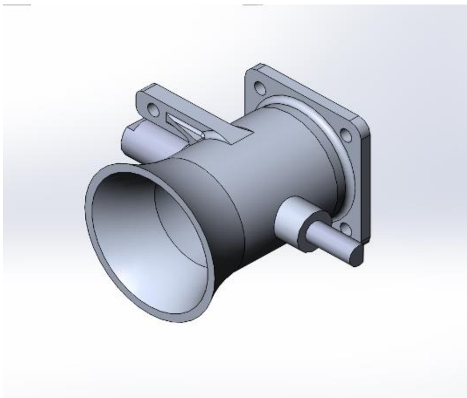


Figure 1 : Throttle body CAD Figure 2: Manufactured (Aluminum 6061)

2. Venturi

As per the limitations of the rules the throat diameter of the venturi should not be more than 20mm. The main aim of the venturi is to accelerate the flow of air into the plenum.In last year's design the throat was in the middle of venturi ,by this geometry high throat velocity was attained, but it resulted in low static pressure inside the plenum, this had a negative effect on the performance of engine.

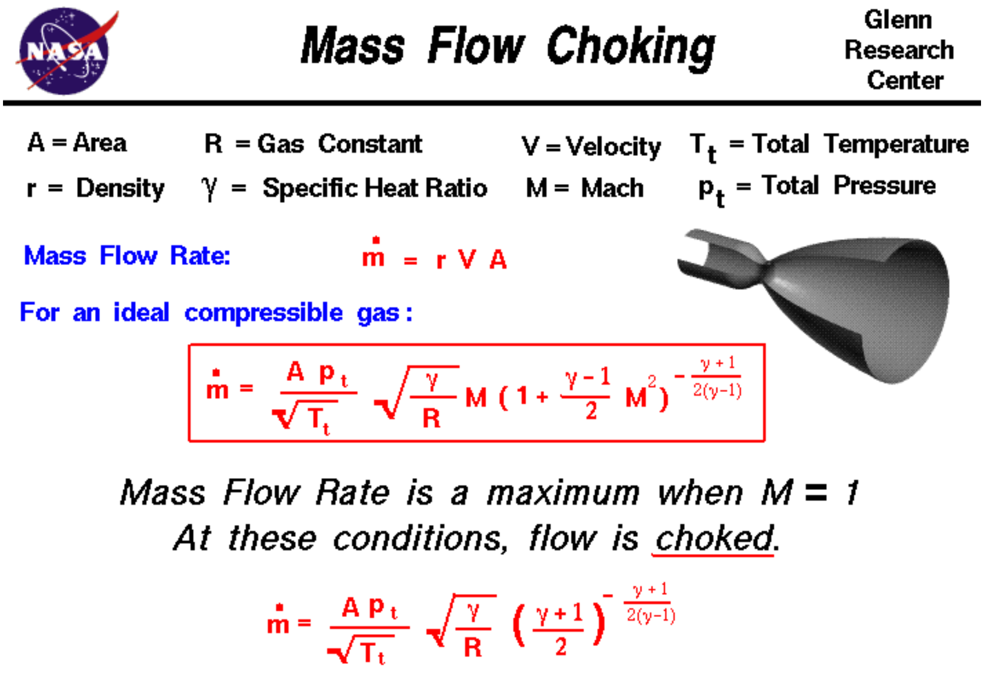

Figure 3 NASA Mass Flow Choking Equation

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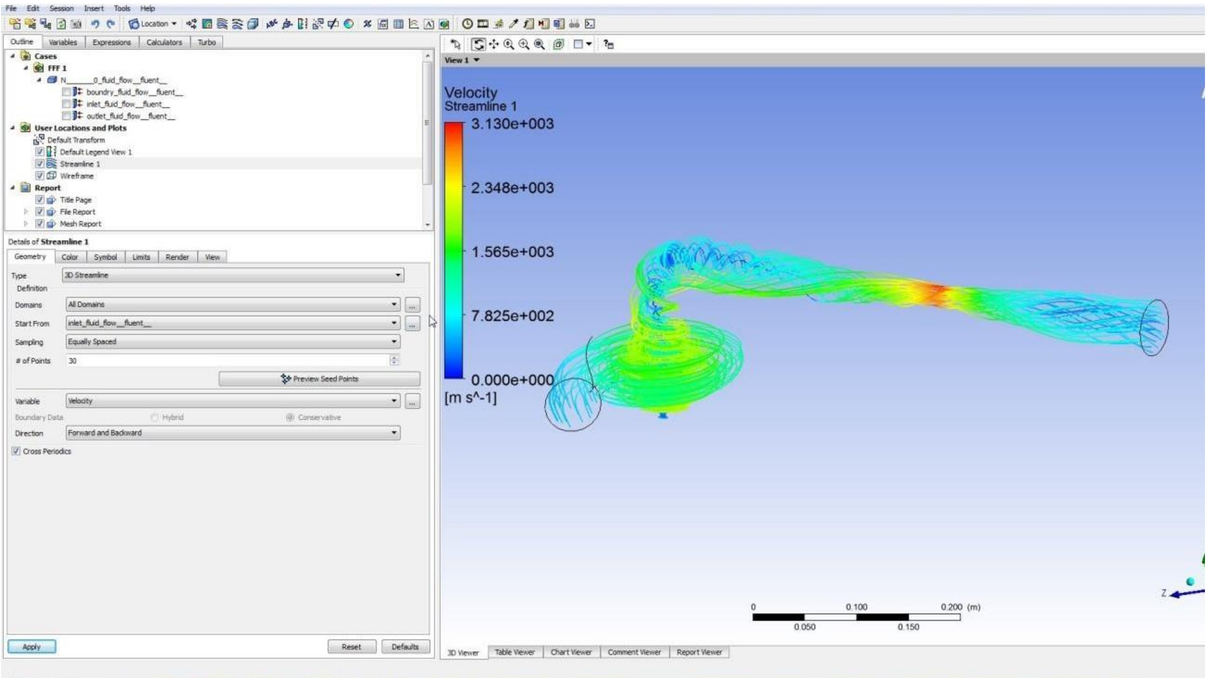

Figure 4 Previous Year's Design (Velocity Contour)

The simulations from computational fluid dynamics have shown that there is low static pressure development inside the plenum. This year's intake geometry is designed in such a manner that there is sufficient development of static pressure inside the plenum. Hence the throat of the venture was shifted away from the plenum on compromising the velocity at the throat.

Venture was finalized by simulating various geometries, firstly keeping the throat fixed of 20 mm was made then changing converging angles keeping diverging angle fixed. In second step converging angle was fixed and changed diverging angle from this we just analyzed how changes by changing converging and diverging angles flow. The inlet then converges to the restrictor diameter. After the restrictor, the airway then diverges until meeting the inner diameter required for attachment to the plenum.

Converging angle (degree)	Diverging angle (degree)	Inlet pressure (pa)	Outlet Pressure (pa)	Restrictor Velocity (m/s)
14	5	101325	101316	194
14	6	101325	101320	177
14	7	101325	101319	168

Table 1: Variation in throat velocity due to change in venturi angles

3. Plenum:

Plenum can be defined as the reservoir, which stores the air and supplies to the combustion chamber during the intake stroke. The volume of the plenum is the most unanswered point the design, and hence to calculate the volume we did the reverse engineering. First step was to choose the target RPM and then calculating the amount of air needed per second and ultimately deciding the volume.If the plenum volume is to large it will create less throttle response and if the plenum volume is very low then it will create negative pressure which will lead to less efficiency.

