Design and Analysis of Two Wheeler Exhaust System by Using CFD Tool

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Abstract - Two wheeler silencers (Exhaust Muffler) is the important part of engines which not only silence the engine volume but also threw away exhaust flue gases generated in engine. Different manufacturers are having different Muffler designs but the basic purpose is same. To study the behavior of flue gas flow inside the silencer, several methods are adopted. Practical experimentations are also carried out but they are costly and time consuming. Effective transfer of flue gases inside the silencer Muffler will give the better silencing of engine. The pressure and velocity variation inside the silencer makes it effective to silence the noise and flue gas dissipation. In this paper the study of the flue gas flow inside the silencer is examined with the help of CFD tool. The basic purpose is to find out the pressure, velocity, temperature and turbulence difference inside the silencer to find chances of improvement in the design of silencer. For this purpose CAD and CAE tools are used. CATIA V5R19 and ANSYS Fluent 14.5 are the CAD and CAE software are utilized for the virtual designing and CFD analysis of two wheeler silencer.

Key Words: Silencer, Flue gas, Noise, Turbulence, CAD Tool, CFD Tool

1. INTRODUCTION

Motorcycle exhaust system also known as muffler is made to route exhaust gases away from the engine. As fuel burn inside the engine gases and fume are produced, so this gases and fumes need to be taken out from the engine. The exhaust system does the work. The muffler also captures some of the harmful toxins in the gases before they are released into the atmosphere. It also helps regulating engine noise. Some are made to create specific sounds to certain motorcycles.

Silencer has to muffle the vibrations of the exhaust gases, reduce their velocity and thus reduce the amount of noise emitted from the engines. The pulsating low from each cylinder's exhaust process of an automobile petrol or diesel engine sets up pressure waves in the exhaust system-the exhaust port and the manifold having average pressure levels higher than the atmospheric. This varies with the engine speed and load. At higher speeds and loads the exhaust manifold is at pressures substantially above atmospheric pressure. These pressure waves propagate at speed of the sound relative to the moving exhaust gas, which escapes with a high velocity producing an objectionable exhaust boom or noise. A suitably designed exhaust silencer or Silencer accomplishes the muffling of this exhaust noise, which means that the exhaust gases from an internal-combustion engine are passed to attenuate (reduce) the airborne noise of the engine. To be efficient as a sound reducer, a muffler must decrease the velocity of the exhaust gases and either absorbs sound waves or cancel them by interference with reflected waves coming from the same source.

A typical sound-absorbing material used in a muffler is a thick layer of fine fibers; the fibers are caused to vibrate by the sound waves, thus converting the sound energy to heat. Mufflers that attenuate sound waves by interference are known as reactive mufflers. These devices generally separate the waves into two components that follow different paths and then come together again out of phase (out of step), thus canceling each other out and reducing the sound.

1.1 Aims and Objectives of study

1) To develop suitable method for designing of two wheeler silencer.
2) Study of literature available on the flow analysis of flue gas inside the muffler.
3) Virtual cavity CAD Model generation of two wheeler silencer.
4) Study of CFD Analysis for three different flow velocities.
5) To find chances of improvement in the design of silencer.
6) Study of result generated through CFD analysis

2. METHODOLOGY

- The two wheeler exhaust system is selected and dimensions of silencer is measured.
- Modeling of the exhaust system is done according to the dimensions measured in CAD tool.
- The CFD analysis is performed for three different velocities of the flue gases i.e. 50 m/s, 60 m/s and 70 m/s to find out pressure, velocity, temperature and turbulence difference.
- Results are obtained for three different velocities.
- The modifications are done in the existing design of exhaust system i.e. the length of silencer at inlet is reduced and the porosity of the silencer is increased.
- The CFD analysis is performed for the modified silencer for three different velocities of the flue gases i.e. 50 m/s, 60 m/s and 70 m/s to find out pressure, velocity, temperature and turbulence difference.
- Results are compared for the existing design and modified design of the exhaust system.

