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Selection of Restrictor and Plenum Model of Muffler Using Finite Elemental Simulation

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Abstract:
This paper mainly focusing on the selection of the restrictor model and plenum model of the muffler. The restrictor model mainly used in formula student racing competition are held across the world coordinated by society of automotive engineers. In this competition rule to restrict the power which is delivered to the cylinder. Three different shapes (oval shape,cylinder and sphere shapes) are chosen for testing. So they restrict the 20mm air restrictor before reaching the cylinder. To eliminate the restrictor to minimizing the pressure difference between the intake and outlet. To achieved the convergent-divergent angles changed by 20mm diameter to find out the angle to get less pressure drop. In-order to acquire the results of convergent angle of 17º and divergent angle of 4º had less pressure drop so that it is useful in muffler. Among three, sphere shapes is performed less pressure drop than compared with other shapes.

Keywords*: Restrictor model, Plenum Model and Muffler*

I. INTRODUCTION

Restrictor device is fixed inside the muffler interior and exhaust noise are caused by mostly interior and exhaust system . It leads to control the air pollution mostly. So it is required to reduce the exhaust and interior noise generated from system.This can be achieved by reducing the noise we connecting it with mufflers. Mufflers are best used to reduce the noise pollution. But design of muffler according to exhaust and interior noise is a very big task.The design should be good to exhaust because the bad design will cause transmission loss, insertion loss, increasing fuel consumption and piston effort to exhale the gases out. By using 3-D analysis of geometrically difficult mufflers is carried out for investigating various shapes of mufflers along with effects of expansion ratio, length of chamber, extended inlet and outlet mufflers with various position and angles of side outlet tubes and multiple chamber mufflers and silencers.

The primary goal was to deal the air equally to the intake port, as doing so improve the engine ability to efficiently produce power and torque . The geometrical design of the intake system affects the volumetric efficiency of the engine, and thus directly affects the performance of the vehicle. The challenge, therefore, was to optimize the design of the intake system. There are several objectives to consider of intake system:

i. Minimise pressure loss, as pressure loss results in a decrease in output power.

ii. Minimise bends and sudden changes in geometry, as these geometric affects can cause by pressure loss.

iii. Maximise air velocity into the cylinder, as this provides a better mixture of fuel and air, which results in better combustion and performance.

iv. To select optimum plenum size according to the engine to maximum mass flow rate in order to improve the volumetric efficiency.

v. Minimise the mass of the system, a common goal of every subsystem of the vehicle.

vi. The main objective for designing the

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cylinder runner is to propagate back the higher-pressure column of air to intake port within the duration of the intake valve's closure.

Xiang Yu et al. (1) studied the process sub chamber optimization for silencer construction. A theoretical basis is given for the definition of the silencer's overall transmission loss using the TLs of each of the multiple sub chambers related to the cascade and interaction between them. Amit kumar gupta et al (2) experimentally studied the propagation loss of the different cross section by preserving the constant volume of the expansion chamber by means of an acoustic simulation instrument. He found that the more noise attenuated by two baffle plates. P.B.Bhadke et al (3) analyzed by specific comparison of the inlet diameter of the muffler. A.P.Bhattu et al (4) the effect of extrusion of the inlet and outlet pipe inside the chamber and also the location of the extra inlet tube (i.e. divided inlet) into the chamber were studied and this parameter was then optimized to achieved the lowest sound pressure transmission loss. Shubham Naikwad et al (5) mufflers are studied to be an important part of the engine system and are widely used in exhaust systems to reduce the sound transmission from exhaust gases. M.P.Tambe et al(6) it is considered that sound is mainly produced by I.C. motors. Engine generated exhaust noise reduction is a important issue is analyzed . Jianmin Xu et al (7) calculated the pressure loss in muffler Longyang Xiang et al (8) calculate and evaluate the noise behaviour of the blower used on fuel cell vehicles. The multi chamber micro perforated muffler with adjustable transmission loss is proposed for silencing according to noise behaviors. The blower noise includes the wide band noise with frequency range of 500-1000Hz and the narrow band Harmonics with frequency range of 2000-3500 Hz. Shen chao et al (9) studied the different algorithms to improve the performance of acoustic attenuation and the flow characteristics of reactive mufflers. S.V. Gaikwad et al (10) prepared that to reduce the noise level of exhaust gas. The muffler's output is measured by examining pressure variability, exhaust gas flow pattern , expansion chamber length , transmission loss. This study helps to reduce the emissions from environmental noise. Analytical findings are contrasted with numerical results obtained from results.

