DESIGN AND FEM ANALYSIS OF TWO-WHEELER EXHAUST SYSTEM

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ABSTRACT

The exhaust system has to perform many functions like creating pressure difference, controlling vibration and controlling noise. The flue gases releases at very high temperature and high pressure pulses creates a high vibrations. So, it is very necessary to control the vibrations and noise for the comfort of operator and to increase the life of engine. There are various components inside the exhaust system are muffler, silencer, baffle assembly etc. The exhaust system has suffered different types of loading like pressure load, acceleration load, fatigue loading and loading due to self-weight. So in this journal paper, we study the behaviour of silencer and exhaust system on different loading. The model is made on solid works with close dimensions, and analysis is done on Ansys workbench 15.0 software.

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1. INTRODUCTION

The function of silencer is to reduce noise, vibration and pollution. This can be done by two ways one is catalytic convertor and other is silencer. For the working of catalytic convertor the temperature must be approx. 900 oC and this temperature cannot be reached in two wheeler so catalytic convertor cannot be used in two wheeler exhaust system. The other is silencer, which works on the reflection phenomena, it transmits the sound waves towards the end of chamber and chamber reflects back towards the source, these reflect each other and cancel each other. It helps in the reduction of sound.

There is opening and closing of the exhaust valve with each cycle of combustion and the pressure varies from high to low or from low to high, hence silencer has to bear all the vibration. The vibrations vary with the load and the speed, at high load and speed the vibrations are high and thermal stresses are high.

The silencer has thermal stresses so to increase the life of silencer the thermal stress need to be focused and uniform distribution of thermal stresses must be there. The length of the exhaust pipe also affects the efficiency of the engine. If the exhaust gases have to travel a large distance the efficiency decreases as in sports bike it is easily seen that the exhaust pipe is small in length. The Objectives of this paper are

- -Cad modelling of existing silencer.
- -Cad modelling of internal parts of silencer.
- -Analysis of internal parts of silencer.
- -Analysis of full exhaust system.

2. Analysis of Silencer

Silencer is mainly pressure reducing instrument, but back pressure effects a lot generally more the back pressure less is the efficiency, back press is the pressure which restricts the flow of exhaust gases from combustion chamber mainly better the muffler in restricting sound more back pressure is created. So, there should be optimization between the two noises and back pressure.

Size

The available space has also an influence on the size and the type of muffler that may be used. A muffler is mainly designed for optimum attenuation however if it takes large space then, it is useless. Largermuffler is high in weight, and leads to high manufacturing cost. For a high performance vehicle it affects performance/acceleration, etc. Therefore, a small light weight muffler is desirable.

Transmission Loss

Transmission loss is the characteristic parameter, which shows the performance of muffler. Transmission loss is varying with respect to change in geometry parameters such as diameter of pipe, number of holes, and number of pipes.

Figure 1: (Silencer Assembly).

Figure 2: (Model Silencer Assembly).

ANSYS is finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of breaking a complex system into very small pieces (of user defined size) called elements. The software uses equations that govern the elements size and solves them all. These results then can be presented in graphical forms, or tabulated form. This type of analysis is mainly done to complex geometries. The analysis is carried out in ansys fluent the solver is pressure based solver. Energy model is kept on. The flow material is the air. Boundary condition of inlet is pressure type and outlet is the

pressure outlet type. The proper initialization is fixed and the calculation is made to run. The following results are obtained as below.

Figure 3: Meshing Pattern.

Figure 4: Meshing.

Figure 5: Pressure Distribution in Particles.

Figure 6: Pressure Distribution in Fluid.

Following changes are being considers

Figure 7: Velocity Distribution in Silencer.

Figure 8: Velocity Distribution Near Holes.

Figure 9: Strain Rate in Silencer.

3. Analysis of Full Exhaust System

Figure 10: Shear Stress in Silencer.

Figure 11: Internal Views of Exhaust System.