2.1 CAVITY CAD MODEL PREPARATION

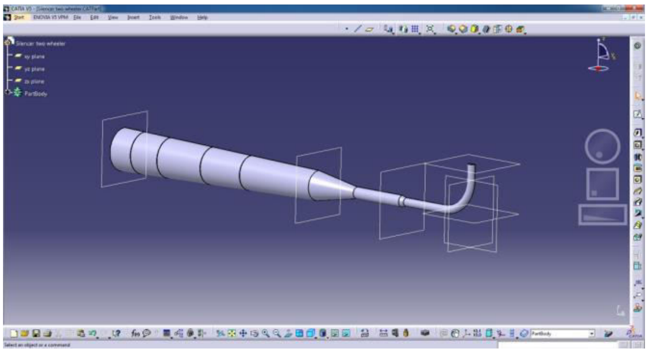

Fig.-1: Cavity CAD model developed in CATIA V5R19 Software

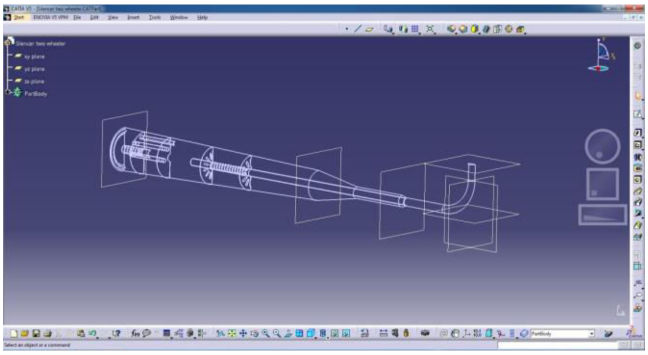

Fig.-2: Wireframe view of Cavity CAD model developed in CATIA V5R19 Software

Figure 1 and 2 shows the cavity CAD model of two wheeler silencer. It is developed in CATIA V5R19 software.

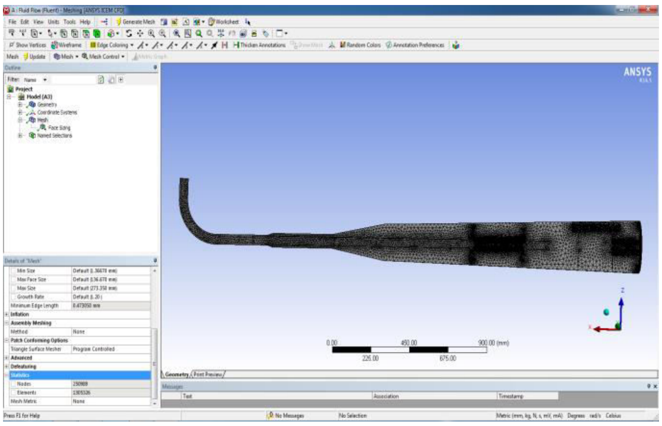

Fig. 3: Meshed view of silencer

3. CFD ANALYSIS OF TWO WHEELER SILENCER

By performing CFD analysis of silencer various results are obtained. These results are generated as per the case selected. We have considered three cases namely 50m/s velocity, 60 m/s velocity and 70 m/s velocity for this study. All results are listed and discussed as follows.

3.1 Results for Case I (50 m/s Flue gas velocity)

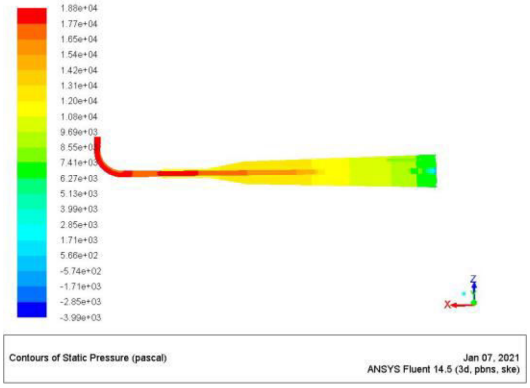

Fig.-4: Contours of Static Pressure for 50m/s velocity

Fig. 4 shows the pressure contours within the silencer muffler for 50 m/s velocity. The color pattern generated shows that,the pressure is gradually decreasing from the inlet to outlet. At the inlet, it is 18.8 MPA. While travelling through muffler passages, it is decreasing to 1.7 MPA