II. METHODOLOGY

FINITE ELEMENT ANALYSIS OF MUFFLERS

Multidimensional approach analytical methods are very complicate and greater conflict appears between the analytical and experimental TL trend, after cut-on frequencies due to deviation from plane wave theory. If increasing effect in computational speed and storage capacity of systems, the numerical simulation method are widely accepted. Finite element method (FEM) widely used in design and analysis fields. A lot of work is done in smaller as well as larger systems. But design of larger system is difficulties because of testing and high costs of these silencer. The ability to accurately predict the performance before construction and commissioning would be very beneficial.

III. RESULTS AND DISCUSSIONS

A. Selection of best Restrictor model:

Difference between Venturi and Orifice:

Venturi tube	Orifice tube
Coefficient of discharge is between 0.95 to 0.975.	Coefficient of discharge is between 0.58 to 0.65.
Pressure loss is low on a scale of high to low.	Pressure loss is medium on a scale of high to low.

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Manufacturing cost is high.	Manufacturing cost is cheaper.
Manufacturing is difficult as there is a conical profile to be made.	Manufacturing is easy as there is just a hole to be drilled on a plate.

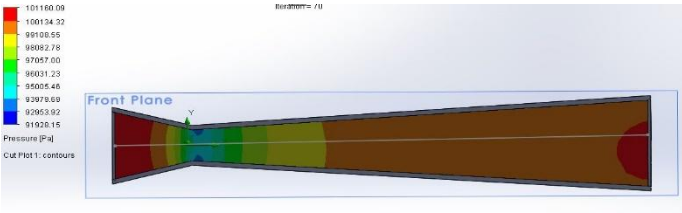
The restrictor is designed in the form of convergent – divergent nozzle. By varying the convergent-divergent angles, the best design is selected based on the low pressure drop at the end of divergent portion. The inlet cross-section diameter is 44mm, restrictor diameter is 20mm and the outlet diameter is 54mm.

Boundary conditions are:

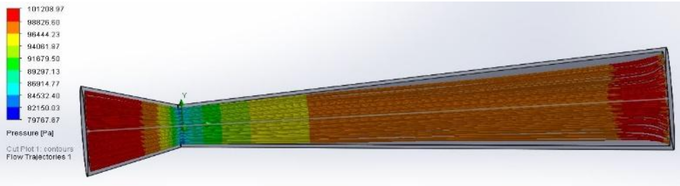
Inlet: 1 atm pressure

Outlet: 0.0189208 m^3/s

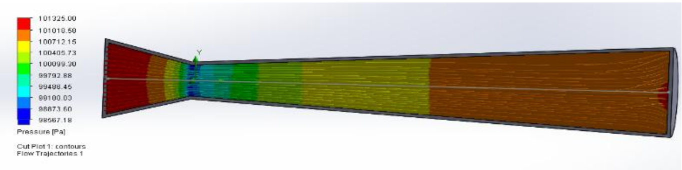
Iteration (1): Convergent angle =15⁰ and Divergent angle = 4⁰ (Pressure plot)



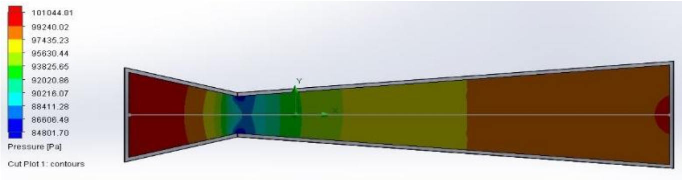
Iteration (2): Convergent angle =16⁰ and Divergent angle = 4⁰ (Pressure plot)



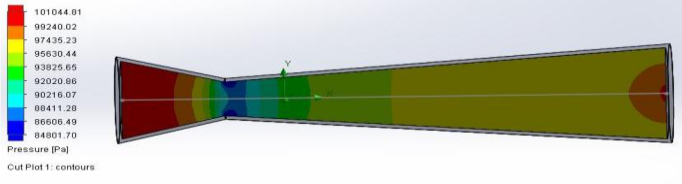
Iteration (3): Convergent angle =17⁰ and Divergent angle = 4⁰ (Pressure plot)



