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Thermal analysis of two wheeler exhaust pipe by Finite element method

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Abstract

Exhaust system in the bike is an important part of the motorcycle which play an important role in both economy and engine performance. Usually the exhaust pipe in general is used to carry the burnt gases from the outlet valve of the cylinder to the atmosphere. Depending on the capacity and engine design there might be one or more exhaust pipe. High pressure high temperature exhaust gas enters the exhaust pipe which should be cooled and is converted to non-polluting gasses.

The problem identified for this journal work is to ensure the uniform heat flow along the passage of hot gases and design the passage surface such has to identify the harmful effects of hot-spots over the length of the exhaust pipe especially at the outer body of exhaust pipe. And enhance the life of exhaust pipe. The Exhaust pipe is considered which is modelled by CATIA V5 and is thermally analysed in ANSYS 19 where we find the percentage of elements at the different temperature.

Keyword

Exhaust pipe, Carrier component, Effective heat transfer area, Critical heat points, Fluent Analysis.

1. Introduction

Exhaust pipe is an important part of the engine which collect the exhaust gases from the cylinder to the atmosphere. They are usually a bent pipe which is made of stainless steel, connecting the catalytic converter and muffler.

The exhaust gases varies in design from one vehicle to another depend on their purpose of use and the styling required. Its structure as direct impact on the engine performance, power, economy and emission.

The main cause of the Exhaust pipe is to reduce the high frequency sound waves which is released from the engine outlet port, there will be series of holed plate through which the air enters and due to which it reduces the pressure. At the end the high pressure and high frequency sound wave is transformed into heat energy which is then released to atmosphere.

Exhaust manifold of an automobile usually consist of 3 parts such as exhaust manifold, catalytic convertor and resonator. So all the gaseous generated in the combustion chamber must pass through all the 3 parts.

In order to control the emission of harmful gases such as CO, NOx, CxHy the exhaust gases are passed mostly through 2 catalytic convertor installed in the exhaust pipe. And the critical factor which effect the efficiency of the catalytic convertor is the temperature.

This paper give the analysis of 150cc gasoline engine exhaust and the behaviour the exhaust gases with respect is studied.

The performance also depends on the length through which the exhaust gases should travel. As we know if the distance to be travelled by the exhaust gas is more than the performance decreases therefore it is observed that most of the sports bike has the smaller exhaust pipe or it is made so that the exhaust gas has to travel through a very little parts. Hence we observe slightly loud noise in sports bike compared to normal bikes.

The backpressure also play an important role for efficiency of an IC engine. Lesser the backpressure, more the work will be available to reach the flywheel for further work[1].
The silencer is the important part in the exhaust system is has to withstand high amount of stress, temperature, vibration, fatigue. Therefore as we make improvement in the exhaust system enhances the function of the exhaust system which intern increases the life and performance of the engine.

1.1 Literature survey

According to the [2]A. S. Mate, V. Kumbhar, and N. Panvel how conducted an experiment on Thermal analysis of silencer pipe. The analysis was done on the silener pipe, muffler pipe and muffler assembly. The accordng to them the stress concentration is more at the tip of the hole. So to increase the life of the silencer the stress concentration at the hole has to be reduced.

Rajaduri [3] studied on Structural Durability of Passenger car who explained about the structural durability of the exhaust pipe though FPM Approch which calculate the life and damage of the component on the basis of load applied on the exhaust pipe.

According to [4] S.G.Chaudhari who studied on Design of Exhaust Manifold To Improve Performance of IC Engine and stated that backpressure in the exhaust manifold plays an important role engine performance. Excessive backpressure increases the engine temperature and lowers the performance and also fuel penalty in the cylinder which causes damage of parts and under parformance. According to him good rule-of-thumb is that one inch (25.4 mm) of mercury backpressure causes about 1.0% loss of maximum engine power. Hence, backpressure can be used up to a certain level to improve the engine performance and reduce emissions.

2. Method and Materials

The above CAD model is done by using CATIA V5. The figure sown is side view of the Bajaj Pulsar 150 with all close to exact dimensions are measured and are imported to the CAD model. And the analysis work is carried out by the analysis software with ANSYS fluent transient flow analysis. The analysis of the exhaust pipe is carried out by making certain assumptions:

1) It is carried out at Uniform temperature (293K) and Standard atmospheric pressure.
2) Inlet velocity is a turbulence flow.
3) The boundary wall is fixed and adiabatic.
4) The exhaust gas has all the properties are uniform and similar to air.

