Design and Analysis of Intake and Exhaust System of SAE Supra Race Car

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Abstract - This study takes a look at the design process of the air intake and exhaust system of the SAE Supra Race Car. Over the years, much of the design of this system had been carried out through an iterative trial and error process, so the study attempts to identify the scientific and engineering principles pertaining to the design of this system. The intake system is being subdivided into various components, and the relevant principles will be discussed. Following that, data is collected from the engine cylinders; cam-profile, intake valves etc. and a simulation model of the engine will be developed. This model is then being applied, sequentially, to the various components. 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 flowbench.

***Key Words*: Exhaust system1, Intake system2, Flow analysis3, Performance Simulations4, Simulation Methodology5**

1. INTRODUCTION

The basic function of the intake manifold is to get the air from the carburetor or throttle body directed into the intake ports. A great intake manifold design can provide substantial performance advantages than a less optimal one[4].
Design goals to be met by the intake manifold-
• Low resistance to airflow.
• High air velocity for a given flow rate.
• Excellent fuel and air distribution throughout.

To achieve desired power and torque, air flow characteristics matter in respect to naturally aspirated engines. Getting air into an engine is the key to making power[3]. As per the rules of SUPRA SAEINDIA and FORMULA STUDENT INDIA competition, there is 20 mm restrictor present between throttle body and engine, to limit engine power capability. To achieve stagnation of air, plenum is used. Runner connects the plenum with engine and is tuned at certain rpm to optimize engine performance. As KTM 390
Duke engine was used for the competition; all analysis was done on three parts – Restrictor, Plenum and Runner.
. In exhaust system design of muffler is important. The muffler is a device for reducing the amount of noise emitted by a machine. To minimize the exhaust noise, the engine exhaust is connected via exhaust pipe to silencer called muffler. The silencer makes a major contribution to exhaust noise reduction. While designing exhaust system main attention is given to design a muffler to reduce the noise and back pressure. By varying the muffler design parameters the flow will be analyzed. So the Exhaust system is to be designed with the aim of reducing the noise level of stock engine and restricting it below 110db. Also, eliminating or reducing the harmful exhaust gases like Oxides of Nitrogen, Carbon-mono-oxide and unburned Hydrocarbons is a major concern. While doing all this, back pressure is to be kept as low as possible. The Catalytic convertor that we used in our system is a two way type in which Platinum, Palladium and Rhodium are used. The Muffler design consists of three chambers and a Helmontz Resonator to decrease the noise level. The principle of superimposition of waves helps to cancel of the sound waves produced and decrease the noise level to a greater extent. The tail pipe is kept narrower to cancel out the sound waves[1,2,].

2. SCOPE

• To optimize design of convergent- divergent type restrictor.
• To optimize plenum shape for having least flow resistance and maximum air flow velocity.

• To obtain optimum plenum volume.
• To obtain optimum runner diameter.

3. SIMULATION METHODOLOGY

3.1Intake System1

Restrictor:
Considering packaging within vehicle, length of restrictor is constrained to 132.5mm. For convergent section, both the end diameters are constrained (48mm of throttle body and 20mm of the restrictor). For divergent section outlet diameter is 42mm. Considering parameters such as Pressure Difference at inlet and outlet of restrictor, Total Length of Restrictor, Velocity at Outlet and Pressure Recovery, Restrictor with Convergent angle 22º & Divergent angle 12º is selected.

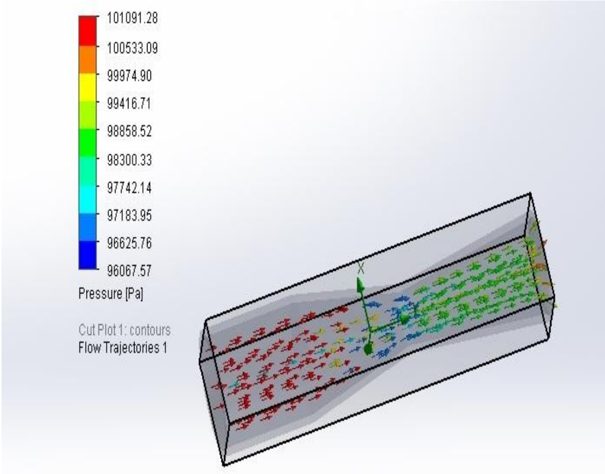

Fig.1 Solidwork Flow Simulation
(Pressure Profile)

Plenum:
As rpm goes up you need a larger plenum, but a larger plenum will reduce throttle response and low-end power. A plenum also minimizes peak air velocity through the carburetor (or throttle body).The induction pulses in an intake cause velocity to rise and fall with each pulse. Inlet boundary condition was 1 atm pressure and outlet condition was outlet pressure which is taken from analysis results of Solidwork flow simulation of whole intake system. In Horizontal cylindrical shape, central high velocity flow has wider flow area, as less vortices are created. Also, velocity values are higher compared with other plenum shape, so Horizontal cylindrical shape was chosen.