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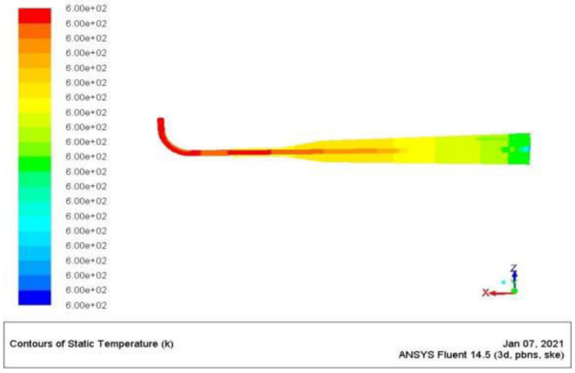

Fig.-5: Contours of Temperature inside the silencer

Fig. 5 shows the temperature contours for 50 m/s velocity of flue gas. The initial flue gas temperature was considered as 600^0 K and maximum portion of silencer is appeared into red and yellow color. The temperature can be reduced through convection process which occurs on the surface of silencer.

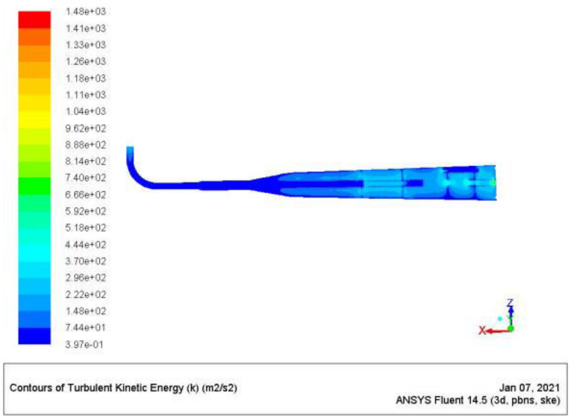

Fig.-6: Contours of Turbulent Kinetic energy inside the silencer

Fig. 6 shows the contours of turbulent kinetic energy. It indicates the blue and sky blue color which possesses value 74.4 to 518 m^2/s^2 on color scale. The maximum kinetic energy will be generated at the outlet i.e. 1.48e3 m^2/s^2.

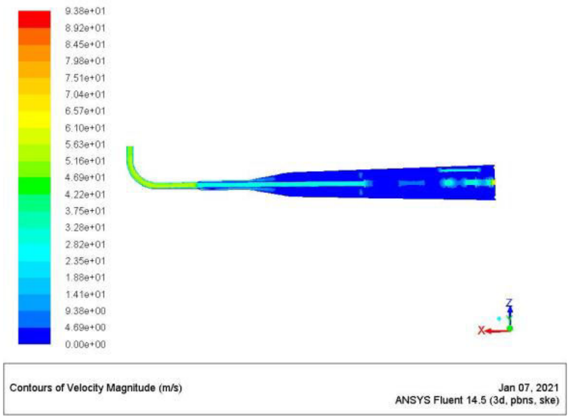

Fig.-7: Contours of velocity distribution along the silencer

Fig. 7 indicates the velocity drop in primary section. Whereas at the intermediate section it again drops to 46.9 m/s. This reduction in velocity proves the reduction in noise.

3.2 RESULTS FOR CASE II (60 m/s Flue gas velocity)

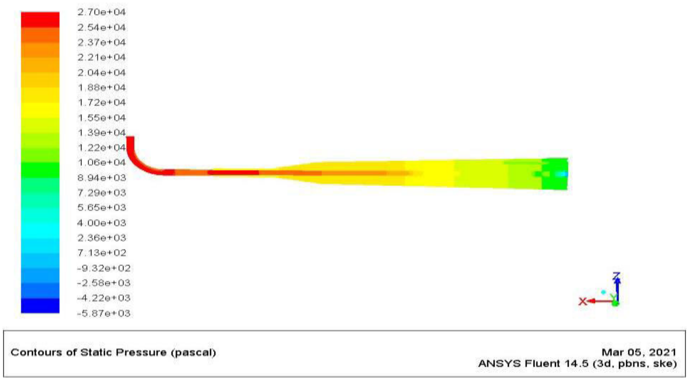

Fig. 8: Contours of Static Pressure for 60m/s velocity

Fig. 8 shows that the pressure is gradually decreasing from the inlet to outlet. At the inlet, it is maximum i.e. 27 MPA. While travelling through muffler passages, it is decreasing to 0.71 MPA.

