Design & Development of Intake Manifold for FSAE Car Using CFD & Experimental Validation.

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Abstract : : The undertaking manages the advancement of venturi type air admission restrictor that can be utilized in FSAE (Formula Student) rivalries. According to the rulebook given by FSAE the air going into the engine from the throttle body or carburetor must go through a 20mm diameter opening. On the off chance that this standard is abused by any of the group the vehicle is excluded from the occasion. The purpose for this standard is to decrease the power output of the engine which will guarantee the wellbeing of the driver. So as to remunerate the loss of intensity there must be a game plan that will repay this misfortune. Here Venturi is utilized as a limitation gadget. Creo 2.0 is utilized for CAD demonstrating and ANSYS 18.1 (Fluent Solver) is utilized for CFD(Computational Fluid Dynamics) examination of the venturi.

***IndexTerms* - Formula student, CFD.**

I. INTRODUCTION

The performance of an internal combustion engine depends directly on the amount of air elaborated in every cycle during its functioning. On this basis, a way to limit the maximum power of an engine is to introduce a pressure loss along the intake manifold. According to this principle, Formula SAE rules impose the adoption of a restrictor, with a diameter of 20mm, along the intake line between the throttle valve and the engine inlet. More in detail, the restrictor has the aim to cause a pressure drop that is proportional to the second power of the instantaneous velocity of the airflow. In order to reduce the influence of the restrictor, it is necessary to minimize the maximum instantaneous flow velocity through it.

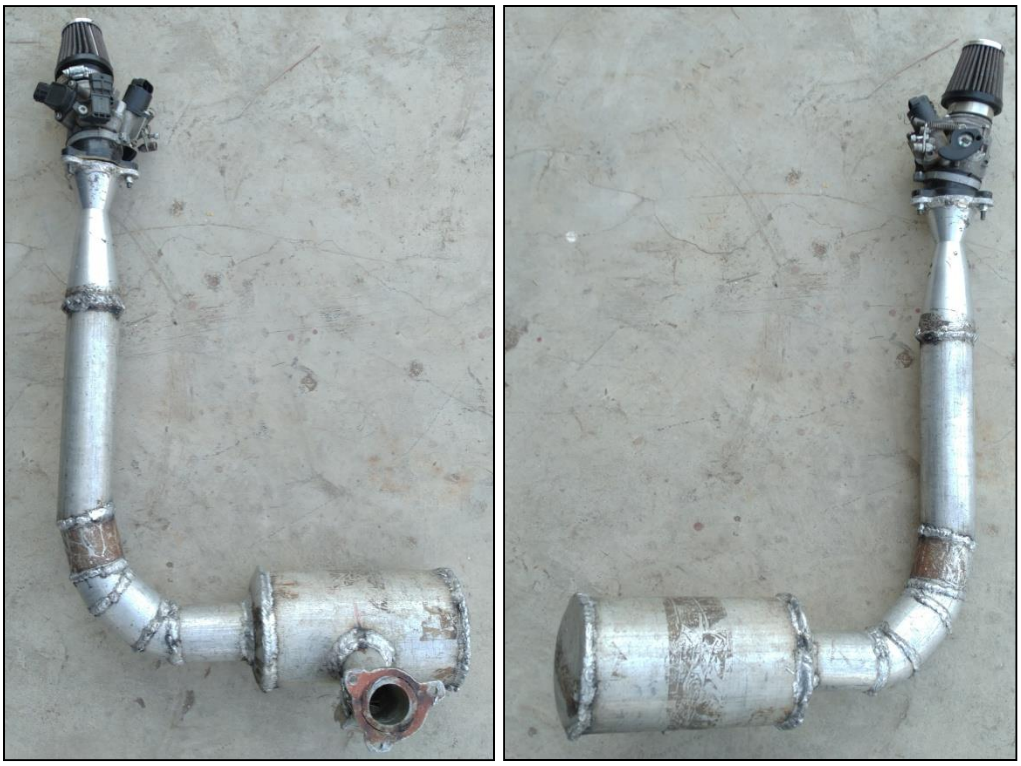

FIG 1: Air Restrictor

II. PROLEM STATEMENT

The output and torque of a engine have the best impact on the engine's character. These, thusly, are enormously influenced by how much the chamber is filled and the geometric type of the admission tract. High torque requires an admission complex with geometry distinctive to one for high power output. A medium admission complex length with a medium measurement speaks to a trade off yet it results in the lower torque and power at low and high speeds which at last outcomes into corrupted execution and less efficiency. Variable admission complex represents a perfect choice to take care of this issue.

