Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 11, November - 2017

Thermal and Modal Analysis of Engine Exhaust Manifold for Different Materials

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***Abstract* - The ultimate goal of this project is to investigate the thermal and modal analysis of multi cylinder engine exhaust manifold used in TATA tipper BS-II. The manifold has been analyzed for different materials such as Grey cast iron, Carbon steel and Stainless steel using finite element analysis. The most commonly used material in manifold is Grey cast iron which is less costly but the weight of the material is much higher than the other materials. The exhaust manifold is designed by using Creo 3.0 and analyzed in ANSYS 17.0. The heat flux, temperature distribution and modal analysis are investigated for different materials. Finally, the results were compared with the existing material. By this comparison it shows that Stainless steel has better heat flux and temperature distribution compared to other materials. It also shows that the modal deformation of Carbon steel and Stainless steel have better than the Grey cast iron.**

Keywords* - *Exhaust manifold, Thermal analysis, Modal analysis and Heat flux

I. INTRODUCTION

In an automobile engine, exhaust system is an important part which carries hot gases from the cylinder to atmosphere and also reduces the noise of the engine. An exhaust system consist of cylinder head, manifold, turbocharger, catalytic converter and muffler. The burnt hot gases from the engine cylinder as a temperature of 800˚C and pressure from 100Kpa to 500Kpa. Due to this high temperature the manifold suffers a lot of thermal stress during its life cycle, so it required more consideration while designing an exhaust system.

II. LITERATURE SURVEY

N. Sabareesh et.al [2017], has performed on design and analysis of exhaust manifold. In this study, they have modeled the manifold using CATIA software and simulated using ANYSYS software under various surrounding temperature for the structural steel and grey cast iron material. In this study, they have determined the thermal stress, heat flux and deflection under operational condition. The results were obtained and they have concluded that the structural steel have better performance than the grey cast iron. Also the temperature distribution is better in structural steel compare to the grey cast iron [1].

V. Ashok Kumar et.al [2016], has investigated on manifold optimization of an internal combustion engine by using thermal analysis. In this study, the manifold is designed using Pro-E and simulated using ANSYS package. The CFD and thermal stress analysis where carried out under different load conditions (2, 6,12,14,16 and 18kg) for materials such as stainless steel, cast iron, silicon nitride & zinc oxide. In this study, they have concluded that in CFD analysis the pressure increases as increasing in the load conditions and mass flow rate, heat transfer rate increased at 12kg & in the thermal analysis results the heat flux is more in cast iron than the steel, zinc oxide & silicon nitride [2].

Vvrls Gangadhar et.al [2016], has investigated design and analysis of exhaust manifold of combustion engine by using CFD analysis. In this study, they have modeled the manifold by using CREO software and analyzed in ANSYS software under different temperature for the Stainless steel, Nickel, Copper and Manganese materials. The design of manifold is modified and existing model has bend radius 48mm with exhaust on one end and modified model has bend radius 48mm with exhaust on centre. In CFD analysis results the temperature distribution and heat flux rate is more in the copper material and less in Stainless steel compare to the other materials [3].

Jae Ung Cho et.al [2016], has investigated on a study on flow analysis of the exhaust manifold for automobile. In this investigation, two different forms of exhaust manifolds were designed which are used in turbo diesel engines and analyzed to determine the thermal stress, pressure difference and deformation for AISI 5000 series steel material. ANSYS package is used for the analysis of this study. These analysis results are applied to turbo diesel engine manifolds which will be designed later and expected to develop products with improved thermal characteristics, durability, structure, and engine performance. The Model 1 has more curvature than model 2. The analysis shows that the model 1 showed smaller deformation, less thermal stress, and less pressure difference than model 2. The manifold of model 1 has greater performance than that of model 2 from the above parameters [4].

III. METHODOLOGY

The current design information and material overview has been gathered from the distinguished work shop. After approval of design information the three dimensional model has been designed using modeling software CREO. From the literature survey it shows that the Carbon steel has better than the Grey cast iron. So, Grey cast iron and Carbon steel are used along with Stainless steel materials. The analysis such as, temperature and modal was different for various materials such as grey cast iron, stainless steel and carbon steel by utilizing ANSYS WORKBENCH Software. The conclusion was made in view of the relative study.

