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Design and analysis of air intake manifold of an FSAE vehicle

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Abstract - *This exploration paper aims at designing and developing an air input manifold to be used in FSAE competitions. According to the rule assessed by the FSAE commission, a 20 mm restrictor should be a part of the input manifold through which only the machine breaths in air for combustion. This rule is assessed to reduce the maximum power produced by an machine. This paper is proved as an preface on how to design and fabricate an air input manifold according to FSAE morals. Software tools used designing and developing an air input manifold are Solidworks(for CADD modeling), Solidworks Flow Simulation(for inflow analysis), The results from CFD analysis and RICARDO are compared to find the most suitable design of IM for inferring maximum machine performance. The complete study and exploration of the IM then's done in agreement to the need of a KTM RC390 machine..*

Key Words: *Air intake manifold, restrictor, Solidworks, FSAE, Flow Simulation, KTM RC390 engine.*

1.INTRODUCTION

This The Formula SAE series competitions challenge brigades of university undergraduate and graduate scholars to design, fabricate, develop, and contend with small, formula- style vehicles at public position competitions. The machine used must be a four- stroke machine with a relegation not further than 610 cc. The FSAE commission has assessed a rule of placing a 20 mm restrictor in the air input manifold if the machine being used is energy fitted and not carburate may that be a single or multiple cylinder machine. This rule has been assessed so as to check the maximum power produced by bigger machines. The order in which the factors of the IM should be placed are as in air sludge, garrote body, restrictor and input runner. For any machine having further than one cylinder, it has enough suction power to pull the air in through this 20 mm restrictor. But for a single cylinder machine due to lack of suction power, at low RPMs the machine booths due to inadequate air for combustion. In such a situation, a belly pot has to be placed after the 20 mm restrictor so as to compensate the need of air for combustion. Then on stop's focus on the ideal of air input manifold for a single cylinder machine.

1.1 Intake manifold

The primary function of the input manifold is to deliver air to machine and this factor makes it a veritably important aspect to design a quality input system. The effectiveness of the machine completely depends upon the figure of the input design and one must always consider the following points as per the design point of view of a input manifold.

1. Maximize the air haste in the machine cylinder.

2.Minimal pressure loss.

3.Minimal bends and angles with unforeseen changes in

figure.

4. Mass inflow rate of air should be near about match no. 1.

5.Exclude the sharp corner in design to reduce the vibration i n input manifold.

1.2 Fluent Analysis

It's necessary to choose right software for the inflow analysis and also the modeling software. Then we've used ANSYS FLUENT for creating figure and also to perform CFD analysis. Hence it offers better parameters which can be used in analysis results in better mass inflow rate of air. In order to compare mass inflow rate corresponding to different clustering and diverging angles are defined and separate duplications have been done to conclude the minimal pressure drop in the restrictor.

2. Plenum

Plenum facilitates the distribution of air and energy admixture into the cylinder. The pressure within the manifold should be lesser than that in the cylinders. the introductory function of the plenum is to produce the below- mentioned high pressure. Plenum is designed according to RAM proposition, which states that a ram air input is any input design which uses the dynamic air pressure created by vehicle stir to increase the static air pressure inside of the input manifold on an internal combustion machine, therefore allowing a lesser mass inflow through the machine and hence

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adding machine power. Plenum volume = 1.7 to 2.7 times the machine relegation Runner The runner is a part which connects the plenum and restrictor with the machine. Plenum volume is specific to each machine, with larger capacity machines taking larger plenum volume. Empirically, plenum volume and or garrote body throat size have been set up to be interdependent, with lower throttle body generally producing better performance when combined with larger plenums, and vice versa. For our machine KTM 390 the volumetric relegation is 390 cc and the plenum designed should have 0.8 times of machine volumetric relegation in order to get good performance by machine.

Volume of plenum, (VP) = 0.8 times (displacement of

engine) = 0.8 X 390 = 312 cc

Creating a chamber in which inlet charge is able to accumulate provides a constant supply of charge in close proximity to the inlet runners. This reserve of charge provides additional momentum to the air / fuel flowing into the cylinder, creating a more efficient intake process, increasing inlet charge and hence providing greater power production.

3. Working

The volume of the input manifold needs to serve the machines demand and it should decide the stylish possible affair from the machine. The air chamber of IM is in two part i.e. the snoot and pot conforming as one and the input runner. originally the air will enter through the snoot where air will lose its pressure energy and gain kinetic energy. But the machine needs to breath at atmospheric pressure and temperature so as to maintain stoichiometric rate to work efficiently. The kinetic energy gained and the pressure energy lost is regularized with the help of the plenum or belly pot and this regularized air at STP is also delivered to the input runner. The input runner is mounted with energy injector and air mapping detector. The injector injects energy i.e. petrol into the sluice of air coming from the plenum pot and this charge is also delivered to the combustion chamber. The air mapping detector keeps a check on the pressure and temperature of the air before entering the combustion chamber. If there's any change in the temperature and pressure of the air the mapping detector sends this information to the ECU. The ECU, also consequently changes the energy discharge..