III. SCOPE

The FSAE being a very widely spread international engineering event where students from various institutions participate , it forms a diverse environment for students which help exchange the practice of interchanging the ideas with other students from various cultures and background creating a fit working experience in engineering industry.

IV. RESEARCH METHODOLOGY

The fundamental structure parameters to be considered for the wind current and Computational Fluid Dynamic (CFD) examination is the plan limitations because of combination of the back piece of the body and different principles to be pursued. This air admission complex is set between the air channel and the throttle body of the engine and consequently the inward distance across at the inflow and outpouring of the spout is pre-decided and can't be changed. The length of this body can't be reached out after a specific size, since it will give obstruction to the nearby parts and should be inside the tallness of the primary move band of the body. In this manner the CFD investigation is done for the area of the neck, length and edge related with the goal for it to not have air resistive vortex locales and to diminish the drag stream.

Any CFD issue is explained by putting the suitable limit conditions to the Navier's feeds condition. Utilizing Finite volume strategies, the conditions are recast in preservationist structure, and after that understood on each discrete control volume. As there is no disturbance engaged with the framework, there is no contribution of Reynolds stresses and swirl flows. Hence the Navier feed condition can be explained by regarding the framework as limit esteem issue. Choice of the suitable limit conditions is significant on account of tackling limit esteem issues, generally prompts numerical insecurity of the framework. Thinking about the above components as a main priority, the mass stream rate for gagging condition is determined.

Considering any models in CFD examination, there can be 3 kinds of mistakes which must be considered truly while taking care of the issue:-

(a) Due to the ill-advised lattice, there can be deviation from the real model which prompts blunder in the framework. This issue is fathomed by applying organized work and applying assembly basis.

(b) Numerical flimsiness because of inappropriate limit conditions or truncation blunders while change of fractional differential conditions into arithmetical conditions. The little mistake will become quickly wandering from the real blunder. This issue is settled by giving fitting and reasonable space step.

(c) The work has been brought into ansys and understood. The numerical mistake is observed till the estimation of blunder gets diminished to 0.001% so numerical soundness is accomplished .

Inlet complex by and large encounters two sort of pressure waves one being pressure & other is suction wave. Admission complex can be tuned so that the volumetric proficiency of beyond what 100% can be accomplished. Subsequently improvement in the torque output and intensity of the engine is conceivable. Air moving through the admission complex runner, past the admission valve and into the chamber streams alike until the admission valve closes. After the conclusion of valve air strikes on the shut valve and high pressure wave is made. This is the pressure wave and goes forward and backward along the shut admission runner length. Tuning the admission complex is only making the pressure wave return at the channel valve precisely when it opens. This pressure wave at that point hurries into the chamber to the vibe it at qualities more than that of typical one and most extreme volumetric proficiency is accomplished. The impact is named as Ram impact charging and length of admission complex to accomplish that Ram impact can be anticipated by Chryslers Ram Theory.

Another wave is the rarefaction or suction wave, it produces when the channel valve opens & the vacuum of the chamber is presented to the channel complex. This low pressure when goes from channel valve opening to the opposite end of admission complex for example to the environment if there should be an occurrence of single chamber engine and gets reflected as pressure wave. The high pressure wave at that point created goes back towards channel valve. The planning of entry of this reflected high pressure wave can be tuned with opening of the admission valve by fittingly structuring the delta complex. Tuning of the admission complex along these lines builds the nearby thickness of the air at the inlet. In chamber pressure get expanded at ivc causing most extreme conceivable volumetric proficiency.