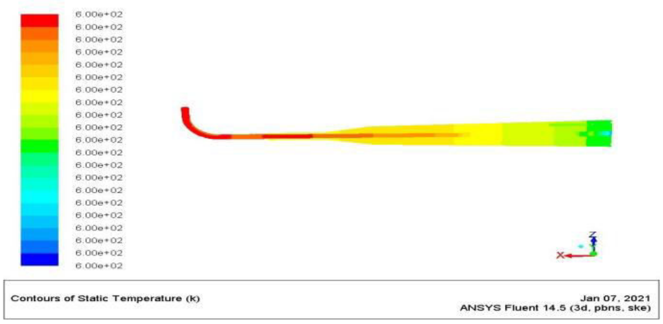

Fig. 9: Contours of Temperature variation inside the silencer

Fig. 9 shows the temperature contours for 60 m/s velocity of flue gas. The initial flue gas temperature was considered as 600^0 K.

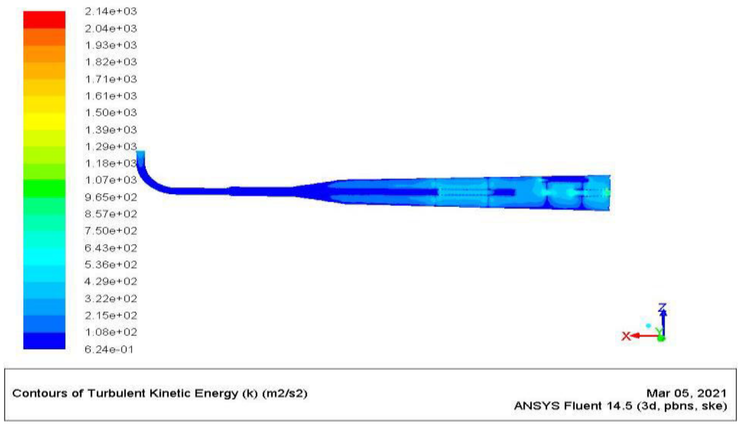

Fig. 10: Contours of Turbulent Kinetic energy inside the silencer

Fig.10 shows the contours of turbulent kinetic energy. It indicates the blue and sky blue color which possesses value 108 to 1180 m^2/s^2 on color scale. The maximum kinetic energy will be generated at the outlet i.e. 2.14e3 m^2/s^2.

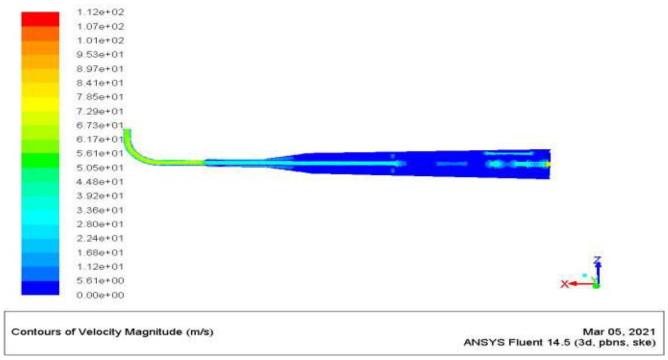

Fig. 11: Contours of velocity distribution along the silencer

Fig.11 indicates the velocity drop in primary section. Whereas at the intermediate section it again drops to 56.9 m/s.