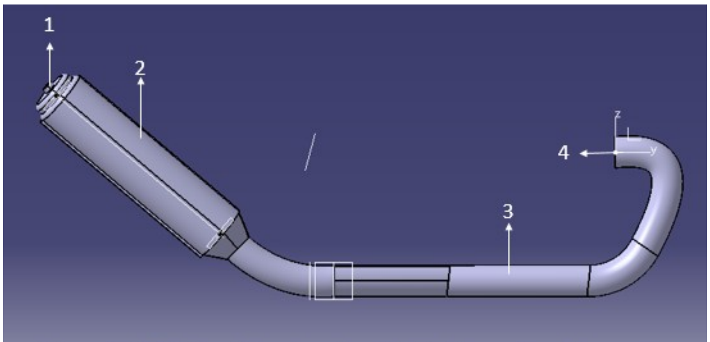

Figure1: 3D Modelling of Exhaust pie

2.2 Setting up of Boundary condition

The research paper gives the exhaust pipe analysis of Bajaj Pulsar150 who's engine specification, max torque and power output are listed in the below table [5]

Parameter	Specification
Fuel type	Petrol
Engine type	4-stroke,Air Cooled,
Displacement	150cc
Max Power	9.55 kw @8500rpm
Max Torque	11.65Nm @6500rpm
Idle RPM	1300+/-100
Max engine Temp.	110^{o}
Tappet clearence: Inlet Clearence	0.05 0.10

Table 1: Engine Specification

The Boundary condition for the following experiment are shown in table 2 and are referred from [6]. And the inlet velocity was set to turbulent flow, and has a value of 0.13 kg/s; and the outlet pressure was set as ambient pressure, and has the value of 101325Pa;on the wall of all the components the velocity was zero.

And the inlet exhaust gas temperature was considered as 400°C [5] which was the result of the endurance test.

Additional information on boundary conditions

a) Fixed and Adiabatic boundary wall.
b) Fixed wall temperature 300K.
c) No slip wall.

The analysis is done by Ansys high-performance computational fluid dynamics that delivers reliable and accurate solution quickly and robustly across the wide range of CFD and multi-physical application.

Parameter	**Setting**
Import	Flow 0.13kg/s, Temp.400°C
Export	Relative Pressure 30KPa
Wall	No Slip Wall, Temp.23°C

Table 2: Import and Export boundary cndition

2.3 Meshing and assigning material properties

Complete analysis work is done in ANSYS 19.0. The total volume of the mesh is 8.9166e-003 m³. In which no mesh metric was set and all the material properties were set as the material considered was aluminised mild steel[7]. And the meshing result were tabulated in the below table.

Bounding Box Diagonal	1.28730 m
Average Surface Area	1.6533e-002 m²
Minimum Edge Length	5.e-003 m
Nodes	19170
Elements	94062

Table 3: Mesh result

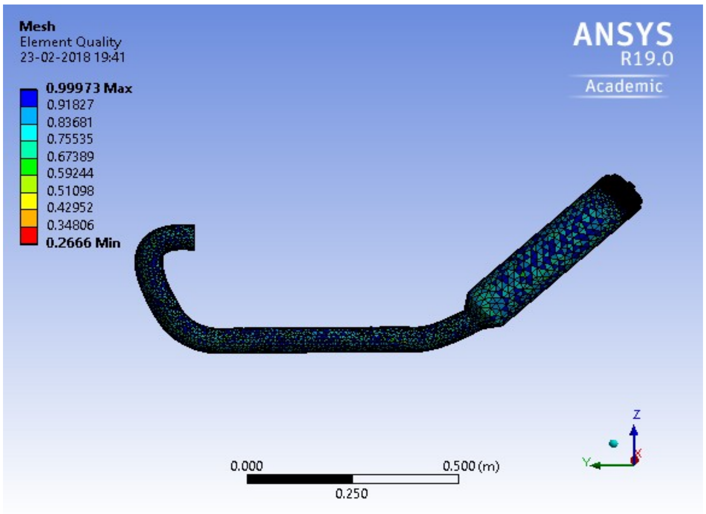

Figure 2: Meshed quality of Exhaut pipe

Bounding direction	**Length**
Length X	0.12 m
Length Y	1.1971 m
Length Z	0.45784 m

Table 4: Length of the model in perticular direction

Density	2.77e-0006kg mm^-3
Co-efficient of thermal expansion	2.3e-005 C^-1
Specific Heat	8.75e+005 MJ kg^-1 C^-1
Compressive Yield Strength	280 Mpa
Tensile Yield Strength	280 Mpa
Tensile Ultimate Strength	310 Mpa
Isotropic Secant Coefficient of Thermal Expansion	22 Mpa

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Table 5: Material properties of the exhaust pipe

2.4 Analysis with ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user- designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations[8].

The analysis is carried out in ansys fluent the solver is pressure based solver. Energy model is kept on and the viscous model is set to k-epsilon. The flow material is the mixture of gases such as nitrogen, carbon dioxide, water vapour, carbon monoxide, oxygen and methane.
Boundary condiction are inlet is velocity type and outlet is the pressure outlet type. The proper initialization is fixed and the calculation is made to run.