V. DESIGN, ANALYSIS & FABRICATION OF INTAKE

Admission manifolds more often than not comprise of a one or more throttle bodies controlling wind stream to the engine. The wind current at that point enters the plenum which resembles a repository of air. At the point when the valve of any chamber opens the air from the plenum rapidly goes down the admission runner to that chamber. Since the air beats into every chamber as opposed to streaming consistently after some time it is important to have the capacity of air in the plenum. Without air stockpiling every chamber would need to pull the air charge through the restrictor. The most extreme speed of air through a venturi is the speed of sound paying little heed to the pressure contrast crosswise over it. The plenum permits the wind stream through the restrictor to be smooth instead of heartbeat taking into consideration a more prominent normal wind stream than without a plenum. The admission runners related to the plenum structure a Helmholtz Resonator. A Helmholtz Resonator comprises of a depression (plenum) with a volume V, and an opening (consumption runner) of cross sectional territory A with length L. Essentially a Helmholtz resonator resembles a coke bottle, the sound that it makes when you blow crosswise over it has an unmistakable recurrence.

The frequency of a Helmholtz resonator is:

F= (V/2π)(√A/VL)^1/2

Where v is the speed of sound in air, A is the cross sectional area of the intake runner, L is the length of the intake runner, and V is the volume of the plenum. Often for intake manifolds the speed of sound in air v is multiplied by a constant that is less than 1 to compensate for viscous effects in the runners.

VI. PARTS OF INTAKE MANIFOLD

1. VENTURI

The working of venturimeter is based on the principle of Bernoulli's equation. Bernoulli's Statement:-It states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant. The total energy consists of pressure energy, kinetic energy and potential energy or datum energy. The venturimeter is used to measure the rate of flow of a fluid flowing through the pipes.

The Bernoulli's Equation is given by:

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

FIG 2: Bernoulli's equation

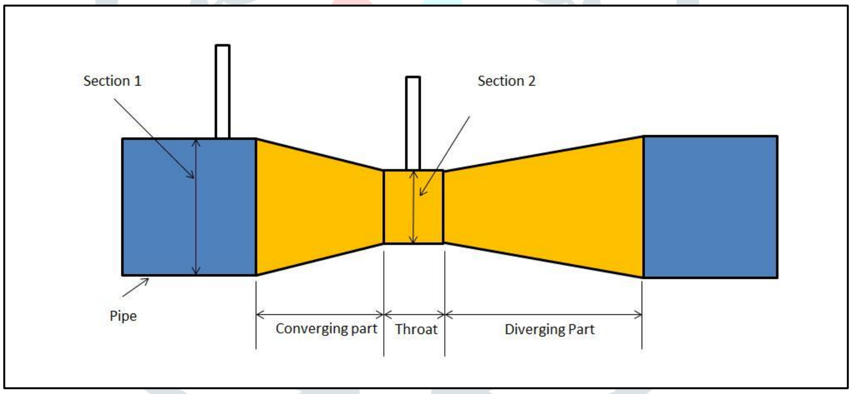

FIG 3: VENTURIMETER

2. RUNNER

The runner length is the most significant factor as it influences the rpm of the engine.

- The runner length is settled on the nuts and bolts of wrap standard expressed by Supra SAE INDIA.
- The time after which delta valve opens again if matches to the season of entry of high pressure wave of air at inlet at that point Ram impact happens causing most elevated conceivable pneumatic stress at IVC.
- Tuning relates to altering the length of admission runner with the goal that this pressure wave comes to precisely when the inlet valve opens.
- The time required for the air fuel blend to achieve the burning chamber relies upon the runner length.
- The runner length is determined by utilizing the **Chrysler slam hypothesis.**

Following parameters are required to ascertain runner length:-

- Inlet valve open time and close time(degree)

- Rpm of engine
- Velocity of sound
- Time required for the wave to make a trip back to delta valve