3.3 RESULTS FOR CASE III (70 m/s Flue gas velocity)

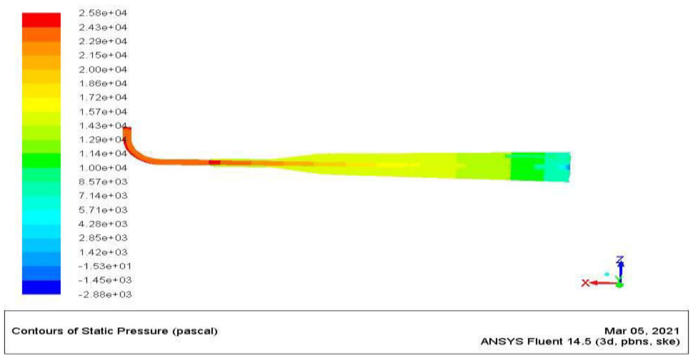

Fig. 12: Contours of Static Pressure for 70m/s velocity

Fig. 12 shows that the pressure at the inlet is maximum i.e. 28 MPA. While travelling through muffler passages, it is decreasing to 1.42 MPA.

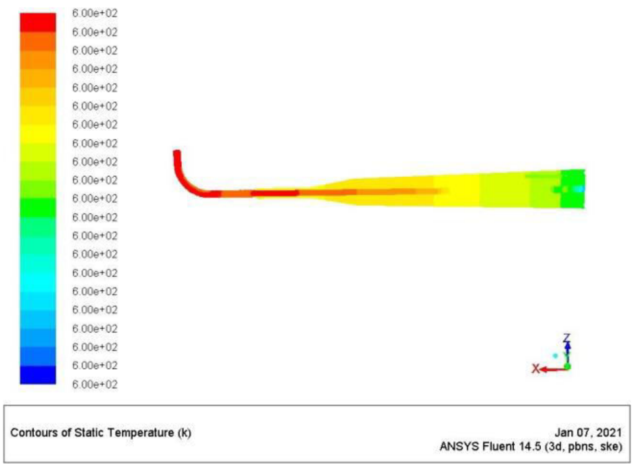

Fig. 13: Contours of Temperature variation inside the silencer

Fig.13 shows the temperature contours for 70 m/s velocity of flue gas. The initial flue gas temperature was considered as 600^0K.

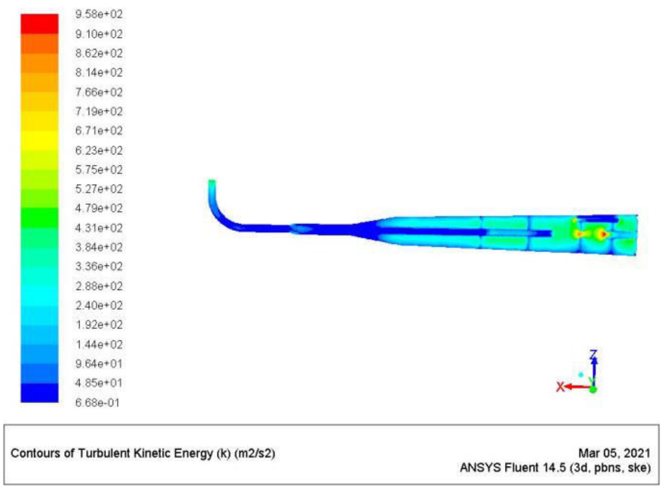

Fig. 14: Contours of Turbulent Kinetic energy inside the silencer

Fig.14 shows the contours of turbulent kinetic energy which possesses value 144 to 527 m^2/s^2 on color scale. The maximum kinetic energy will be generated at the outlet i.e. 958 m^2/s^2.

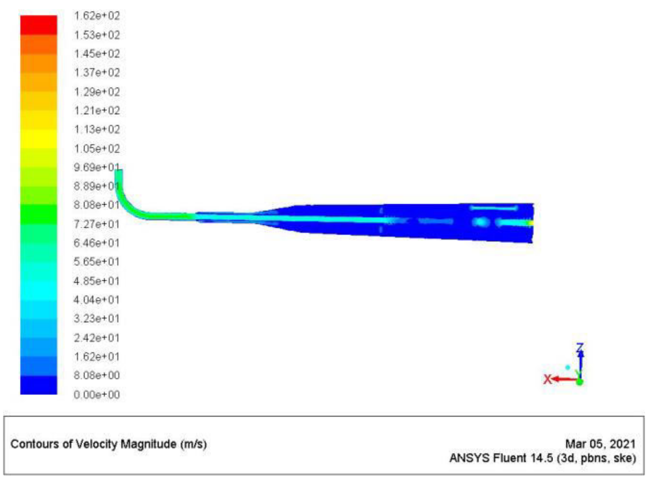

Fig. 15: Contours of velocity distribution along the silencer

Fig.15 indicates the velocity drop in primary section. Whereas at the intermediate section it increases to value 80.9 m/s.

