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

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ABSTRACT: Silencer is the very important part in all types of vehicles. But in two wheelers, it not only throughout flue gases in atmosphere, but also suppresses the engine noise in acceptable range. It is also called as exhaust muffler or simply muffler. The main application of silencer is to silence the sound produced due to the high velocity flue gas moving through it. Also the flue gases should be sent into the atmosphere continuously while engine is running.

It is really interesting and surprising to study the movement of flue gases inside the silencer. Because due to slowing the movement of flue gases while releasing into atmosphere gives very less engine noise. This reduction into the flue gas velocity can be achieved by providing muffler passages inside the silencer and pressurized chambers with narrow openings. The study of flue gas movement inside the silencer can be done easily with the help Computational Fluid Dynamics (CFD) software. For that purpose complete cavity model is to be prepared in CAD software.

The primary objective of this project is to study the flue gas flow inside the silencer and temperature distribution. Based on CFD analysis results suggest the noise control method for two wheeler silencer. For this purpose the virtual cavity model is to be developed on CAD software. Further it is imported into CFD Analysis package like ANSYS Fluent 14.5 to carry out CFD analysis. By applying proper boundary and physical simulating conditions on it results are generated. For three different velocity conditions, change in velocity, temperature distribution, pressure variation and turbulence energy is recorded. Further design changes are suggested as a part of conclusion.

KEYWORDS: Computational Fluid Dynamics, Cavity Model, ANSYS Fluent 14.5

I. INTRODUCTION

The truth is the exhaust system is just as vital in dictating an engine's performance potential as is the intake system. This is mainly due to the fact that the easier the engine can exhale, the easier it is going to be able to inhale the next time around. If burnt gases are unable to completely evacuate the combustion chambers, they may linger on, thus diluting the intake charge upon the next engine cycle. This will result in decreased power. If you understand how the intake system works, then figuring out the exhaust won't be too difficult; it works in the opposite way. While the intake system relies on positive pressure to introduce air into the combustion chamber, the exhaust makes use of negative pressure to work most efficiently.

Fig. 1.2: Two wheeler Exhaust System/Silencer

- **Multiple Baffle Exhaust System/Silencers**

In a multiple baffle Exhaust System/Silencer, the exhaust gas escapes through holes that are punched in the walls of the Exhaust System/Silencer tube. This results in muffling the sound via pulse reflection. These are fairly restrictive.

- **Turbo Exhaust System/Silencers**

Turbo Exhaust System/Silencers have an S-shaped path that allows gas to enter the Exhaust System/Silencer prior to being forced out into the tube. These are restrictive and have poor gas flow.

- **Straight-Through Exhaust System/Silencers**

Straight-through Exhaust System/Silencers make use of a perforated tube. Here, the gas is enforced

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from the inlet of the Exhaust System/Silencer to the outlet. This happens with little flow restriction. The holes in the pipe let the gas release silently.

- **Performance Exhaust System/Silencers**

Performance Exhaust System/Silencers change how bike sounds by using their resonating chamber in order to amplify and tune the existing exhaust note. These type of Exhaust System/Silencers often results in a deeper and more aggressive sound in comparison to standard mufflers.

- **Exhaust System/Silencer Inlets**

The type of inlet that best suits you depends on the existing exhaust system of bike. In case of the standard system, we need to check the owner's manual and get the details of the bike.

- **Working Principle**

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.

Exhaust System/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 Exhaust System/Silencer or Exhaust System/Silencer accomplishes the muffling of this exhaust noise.

II. LITERATURE SURVEY

Jashanpreet Singh, "A Study on Effectiveness of Muffler on a Two-wheeler vehicle Noise". The major cause of noise pollution is due to the traffic noise. Traffic noise from highways creates problems in surrounding areas, especially where there is high traffic volume and at high speed. Noise pollution has hazardous effect on human health. In traffic noise, the major cause of noise is two wheeler vehicle noise. In order to minimize two-wheeler noise, study of two-wheeler motorcycle with different types of mufflers has been analyzed. Acoustic power and sound pressure level at different engine speed with and without different types of mufflers have been studied and variations between them are investigated experimentally. [11]