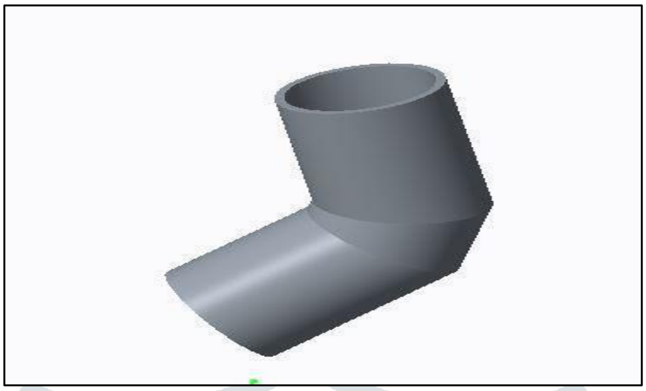

FIG 4: RUNNER

VII. COMPRESSIBLE FLUID FLOW DYNAMICS

The most important parameter in compressible flows is Mach number Ma=V/C where V is flow velocity and C is speed of sound. If Mach number is less than 0.3, compressibility effects can be neglected as there is around 3 % change in density. Whereas if Mach number is from 0.3 to 1 flow is called subsonic and if Ma>1 flow is supersonic, in this regions compressibility increases and its effects are considerable. Compressibility is around 47 % at supersonic flows

TYPES OF FLOWS:

1. **Subsonic flow: -**When the fluid velocity is lower than the acoustic speed (M<1) then the fluid flow is called as subsonic. However Mach number of the flow changes while passing over an object or through a duct. Hence for simplicity, flow is considered as subsonic if Mach number is in the range of 0-0.8. All small amplitude disturbances travel with acoustic speed and speed of the flow in the subsonic regime is less than acoustic speed hence presence of the disturbance is felt by the whole fluid domain. Therefore subsonic flow is pre-warned or prepared to face the disturbance.

2. **Transonic flow: -** When the flow Mach number is in the range 0.8-1.2 it is called transonic flow. Highly unstable and mixed subsonic and supersonic flows are the main features of this regime.

3. **Sonic flow: -** When flow Mach number is 1 it is called sonic flow.

4. **Supersonic flow: -** When the flow Mach number is more than everywhere in the domain then it is called as supersonic flow. This flow is not pre-warned since the fluid speed is more than the speed of sound.

5. **Hypersonic flow: -** As per the thumb rule, when the flow Mach number is more than 5 then it is called as hypersonic flows. This is not the fixed definition for hypersonic flow since hypersonic flow is defined by certain characteristics of flow.

We have considered Mach number as 1 i.e. sonic flow.