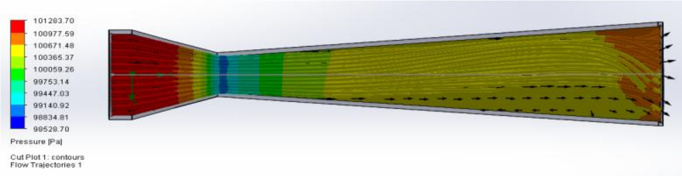
Iteration (4): Convergent angle =15⁰ and Divergent angle = 5⁰ (Pressure plot)



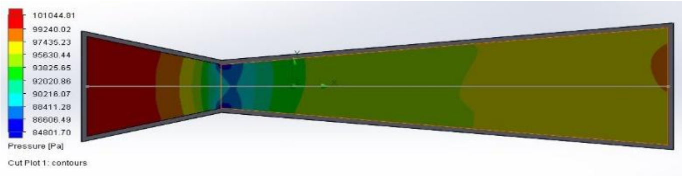
Iteration (5): Convergent angle =16⁰ and Divergent angle = 5⁰ (Pressure plot)



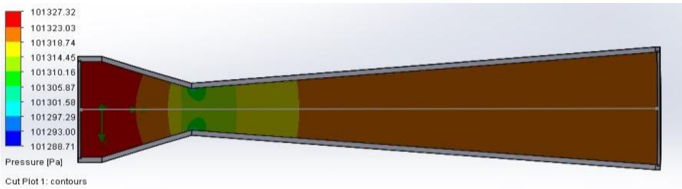
Iteration (6): Convergent angle =17⁰ and Divergent angle = 5⁰ (Pressure plot)



Iteration (7): Convergent angle =15⁰ and Divergent angle = 6⁰ (Pressure plot)



Iteration (8): Convergent angle =16⁰ and Divergent angle = 6⁰ (Pressure plot)



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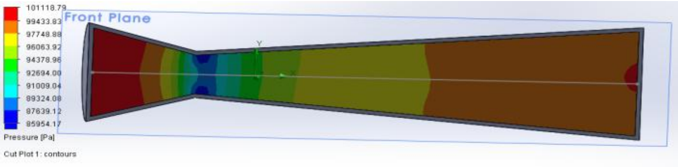
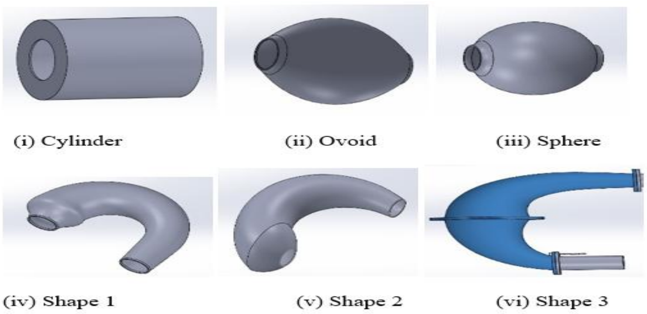
Iteration (9): Convergent angle =17⁰ and Divergent angle = 6⁰ (Pressure plot)



Iteration No	Convergent angle (in degrees)	Divergent angle (in degrees)	Pressure at outlet (in Pa)	Pressure drop(Pa) = Atm pressure – pressure obtained at outlet
1	15	4	100486.1	838.8238
2	16	4	100565.5	759.4019
3	17	4	101140.7	184.2414
4	15	5	100522.0	802.8254
5	16	5	100842.7	823.759
6	17	5	100950.9	374.0333
7	15	6	97755.31	969.69
8	16	6	100840.7	874.23
9	17	6	99875.77	1449.2276

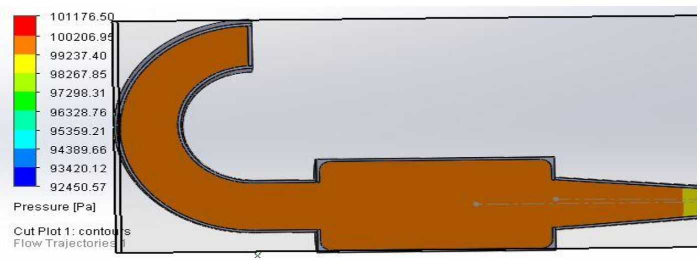
B. Selection of best Plenum model

Different geometries are designed in solid works and the best geometry is selected which has the less pressure drop.