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IV PROBLEM STATEMENT

The major problems encountered in the TATA tipper are as follows:

1) In the existing design the heat transfer rate was high.
2) Higher back pressure in the manifold occurs due to the cracks at the curved surface.
3) High corrosion which reduces the life of the manifold.
4) Weight of the manifold is more.

The three dimensional model of the manifold is designed by using the Creo3.0 software and is as shown in Figure 1.

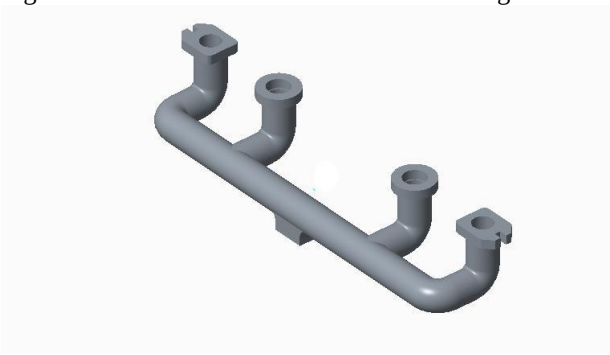

Figure 1 3d model of Manifold

Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining appropriate results. Finite element method is a flexible technique used in various industries to resolve several practical engineering problems.

V BOUNDARY CONDITION

In this study, the manifold is analyzed for different conditions such as modal and thermal analysis. In case of thermal analysis the manifold temperature is applied at inner surface and convection is applied to outer surface of the manifold as shown in the Figure 2 and Figure 3..

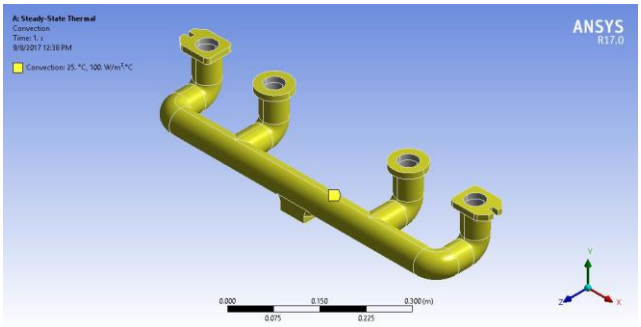

Figure 2 Convection condition

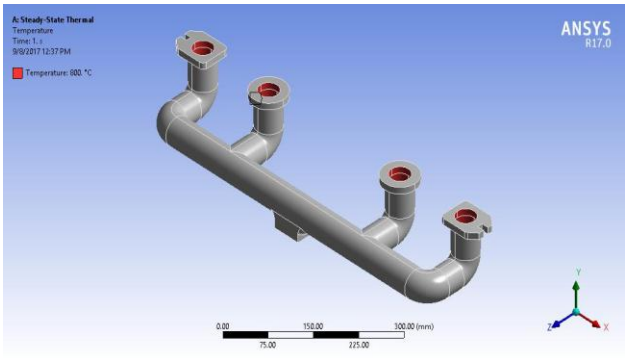

Figure 3 Temperature condition

In case of modal analysis the manifold is fixed at the bolted end surface as shown in Figure 4.

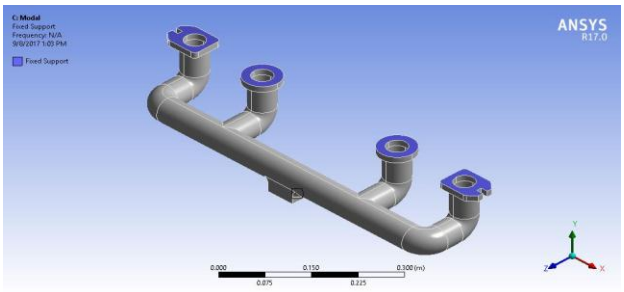

Figure 4 Fixed condition

VI RESULT AND DISCUSSIONS:

Thermal analysis: Figure 5 shows the temperature distribution of cast iron manifold. The exhaust gas temperature of 800 ^{0}C and convection of air 100 W/m^2 ^{o}C is input for manifold component. The result shows that maximum temperature of 800°C is distributed throughout the tube. The minimum temperature of 637.71^{0}C was observed near the edges of the inlet an outlet faces of manifold. Figure 6 shows the heat flux of cast iron exhaust manifold. The maximum heat flux is achieved in the hot gas flow area that is 3.56 x e^5 w/m^2.