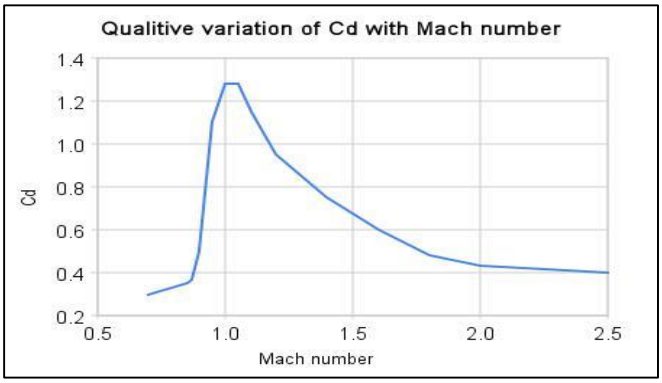

FIG 5: GRAPH OF Cd vs Mach Number

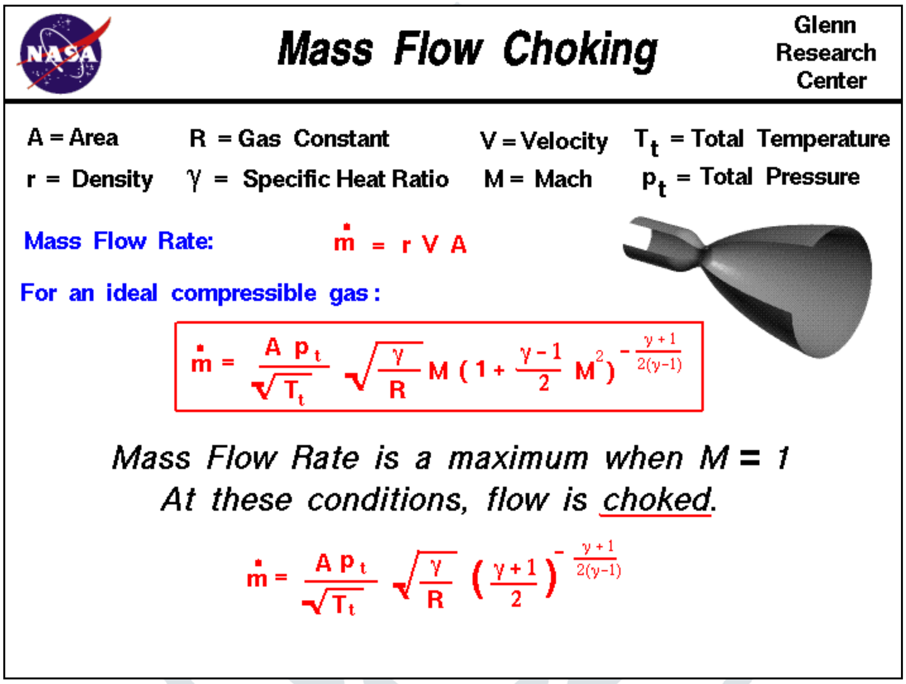

FIG 6: NASA MASS FLOW EQUATION

Calculating maximum mass flow rate from above equation using available data values as stated below:

M = 1 (choked flow)

A = 0.001256 m² (20 mm restriction)

R = 0.286 KJ/Kg-K

γ = 1.4

Pt = 101325 Pa

T = 300 K

Mass flow rate = 0.0703 kg/s

VIII. CFD ANALYSIS

Fig demonstrates the CFD examination of the whole admission complex. From the fig we can see that speed is most extreme at the throat of the venturi and it lessens steadily along the separating area. The stream is smooth and along the straight line in the plenum and runner. The structure of plenum is with the end goal that there are no misfortunes along the plenum which gives us rich blend of fuel and air required for ignition at various engine velocities. There is least reverse of air and no vortex development in the plenum. The plan gives us nonstop stream all through the admission complex and least pressure drop over the delta and outlet of venturi. This structure gives us rich blend of fuel and air at various engine velocities which results in least draw from the engine and builds the influence definitely. Along these lines this investigation on CFD gives us the best execution to do the assembling of admission complex dependent on our structure.