Mr. Vishal M. Shrivastav[1], Prof. S. B. Bawaskar, "Design and Analysis of Exhaust System for the Two Wheeler using FEA". Their work focuses on the exhaust mufflers for two wheeler vehicles. Study will include CFD analysis and Fluid structural interaction analysis to be performed on the current design of the exhaust muffler with boundary conditions as per engines. Design of the muffler will be generated according to requirements. Exhaust gas temperatures, Velocities and back pressure will be evaluated and verified through Finite Element Analysis package ANSYS. Also the modal analysis is performed to study the effect of geometric change on natural frequency of system. Actual testing will be performed by manufacturing modified exhaust muffler and test it on the two wheeler engine test rig for back pressure and noise. [12]

This process is also called as descritisation. In this process entire model is divided into small number of pieces called elements and they are connected together by means of points called nodes. Following figure 5.1 shows the meshed view of two-wheeler Exhaust System/Silencer along with number of nodes and elements.

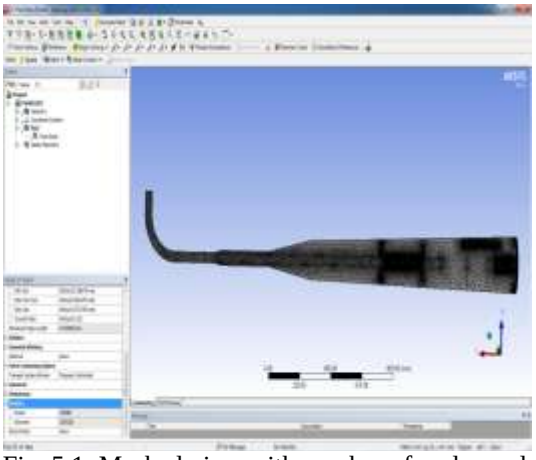

Fig. 5.1: Meshed view with number of nodes and elements.

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Table 5.1: Nodes and Elements

Sr. No.	Parameter	Value
1	Number of Nodes	250989
2	Number of Elements	1305326

III. BOUNDARY CONDITIONS APPLIED

While performing CFD analysis, different boundary conditions are needs to be applied. These boundary conditions will be same as the physical conditions. Means the velocity and pressure values ate the inlet and outlet must be same. Similarly the other physical conditions must be simulated well. The flue gas properties and metal properties are needed to be applied in CFD Tool.

Flue Gas Properties

- Velocity of flow {m/s}:- 50, 60, 70 m/s
- Convective Heat Transfer Coefficient{h} of outer surface of Exhaust System/Silencer:- 1000 W/m2-K
- Free-stream temperature of the surroundings{T free}:- 300 K(approx)
- Temperature of air at the inlet{T inlet}:- 600 K(approx)

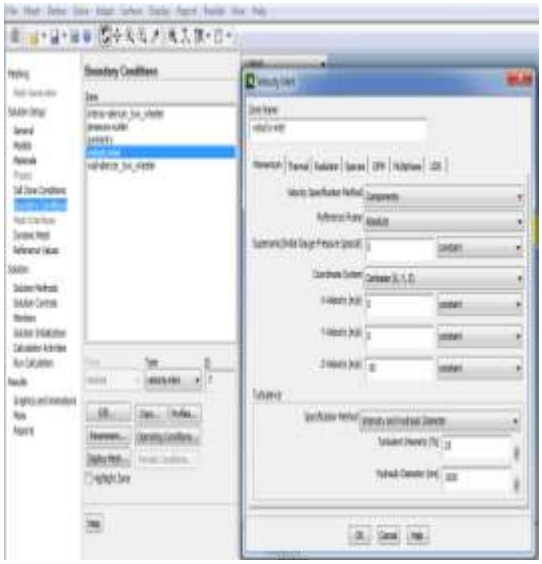

Fig. 5.2: Boundary Conditions and properties of Exhaust System/Silencer applied.

6.3 Temperature Distribution in Exhaust System/Silencer

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

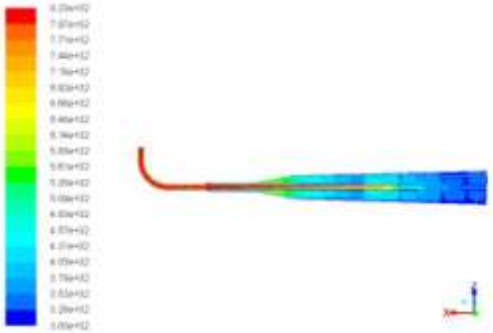

Fig. 6.1: Temperature Distribution along the Exhaust System/Silencer for 50 m/s velocity

Fig. 6.1 shows the temperature contours for 50 m/s velocity of flue gas. The initial flue gas temperature was considered as 8000 K. The maximum temperature recorded is 8230C which is more than supplied by the engine. This increment in temperature is only due to the continuous heat generation in the engine.