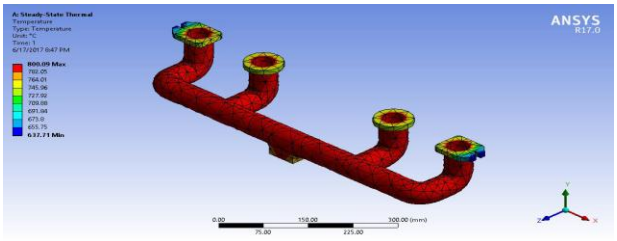

Figure 5 Temperature distribution

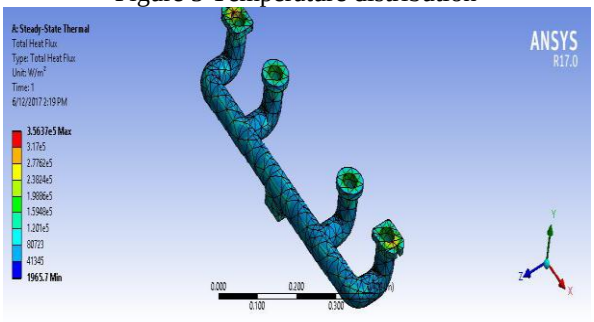

Figure 6 Heat flux distribution

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The Table 1 shows the thermal analysis results for different material such as cast iron, carbon steel and stainless steel. From thermal analysis, it was found that stainless steel has minimum temperature and minimum heat flux rate compared to the cast iron and carbon steel materials.

Table 1 Thermal analysis for different materials

Materials	Temperature ^{0}C		Temperature difference	Heat Flux in w/m^2
	Min.	Max		
Cast Iron	637.6	800	162.3	3.56 x e5
Carbon Steel	657.2	800	142.7	3.62 xe5
Stainless Steel	403.7	800	396.3	2.81 x e5

VII MODAL ANALYSIS:

The Figure 7 and 8 shows the modal analysis of the manifold for cast iron material. The analysis as carried out for four modes. The frequencies obtained are 913.85, and 958.13 and deformation is 24.106, and 25.187 respectively.

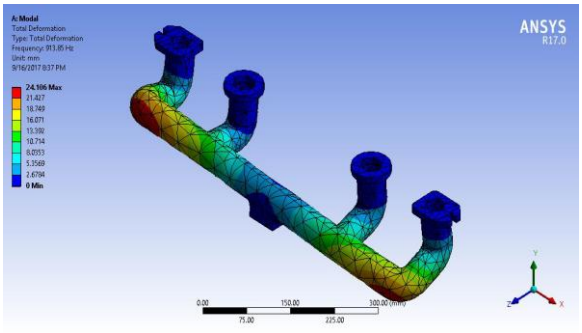

Figure 7

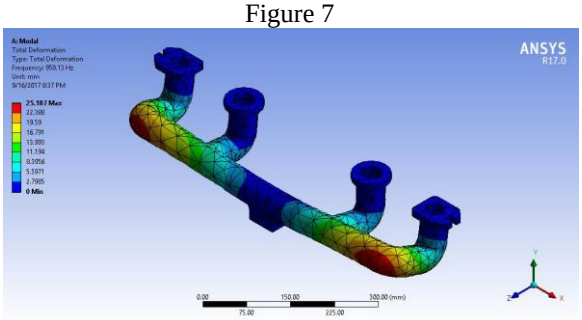

Figure 8

The Table 2 shows the Modal analysis results for different materials such as cast iron, carbon steel and stainless steel. This analysis is carried out for four different frequencies or four different modes to find out the deformations. From the comparative study, it was found that carbon steel and stainless steel has equal deformation and these two materials has less deformation compared to the Cast iron material.

Table 2

Mode No	Total Deformation in mm			Frequencies in HZ		
	C.I	C.S	S.S	C.I	C.S	S.S
Mode 1	24.1	23.0	23.2	913	1180	1167
Mode 2	25.1	24.1	24.2	958	1237	1224
Mode 3	20.0	19.2	19.3	1737	2242	2217
Mode 4	21.1	20.3	20.268	1815	2343	2317

VIII CONCLUSIONS

- The exhaust manifold of tipper vehicle has been analyzed under thermal and modal condition for different materials.
- Carbon steel and Stainless steel are the two different materials which are compared with the existing material which is cast iron.
- In thermal analysis among the three materials, stainless steel was good compared to other material.
- In modal analysis, stainless steel and carbon steel has obtained good results compared to cast iron material.

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