3.3Results for Case IV (50m/s Velocity with Reduced Length)

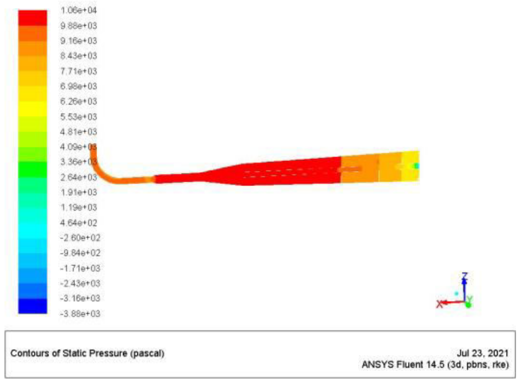

Fig. 16: Contours of Static Pressure for 50m/s velocity

Fig. 16 shows the pressure contours within the silencer muffler. This result is obtained for 50 m/s velocity with reduced primary length and obstacles in section D. The color pattern generated shows that the pressure is higher in between muffler section. At the inlet, it is pressure is 9.88 MPA. While travelling through muffler passages, it is decreasing to 8.43 MPA.

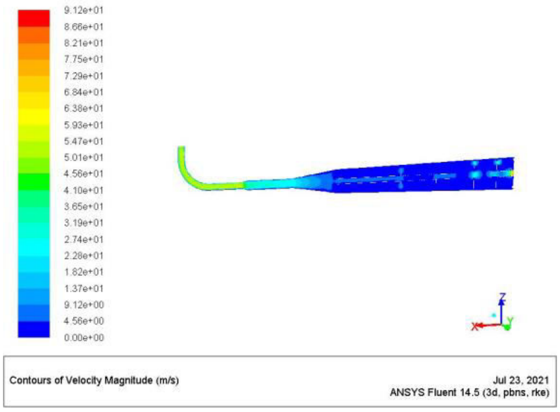

Fig.-17: Contours of velocity distribution along the silencer

Fig.17 shows the contours of velocity distribution along the silencer which appears into the blue color. Blue color indicates the minimum velocity which ultimately reduces the sound produced i.e. 4.56 m/s velocity is observed in blue color which is very less and not enough to produce big sound. Hence the silencer will perform his work efficiently in this case.
Similarly the analysis is performed for flue gases velocity 60m/s as case V and 70 m/s as case VI with reduced length of silencer at inlet and results of these velocities are tabulated in the table.

3.4 RESULTS FOR CASE VII (Increased Porosity)

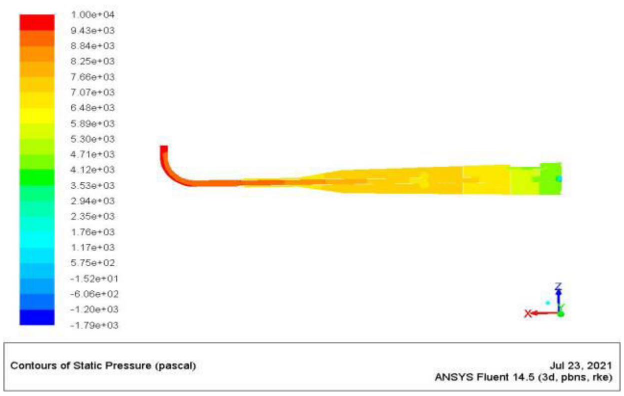

Fig. 18: Contours of Static Pressure for 50m/s velocity

Above result shows the pressure variation when porosity is increased by 4mm with same 50 m/s velocity. The velocity is 18.8 MPa without increasing porosity which is reduced to 10 MPa after increasing porosity.