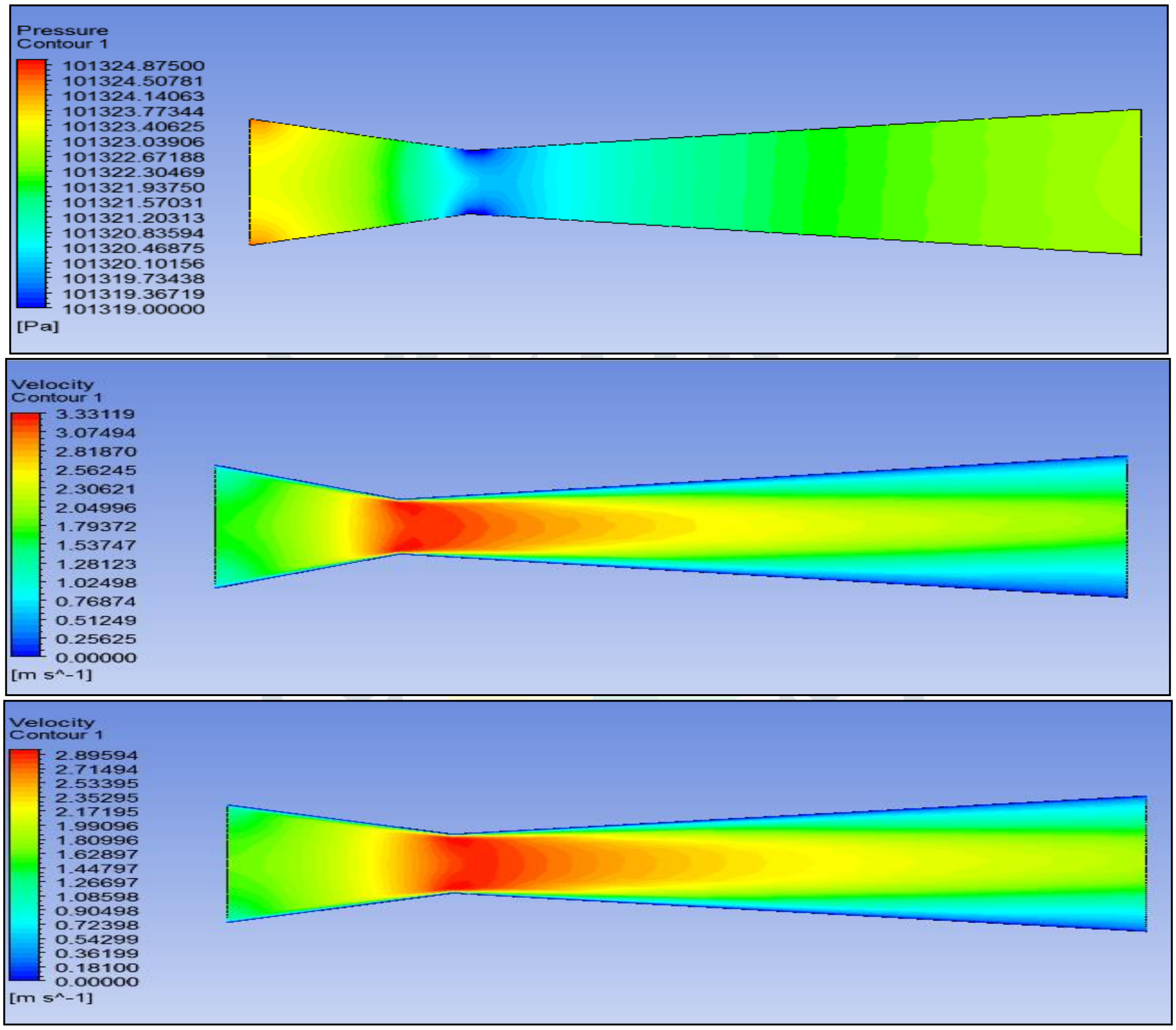

FIG 7: CFD OF VENTURI

Fig demonstrates the CFD examination of the whole admission complex. From the examination done for the current year it very well may be unmistakably observed from the fig that there are enormous number of vortex development in the plenum. Additionally the volume of the plenum is similarly extremely huge, which stores huge measure of air. There are much misfortunes in plenum because of bigger volume which results in inadequate supply according to various engine speed. This structure gives us lean blend of fuel and air at various engine paces which results in most extreme draw from the engine and decreases the power definitely. Likewise the stream isn't constant and smooth all through the admission complex and there happens enormous pressure distinction at the bay and outlet of venturi. At higher rpm engine neglected to give the most extreme power because of poor structure and examination. The fundamental point of this plan is to accomplish most extreme power at higher rpm with least draw from the engine. To accomplish the best execution the structure of admission complex is changed as appeared with all plan parameters and examination done on CFD.