Following changes are being considered-

- Number of holes to be modified.
- By changing geometry of the holes such as elliptical, triangular, rectangular etc. have different effect. If we change the baffle location then it results in change in noise pattern.
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- If we change the baffle location, then it results in change in noise pattern.

Figure 12: Meshing of Exhaust System.

Figure 13: Meshing Internal Parts View.

Table 1

Model Meshing Details	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Curvature Normal Angle	Default (30.0 °)
Min Size	Default (1.39070 mm)
Max Face Size	Default (6.95370 mm)
Max Size	Default (6.95370 mm)
Growth Rate	Default
Minimum Edge Length	0.561720 mm
Use Automatic Inflation	None
Nodes	95710
Elements	29812
Mesh Metric	None

Structural Steel

Table 2

Density	7.85e-006 kg mm ⁻³
Coefficient of Thermal Expansion	1.2e-005 C ⁻¹
Specific Heat	4.34e+005 mJ kg ⁻¹ C ⁻¹
Thermal Conductivity	6.05e-002 W mm ⁻¹ C ⁻¹
Resistivity	1.7e-004 ohm mm

Structural Steel > Alternating Stress Mean Stress**Table 3**

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

Structural Steel > Strain-Life Parameters**Table 4**

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

Structural Steel > Isotropic Elasticity**Table 5**

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.e+005	0.3	1.6667e+005	76923

Figure 14: Pressure Distribution Pulses from Exhaust Valve.

Figure 15: Iteration Diagram.

Computational fluid dynamics (CFD) is the branch of fluid mechanics that uses numerical Analysis to analyse the behaviour of fluid flows. In this, the computer is used for analysis which includes graphical representation and numerical result with the entire boundary conditioned. Presently, result is analysed in FLUIDFLOW fluentmodule, the pressure distribution, velocity distribution, shear stress distribution, strain rate and frequency distribution is obtained on the modal analysis, all are analysed in ANSYS WORKBENCH 15.0.

Frequency Distribution and Displacement

Every object has an internal frequency, at which, the object can vibrate naturally. It is that frequency too, with which it transfer its energy from one form to another like vibration energy to heat energy or kinetic energy. As the frequency increase, the amplitude increases to infinity. And same here, the result of model analysis is finding the frequency, where the amplitude increases to infinity. When the time varying load is applied, it similarly acts as the vibrational forces and when these forces transmitted to the system, it acts in some displacement, and due to friction it also generates some heat.

Figure 16: Deformation 2.

Figure 17: Deformation 1.

Figure 18: Deformation 5.

Figure 19: Deformation 4.

Figure 20: Deformation 6.

Figure 21: Deformation 7.

4. RESULT AND DISCUSSIONS

Table 6

Mode	1	2	3	4	5	6	7
Frequency	17.592	17.582	18.599	185.44	238.52	238.86	266.95
Min.Displacement	0	0	0	0	0	0	0
Max. Displacement	37.255	37.254	37.366	25.407	40.74	40.664	55.567

Frequency is in HZ

Displacement in MM

As we can see in the above result, the 4 mode has least displacement and mode 7 has the highest displacement. With the increase in the frequency, the displacement must increase but mode 4 determines that value where the engine provides the best performance, and the exhaust system work perfectly according to design criteria.

Figure 22: The Pressure Distribution at Different Parts of Exhaust System.

Figure 23: The Velocity Magnitude at Different Parts.

Figure 24: Mass Flow Rate at Different Parts.

5. CONCLUSIONS

We conclude that, optimization using FEA is effective than other method, so we go for Optimization of Silencer, the Design Based on Dimensional Parameter.

After the analysis of temperature distribution, the result comes out that the maximum temperature is at the import port edge and the minimum temperature is on the outlet port edge. And, with the increase in the length of the exhaust system, the losses increases but sound level decreases; and with short exhaust system, the losses become less but sound level increases.

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