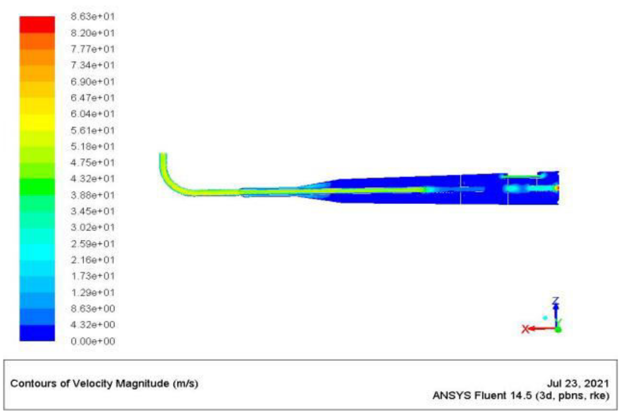

Fig. 19: Contours of velocity distribution along the silencer (50m/s velocity)

Fig.19 shows at the end of silencer the velocity is 86.3 m/s. It means that the increase porosity will reduce velocity as silencer is designed with variation in porosity for minimum pressure drop, maximum amount of pressure is distributed in first chamber. Then in next chamber these pressurized gases are allowed to pass through the less porous pipe which reduces the pressure drastically.

4. TABULATED RESULT FORMATION

All results generated for 50 m/s, 60m/s and 70 m/s velocity are tabulated in following tables.

Table-1 Tabulated Results for three different velocities of flue gases for existing silencer

Sr. No.	Cases	Pressur-e (Max.)	Velocity (Max.)	Turbulence (Max.)	Temperatu-re
1	Case I (V=50 m/s)	19 MPa	93.1 m/s	1.48e3 m2/s2	600^0 K
2	Case II (V=60 m/s)	27 MPa	112 m/s	2.14e3 m2/s2	600^0 K
3	Case III (V=70 m/s)	28 MPa	162 m/s	958 m2/s2	600^0 K

Table 2: Tabulated Results for Reduced length of silencer

Sr. No.	Cases	Pressure (Max.)	Velocity (Max.)	Turbulen-ce (Max.)	Temperatu-re
1	Case VI(V=50 m/s)	10.6 MPa	91.2 m/s	-	600^0 K
2	Case V (V=60 m/s)	11.1 MPa	107 m/s	-	600^0 K
3	Case VII (V=70 m/s)	15 MPa	124 m/s	-	600^0 K

Table 3: Tabulated result for Increased Porosity Of Silencer

Sr. No.	Cases	Pressure (Max.)	Velocity (Max.)	Turbulence (Max.)	Temperature
1	Case VII(V=50 m/s)	10 MPa	86.3 m/s	-	600^0 K

By observing all above results it is found that if we reduce the length and improves the porosity then the pressure drop can be reduced with considerable amount. If velocity reduces then sound produced due to the increased velocity will be get reduced. The maximum pressure obtained in first three cases is increasing as the inlet velocity increases. Also we found the increment in velocity in first three cases and found reduction in next three cases. But the variation in turbulence is linear up to second case only.

4.1 Graph Generation and Discussion

Pressure and velocity both are the macroscopic parameters governing plenty of natural phenomena. Pressure is the measure of force per unit area. Velocity is the measure of the rate of change of displacement. The relation between pressure and velocity can be given through two independent equations/formulation. Pressure and velocity are inversely proportional to each other. If pressure increases, the velocity decreases to keep the algebraic sum of potential energy, kinetic energy, and pressure constant. Similarly, if velocity increases, the pressure decreases to keep the sum of potential energy, kinetic energy, and pressure constant.

Chart 1 shows the graph between velocity and pressure. Up to second case graph is linear in the nature. But after that rate of increment is reduced with some extent and with increment in velocity there is slight increment in pressure.