3. Result and Discussion

The temperature and pressure distribution of Exhaust pipe is very important to check the effect of temperature is maximum on which part of Exhaust pipe. 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. The temperature distribution of the Exhaust pipe is from 343 K to 687 K max and Pressure range from -136 Mpa to 528 Mpa max.

ANSYS 19.0 Workbench is selected for thermal analysis of Exhaust pipe to check the suitability at higher temperature. High temperature of 673 K is applied throughout the body for thermal analysis. The heat flux generation in piston is under safe condition. It is mention by blue colour region .The red colour region is not available which shows that localization of thermal stresses is not available and design and material is safe. The orientation of nodes from its original position is very less which shows that the deformation is less.

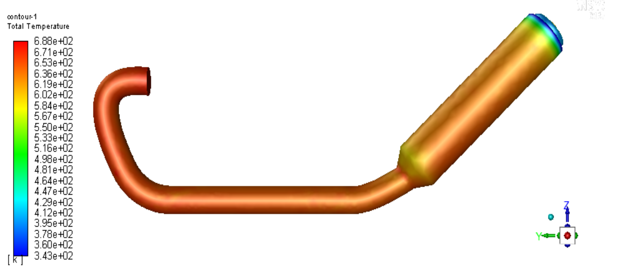

Figure 4: Counterplots of temperature distribution

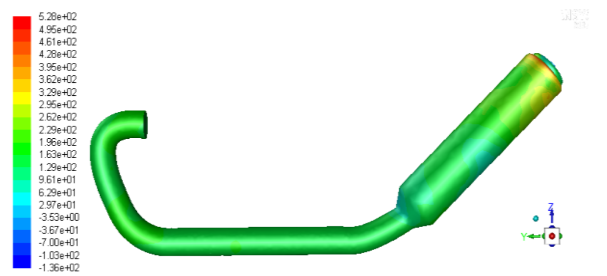

Figure 5: Counterplot of pressure distribution

The no of elements and their working temperature with the percentage value is mentioned below;
1 elements below 317.29807 K (0.0076593137 %)
4 elements between 317.29807 and 355.15933 K (0.030637255 %)
4 elements between 355.15933 and 393.02059 K (0.030637255 %)

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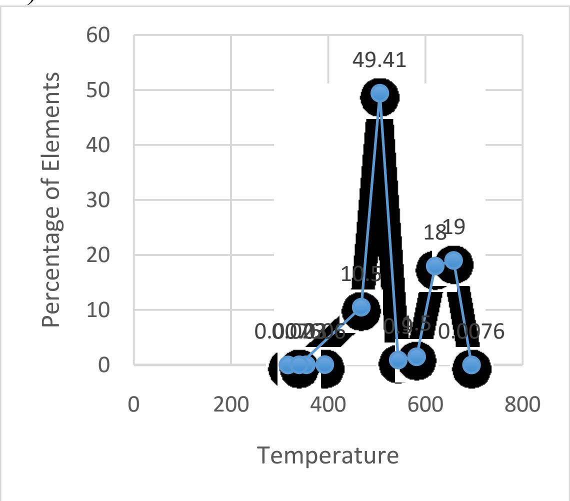
8 elements between 393.02059 and 430.88186 K (0.06127451 %)
3 elements between 430.88186 and 468.74312 K (0.022977941 %)
1371 elements between 468.74312 and 506.60439 K (10.500919 %)
6452 elements between 506.60439 and 544.46565 K (49.417892 %)
117 elements between 544.46565 and 582.32691 K (0.89613971 %)
199 elements between 582.32691 and 620.18818 K (1.5242034 %)
2373 elements between 620.18818 and 658.04944 K (18.175551 %)
2523 elements between 658.04944 and 695.91071 K (19.324449 %)
1 elements above 695.91071 K (0.0076593137 %)



Graph 1: Percentage of element working under different temperature

Large problem are subdivided into smaller group called elements.
The above plot (Graph 1) shows the percentage of different elements at different range of temperature. And we find that the maximum percentage of the element lies in the temperature range 506 to 544K.

4. Conclusion

Concluded from above study and analysis by using ANSYS the thermal stress reduction is very important factor which is responsible for the designing of Exhaust pipe. In this work the main consideration is to optimize the thermally analyse the exhaust pipe and find the hotspots on the outer surface. It is observerd that majority of the elements are working at temperature 506 to 544 K.

Inlet port may appear deformation at work, which usually causes crack on the end of Exhaust pipe inlet port. Due to the deformation, the greatest stress concentration is caused on the inlet port of the exhaust pipe, the situation becomes more serious when the stiffness of the exhaust pipe material is not enough, and the crack generally appeared at the point which may gradually extend and even cause splitting along the exhaust pipe. The stress distribution on the exhaust pipe mainly depends on the deformation of exhaust pipe. Therefore, in order to reduce the stress concentration, the inlet port should have enough stiffness to reduce the deformation.

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