4. Runner Length

Runner can be defined as the part of air intake which is responsible for carrying the air from the plenum to the throttle body where fuel will be mixed.Runner length can be defined as the overall length from the plenum to the inlet valves of the engine. Runner length plays the most important part of the air intake system.If properly calculated and tuned, supercharging effects can be obtained which will increase the power generation of the engine.

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III. CALCULATIONS

Calculations of Effective Volume

Veff= Vd(rc+1)/2(rc-1
Veff= 373.26(12.8+1)/2(12.8-1)
Veff= 5150.988 / 23.6
Veff= 218.262 cc

Calculation Of runner length for different RPM

$$N = 955/k * c * (A/(l * Veff)^{1/2}$$

N= RPM at which peak torque is required
C= Velocity of sound
A= Area of primary throttle body
L= Required runner length
Veff= Effective volume
K= 2 for single cylinder engine

Target RPM	Runner Length(cm)
7000	40.961
7200	38.730
7500	35.682
7800	32.990
8000	31.362
8200	29.860
8500	27.790
8800	25.988

Table 2: Different runner lengths for given RPM

IV. ANALYSIS

A. Aim to maximize pressure recovery at outlet
B. Variables :
  a) Dependent Variables: ΔPressure = Inlet Pressure – Independent Variables
  b) Independent Variables: Converging angle and Diverging angle

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C. Turbulence models used:

Two equation models:

a) RNG k-epsilon model: In this models, constants in the equations are derived analytically using normalization group theory, instead of empirically from benchmark experimental data. Dissipation rate is modified .it gives better performance then standard k-epsilon for more complex shear flows and flows with high strain, swirl and separation.

b) Realizable k-epsilon (RKE)model:
In this model dissipation rate (ε) equation is derived from the mean square vorticity fluctuation which is fundamentally different from SKE(k-epsilon model).hence it actually predicts and provides superior performance for flow involving rotation, boundary layers under strong adverse pressure gradients, separation and recirculation.

Boundary Conditions:
Inlet: PRESSURE INLET = 1 Atmosphere
Outlet: MASS FLOW OUTLET = 0.0703KG/S
M = 1 A = 0.001256 m2 (20 mm restriction)
R = 0.286 KJ/Kg-K
ϒ = 1.4 P0= 101325 Pa
T = 303 K
Mass flow rate = 0.0703 kg/sec