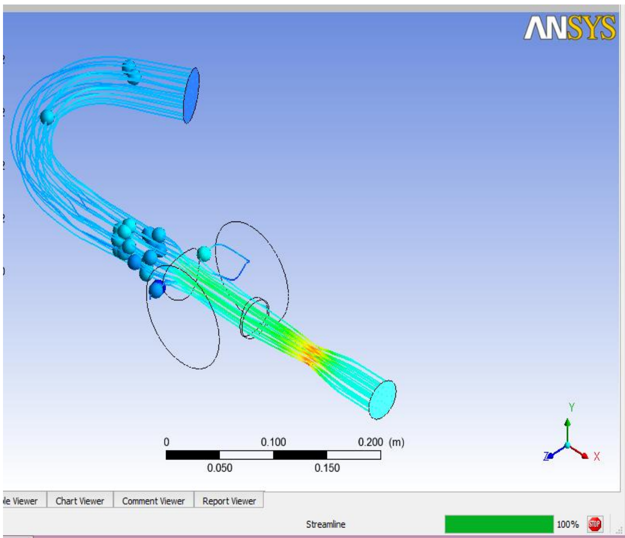

Fig.2 ANSYS Fluent (CFD)
Velocity Streamline

Intake Runner:
Intake runner length is the key factor to decide. The performance of whole intake system is depends on tuning of runner length. Intake runner length is designed for 5000 rpm so as to get low end torque and power based on track & driver's experience. According to Induction wave theory [4,5].
The formula for optimum intake runner length (L) is:
L = (EVCD*0.25*V*2/RPM*RF) – (0.5*RUNNER DIAMETER)
= (464º*0.25*1300*2/5000*4) – (0.5*1.8897)
L =359.032mm

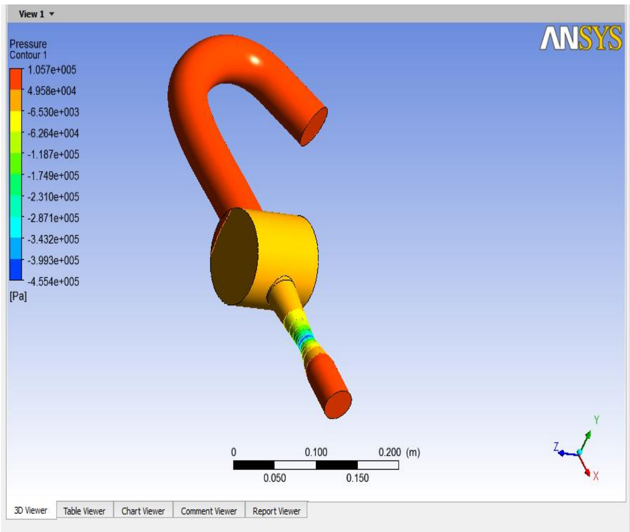

Fig.3 Intake System
(Pressure Contour)

Where:
EVCD = Effective Valve Closed Duration

RV = Reflective Value
V = Pressure Wave Speed =1300 ft/s
D = Runner Diameter = 1.8897 inch
EVCD = 720-(ECD)
EVCD = 720-226-30=464º
30º is subtracted such that pressure waves to arrive before the valve closes and after it opens
EVCD = 464º
According to induction wave tuning theory, intake system was tuned at 5000 RPM, resulting in total runner length of 359.032mm.
Runner Diameter is selected as 48 mm same as throttle body as both are connected through fasteners (Positive Locking).

3.2 Exhaust Design2

The system is designed for following purposes:

- To obtain minimum back pressure.
- To reduce noise level optimally.
- To obtain maximum insertion loss.

Muffler:
Reactive type of muffler is chosen as it provides more attenuation compared to absorptive type of muffler. The main consideration in designing muffler is to reduce noise level below 110dBA and reactive mufflers are best known for noise level reduction but, at the same time back pressure would be increasing, so obtaining minimum back pressure with reduced noise level, muffler is analyzed by Solidwork flow simulation.

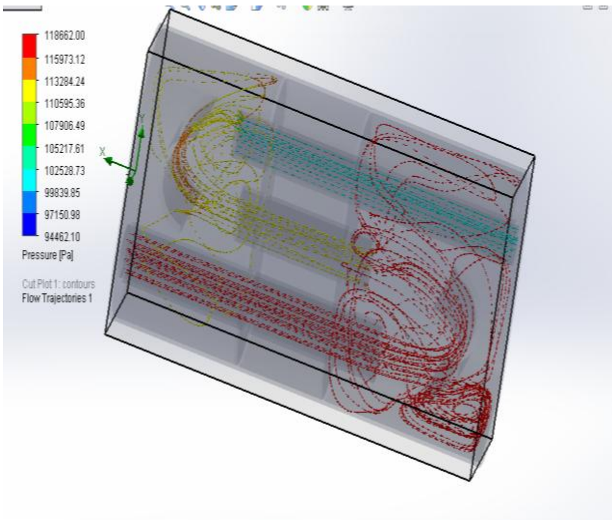

Fig.4 Solidwork Flow simulation
(Pressure Contour)

3. CONCLUSION

Thus we designed an air intake system and exhaust system for SUPRA SAE INDIA race car. We have 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.
We have designed a exhaust system so as to reduce noise level below 110 dB and also to minimize back pressure of the exhaust gases. The harmful gases were to be reduced.

ACKNOWLEDGEMENT

We take this opportunity to precise our deep sense of feeling to our guide Prof. Santosh Kumar Bawage. We also wish to convey our sincere thanks for his consistent involvement, valuable guidance, scholarly encouragement, selflessness time investment and thought provoking discussions which inspired us to make this report fruitful. We are grateful to Dr. D. R. Panchagade, Head of Mechanical Engineering Department for his valuable suggestions. We would wish to categorical my deepest sense of feelings to respected Principal Dr. B. S. Balapgol, for providing us basic infrastructure and different facilities.

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