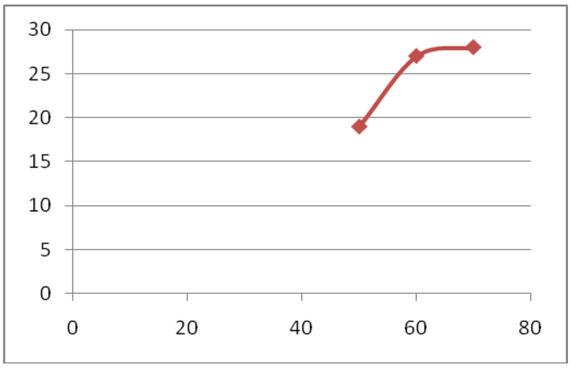

Chart-1 Graph between Velocities vs. Pressure

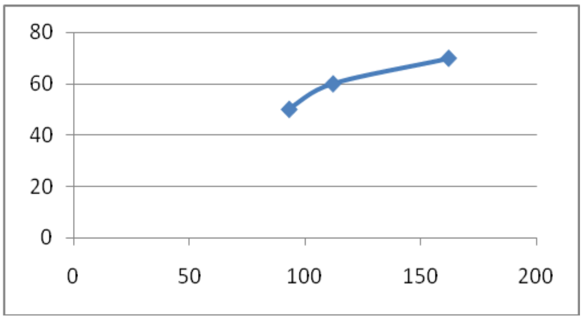

Chart-2: Inlet Velocity vs Velocity Variation in silencer

The variation in velocity is represented as a non-dimensional parameter, that is, as, where is the bed shear velocity or friction velocity corresponding to the individual channel condition and is the longitudinal point velocity at the particular grid point.

Chart 2 shows the graph between inlet velocity vs velocity variation inside the silencer. It is found that the velocity increases in each case as compared with inlet velocity.

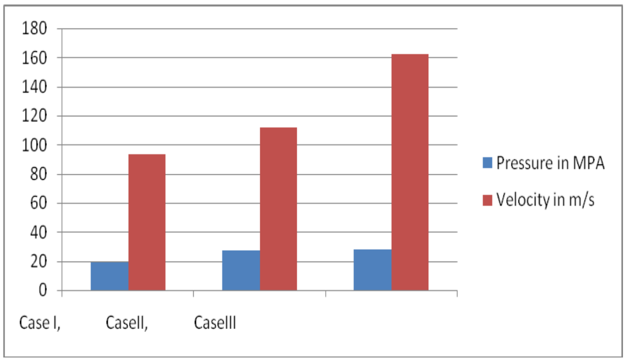

Chart-3 Range of velocity and pressure in each case

Chart 3 shows the graph between velocity and pressure inside the silencer for all three cases. In all cases velocity increases at the outlet, whereas the pressure decreases.

5. CONCLUSIONS

By observing all the CFD results generated for 50 m/s, 60 m/s and 70 m/s velocities in first three cases, it is observed that the velocity of flue gas inside the silencer decreases while at the outlet it increases. The pressure contours within the silencer muffler is obtained for the velocities 50 m/s, 60m/s and 70m/s with reduced primary length and obstacles in section D. At the inlet, the pressure is 9.88 MPA. While travelling through muffler passages, it is decreasing to 8.43 MPA as per the color pattern obtained. The contours of velocity distribution along the silencer which appears into the blue color indicates the minimum velocity which ultimately reduces the sound produced. Hence the noise control is done effectively. By observing above two cases it can be concluded that pressure drop reduces in the middle of the silencer and increases at the end. While the velocity reduces into the entire silencer section which reduces the sound produced. Hence it proves that the pressure drop reduced by 60 to 70 % if we reduce the length of the silencer at inlet. Therefore the silencer design with reduced primary length is well enough to through flue gases in environment without making loud noise. Also the silencer is designed with variations in porosity for minimum pressure drop, maximum amount of pressure is distributed in first chamber, then in next chamber these pressurized gases are allowed to pass through the less porous pipe which reduces the pressure drastically. But it is observed that when the flue gases passes through more porous region pressure is reduced so fast. By observing all above results it is found that if we reduce the length and improves the porosity then the pressure drop can be reduced with considerable amount. If velocity reduces then sound produced due to the increased velocity will be get reduced. Hence the silencer will perform its work efficiently. This will result in increased engine efficiency and low fuel consumption for similar work production by engine.

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