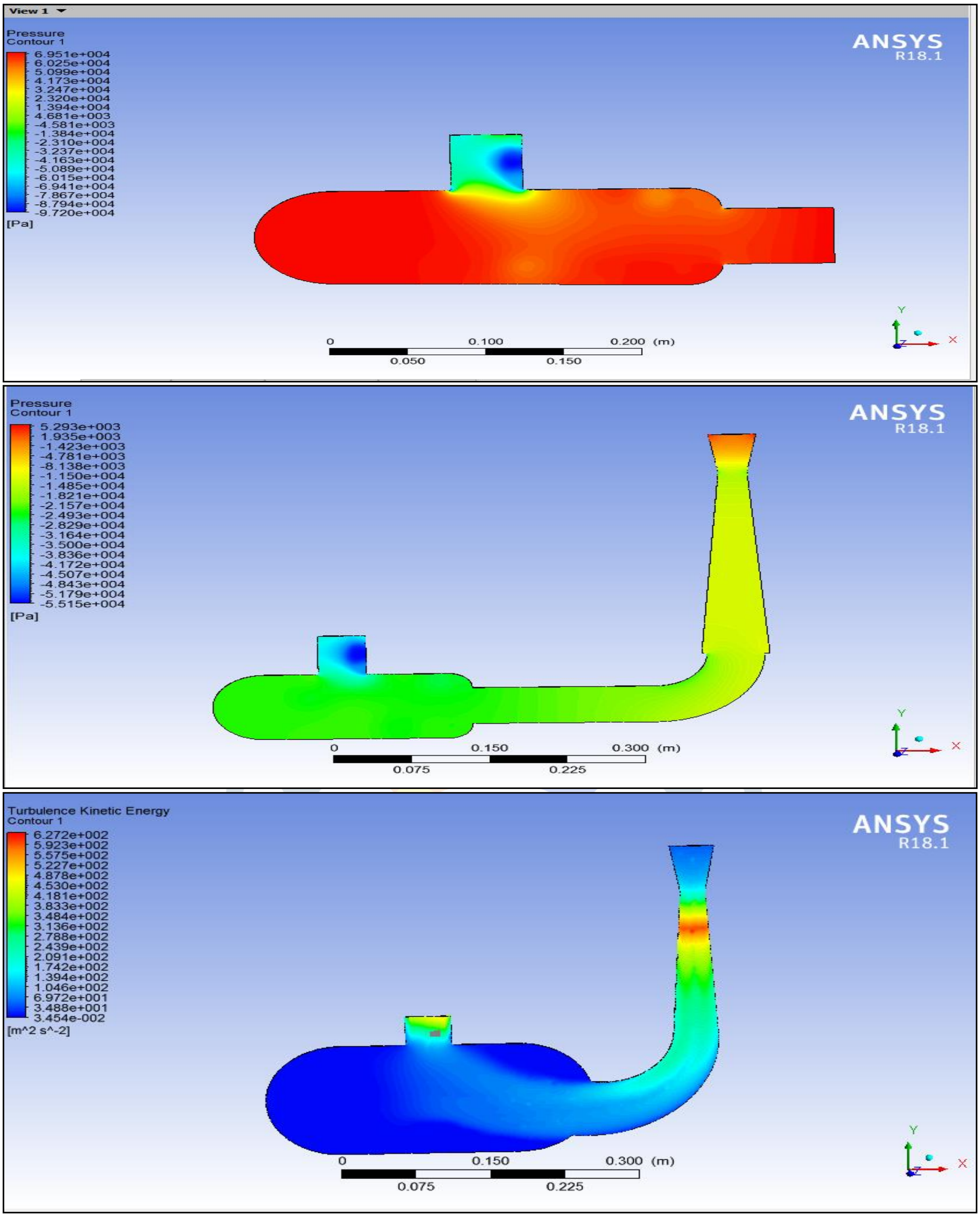

FIG 8: CFD OF AIR RESTRICTOR

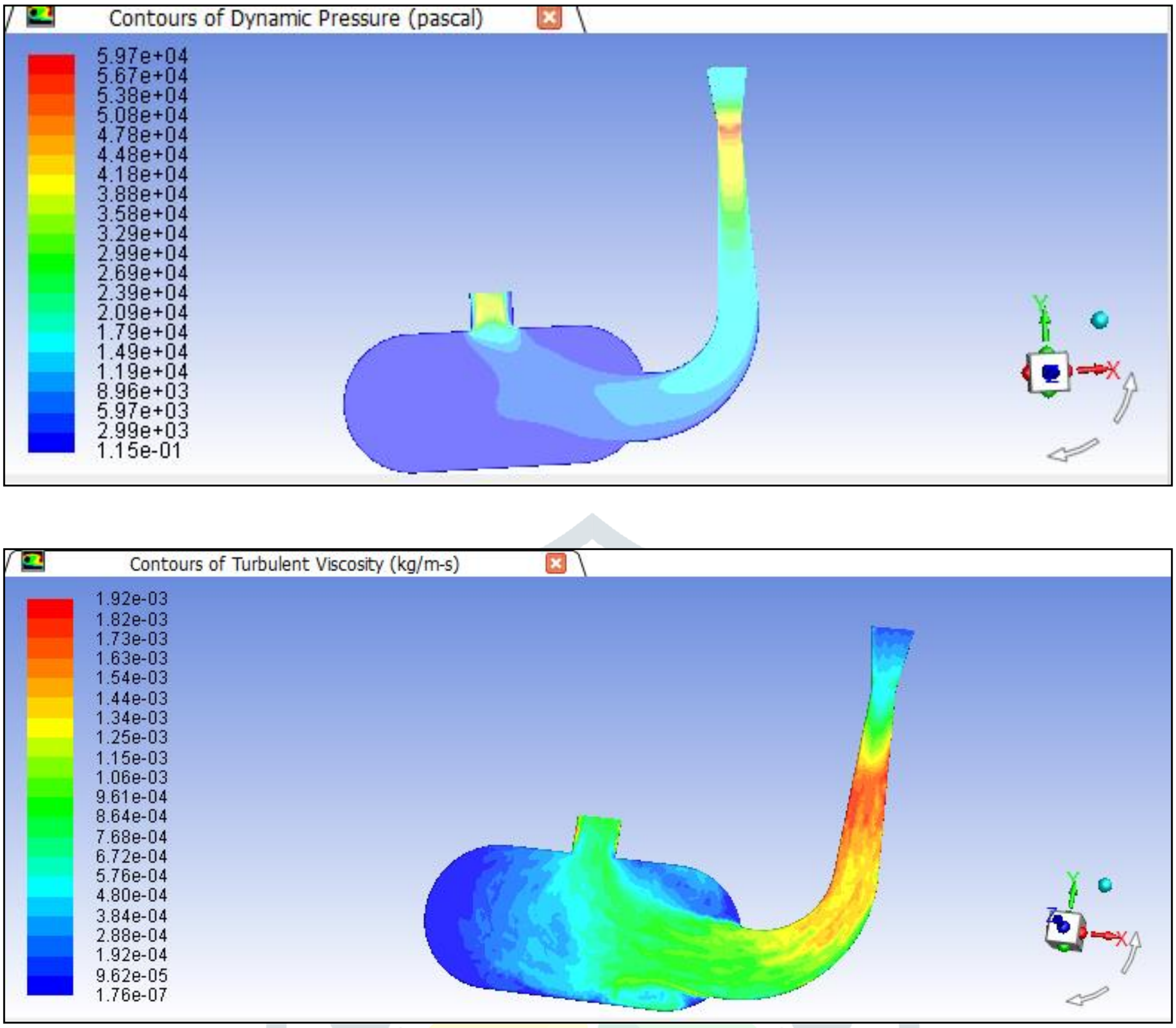

FIG 9: CFD OF AIR RESTRICTOR

IX. RESULTS AND DISCUSSION

This project is dedicated to designing of intake system for a restricted single cylinder engine. Intake system design includes designing of three components viz. Restrictor, Plenum and Runner. Restrictor design is based on the geometric constraints and results of steady state CFD analysis. Plenum volume is based on literature study and its shape is decided through transient CFD analysis. Runner design is based on induction wave tuning principle and its dimensions are based on empirical relations available in the literature.

There is wide scope of future work related to this project. Following points illustrate areas where future work is going to be done and overall performance of Intake

- Future scope for deciding optimum plenum volume: This will be done through observing effect of different plenum volumes on engine performance through engine dynamometer testing. 3-4 different plenum volumes, mostly 1.5 times, 1.75 times, 2 times and 2.5 times engine displacement will be manufactured. One by one, these plenums will be installed on engine and power- torque curves will be obtained. The one which gives best performance amongst all will be selected as final plenum volume. This volume will be incorporated with the shape selected through procedure discussed in earlier sections.
- Final dimensions of runner will be decided through runner tuning which is part of planned Engine Dynamometer testing in future.
- With availability of higher processing capacity computer lab, ANSYS Fluent transient simulations will be done for more than one & half engine cycle operation and it will output more accurate results.

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