4. Calculations

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 = 16.39 inches = 416 mm

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

4.1. Induction wave theory:

The induction wave theory states that the length of the runner depends on the factors such as EVCD, RPM, Speed of sound, RV, Runner diameter.

Formula: Length = (EVCD*0.25*V*2) / (RPM*RV) - (0.5D) Where,

EVCD = Effective valve close duration.

V = Speed of Sound in feet per second.

RPM = Revolutions per Minute.

RV = Reflective Valve D = Runner diameter

4.2. Cam specifications:

EVCD = 720° – ECD - 20° Where,

ECD= 180° +2° BTDC + 44° ATDC

ECD = Effective Cam Duration.

BTDC = Before Top Dead centre.

ATDC = After Top Dead Centre.

4 strokes = 720° Therefore,

ECD= 226° EVCD = 474°

Diameter of Runner = 55mm = 2.1653 inches Length = (474°*0.25*1125*2) / (4500 * 4) – (0.5 *2.1653) = 348.738 mm = 13.72985 inches

4.3. Helmholtz Resonator Theory:

$FP = 162K * c\ ALV\ R-1R+1$
Where ,

Fp= Engine rpm
K=2.0 to 2.5
C= Speed of sound , ft/s .
V= Displacement of cylinder L= Inlet pipe length A= Inlet pipe cross sectional area R= compression ratio 162 is constant incorporating units

Fig -1: Vehicle Overview

Fig -2: Cross sectional

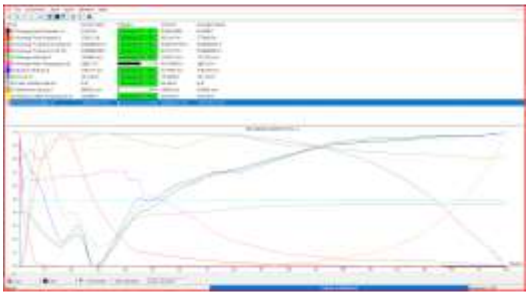

Fig -3: Volume flow rate

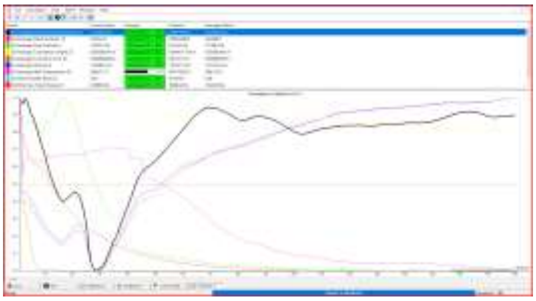

Fig -4: Average circumferential velocity

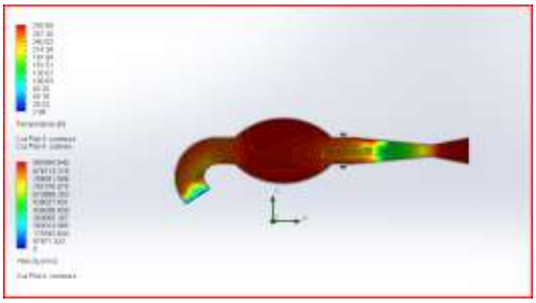

Fig -5: Temperature and velocity

Fig -6: velocity and pressure

5. CONCLUSIONS

Input manifold is a veritably pivotal part for the machine as we've seen its significance bandied over, and all the design considerations are made according to the SAE rule book. The design should be completely optimized to get the maximum performance of the machine. And CFD helps to calculate the inflow analysis of the input manifold.The manifold's figure, including runner length, periphery, and plenum volume, significantly impacts tailwind and volumetric effectiveness. Computational Fluid Dynamics(CFD) analysis plays a vital part in refining these parameters.CFD simulations give detailed perceptivity into tailwind patterns, pressure distribution, and haste biographies within the manifold.These simulations help identify areas of inflow restriction, turbulence, and uneven distribution, enabling design variations for bettered performance.The design and analysis of an air input manifold is an iterative process. CFD simulations and experimental testing are used to validate and upgrade the design. Farther advancements can be achieved through experimental confirmation, 3D printing ways, and advanced tuning strategies for real- world testing.Overall, the developed air input manifold provides a competitive advantage in an FSAE vehicle by enhancing machine effectiveness and performance while maintaining compliance with competition regulations

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