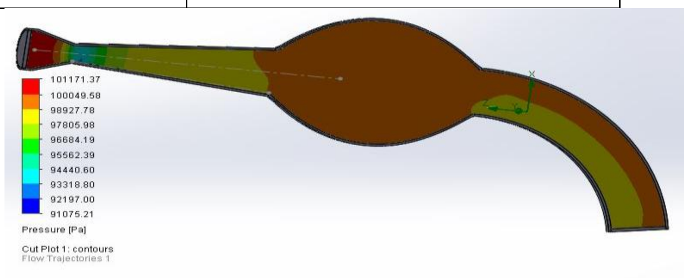


Flow Simulation Visualization and analysis:

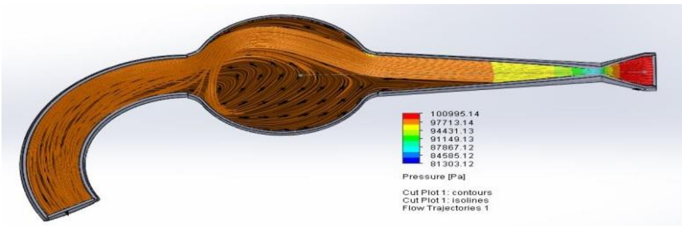
Iteration (1): Cylinder



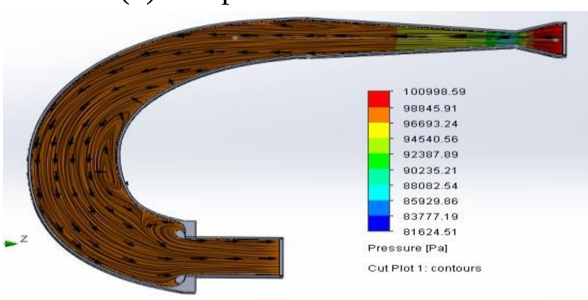
Iteration (2): Ovoid



Iteration (3): Sphere



Iteration (4): Shape 1



Iteration (5): Shape 2

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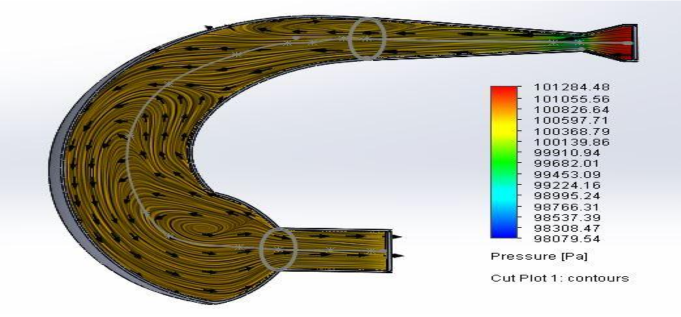
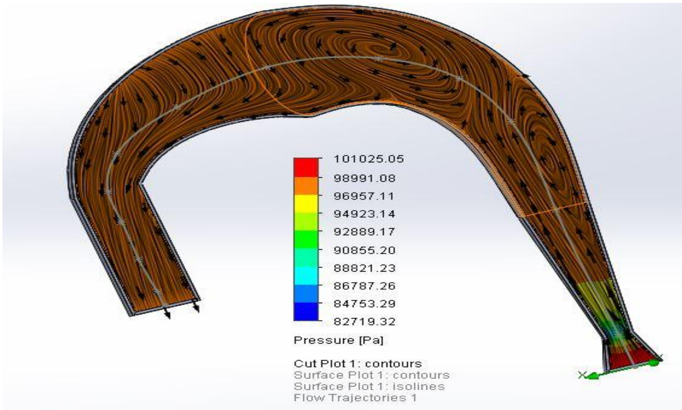


Iteration (6): Shape 3



Iteration No.	**Pressure at outlet (in Pa)**
1. Cylinder	99486.57713
2. Avoid	98929.22058
3. Sphere	96839.62959
4. Shape 1	97447.49712
5. Shape 2	97557.48146
6. Shape 3	100644.6966

Shape 3 is having less pressure drop than compared with other shapes.

6 Conclusion

During this analysis following key points are made.

(i) The restrictor is designed in the form of convergent – divergent nozzle. By varying the convergent-divergent angles, the best design is selected which has the less pressure drop at the end of divergent portion. By the comparison the restrictor with convergent angle = 17º and divergent angle is selected as = 4º.

(ii) According to selection of best plenum model shape 3 is selected because of less pressure drop.

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