Inner pipe has a maximum temperature throughout the section, while the perforated section has massive heat transfer due to reduction in velocity and changing the mufflers. As flue gas enters into big diameter section, heat transfer accurse through convection and radiation. The outer surface of Exhaust System/Silencer is in the contact with the atmospheric air which has much lower temperature than flue gas temperature. Due to this temperature difference heat transfer phenomenon takes place.

If we observe color patter obtained, then it is clearly indicating the gradually decreasing temperature. It means that with reduction in velocity, temperature is also decreasing. Hence, as per result generated Exhaust System/Silencer decrease temperature with considerable amount. It can be reduced only through convection and radiation process which accurse on the surface of Exhaust System/Silencer.

Results for case II (60 m/s Flue gas velocity)

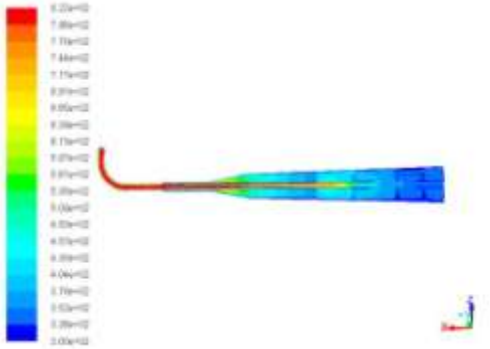

Fig. 6.2: Temperature Distribution along the Exhaust System/Silencer for 60 m/s velocity

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Fig. 6.2 shows the temperature contours for 60 m/s velocity of flue gas. The initial flue gas temperature was considered as 8000 K. The maximum temperature recorded is 8220C which is more than supplied by the engine. This increment in temperature is only due to the continuous heat generation in the engine.

Inner pipe has a maximum temperature throughout the section, while the perforated section has massive heat transfer due to reduction in velocity and changing the mufflers. As flue gas enters into big diameter section, heat transfer accurse through convection and radiation. The outer surface of Exhaust System/Silencer is in the contact with the atmospheric air which has much lower temperature than flue gas temperature. Due to this temperature difference heat transfer phenomenon takes place.

If we observe color patter obtained, then it is clearly indicating the gradually decreasing temperature. It means that with reduction in velocity, temperature is also decreasing. Hence, as per result generated Exhaust System/Silencer decrease temperature with considerable amount. It can be reduced only through convection and radiation process which accurse on the surface of Exhaust System/Silencer.

Results for case III (70 m/s Flue gas velocity)

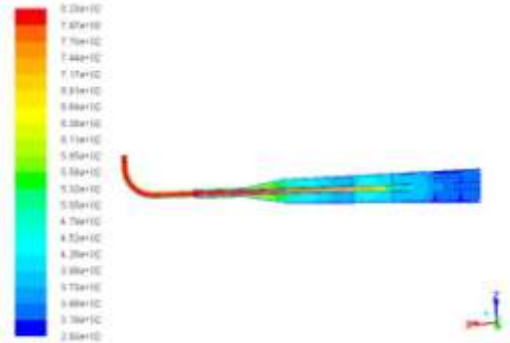

Fig.6.3: Temperature Distribution along the Exhaust System/Silencer for 70 m/s velocity

Fig. 6.3 shows the temperature contours for 70 m/s velocity of flue gas. The initial flue gas temperature was considered as 8000 K. The maximum temperature recorded is 8230C which is more than supplied by the engine. This increment in temperature is only due to the continuous heat generation in the engine.

Inner pipe has a maximum temperature throughout the section, while the perforated section has massive heat transfer due to reduction in velocity and changing the mufflers. As flue gas enters into big diameter section, heat transfer accurse through convection and radiation. The outer surface of Exhaust System/Silencer is in the contact with the atmospheric air which has much lower temperature than flue gas temperature. Due to this temperature difference heat transfer phenomenon takes place.

If we observe color patter obtained, then it is clearly indicating the gradually decreasing temperature. It means that with reduction in velocity, temperature is also decreasing. Hence, as per result generated Exhaust System/Silencer decrease temperature with considerable amount. It can be reduced only through convection and radiation process which accurse on the surface of Exhaust System/Silencer.