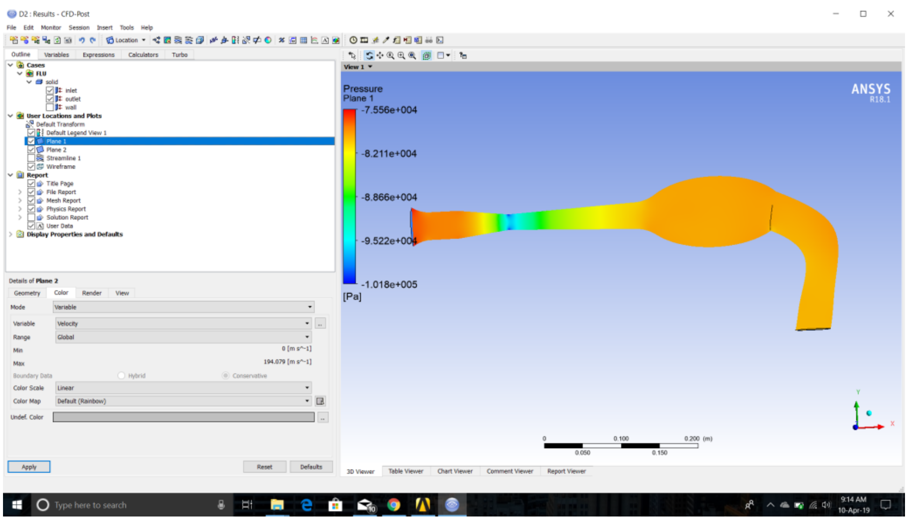

Figure 5 CFD Simulation Pressure Contour

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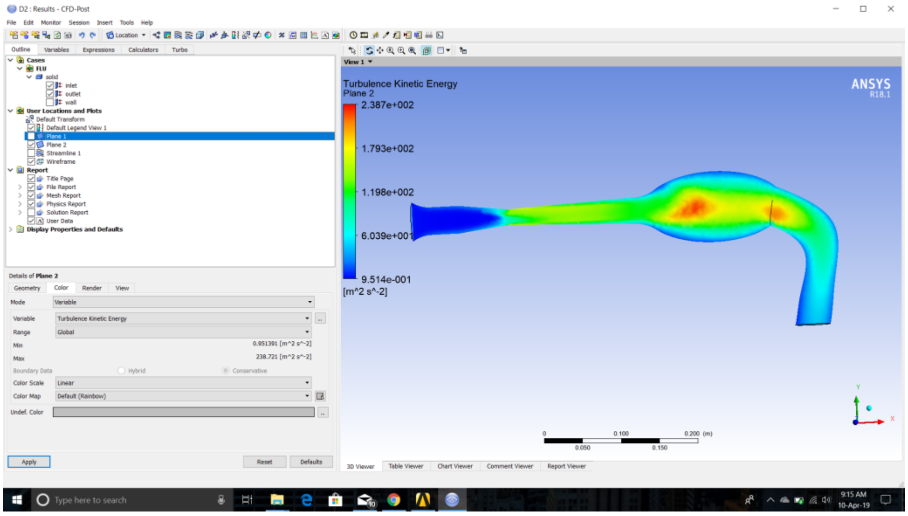

Figure 6 CFD Simulation Turbulent Kinetic Energy

V. MANUFACTURING:

This year's air intake is 3-D printed by Multi Jet Fusion technology. Multi Jet Fusion uses a fine-grained PA 12 material that allows for ultra-thin layers of 80 microns. This leads to parts with high density and low porosity, compared to PA 12 parts produced with Laser Sintering. It also leads to an exceptionally smooth surface straight out of the printer, and functional parts need minimal post-production finishing. That means short lead times, ideal for functional prototypes and small series of end-parts.

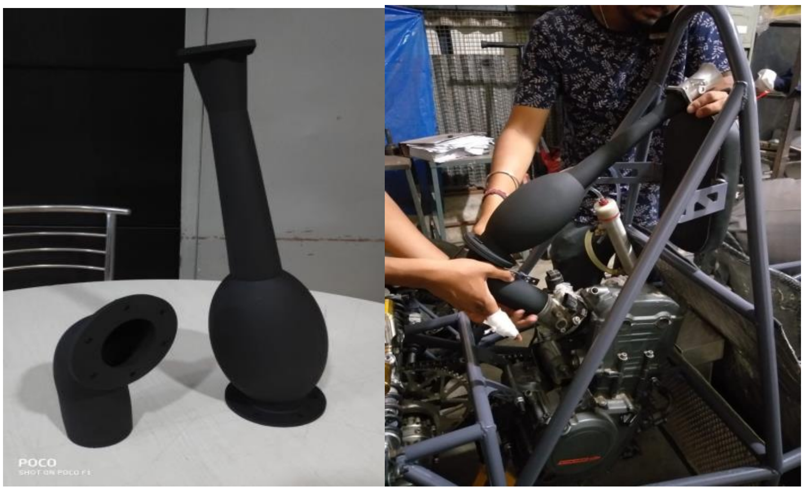

Figure 7: 3D Printed

VI. CONCLUSION

The primary aim of this year's design was to achieve high static pressure inside the plenum. By shifting the throat away from the plenum we were able to decelerate the air and hence increasing the pressure. Due to the simple (Oval) geometry of the plenum the air moving into the combustion chamber was less turbulent. Tuning the runner, keeping the Ram Effect as the theory behind designing super charging effect was achieved and increase in power generation was observed.

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