In all above three cases the temperature is reducing gradually from inlet to outlet of Exhaust System/Silencer. Whereas the slight increment in temperature is observed in case of supplied and maximum temperature recorded.

By performing CFD analysis of Exhaust System/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.

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

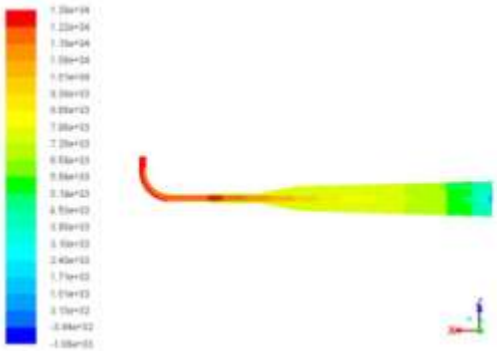

Fig. 7.1: Contours of Static Pressure for 50m/s velocity

Fig. 7.1 shows the pressure contours within the Exhaust System/Silencer muffler. This result is obtained for 50 m/s velocity. If we observe the color pattern generated then we found that, pressure is gradually decreasing from the inlet to outlet. At the inlet, it is maximum i.e. 12.8 MPA. While travelling through muffler passages, it is decreasing to 1.7 MPA as per the color pattern obtained.

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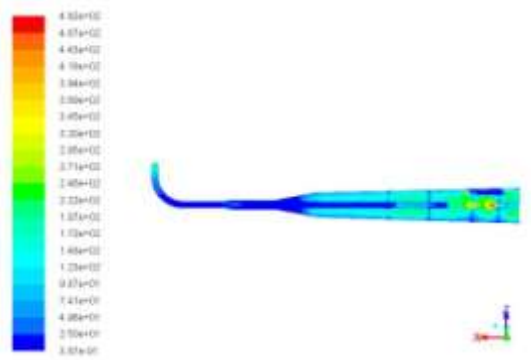

Fig. 7.2: Contours of Turbulent Kinetic energy inside the Exhaust System/Silencer

Fig. 7.2 shows the contours of turbulent kinetic energy. It indicates the blue and sky bluecolor which possesses value between 25 - 172 m2/s2 on color scale. The maximum kinetic energy will be generated at the outlet i.e. 492 m2/s2.

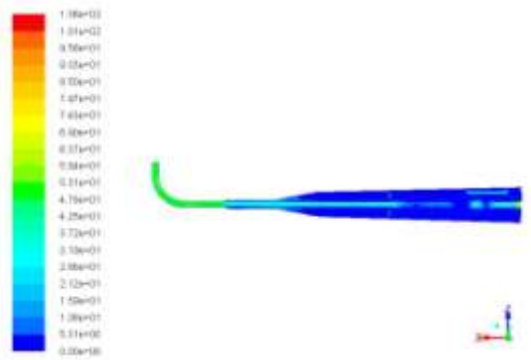

Fig. 7.3: Contours of velocity distribution along the Exhaust System/Silencer

Velocity contours shown in Fig. 7.3 indicates the velocity drop is primary section. Whereas at the intermediate section it again drops to 46.9 m/s. This reduction in velocity proves the reduction in noise. To reduce the engine noise velocity must be decrease inside the Exhaust System/Silencer. Color pattern obtained for velocity contours are explaining the same. This result is very important as it proves the reduction in the engine noise.

Sr. No.	Velocity Cases	Pressure (Max.)	Velocity (Max.)	Turbulence (Max.)	Temperature
1	Case I (V=50 m/s)	12.9MPA	93.1 m/s	492 m2/s2	8230 K
2	Case II (V=60 m/s)	19.1MPA	112 m/s	703 m2/s2	8220 K
3	Case III (V=70 m/s)	25.8MPA	162 m/s	958 m2/s2	8230 K

Table 7.1: Tabulated Results for all three cases

IV. CONCLUSION

By observing all the CFD results generated for 50 m/s, 60 m/s and 70 m/s velocities, it is observed that the velocity of flue gas inside the Exhaust System/Silencer decreases while at the outlet it increases. We found at 70 m/s velocity, performance of Exhaust System/Silencer is better. Each section of Exhaust System/Silencer works properly to manage flue gas flow. Noise control is also done properly. Therefore the Exhaust System/Silencer design is well enough to through flue gases in environment without making loud noise. Hence design change is not required for Exhaust System/Silencer.

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