International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

Analysis of An Exhaust Manifold Using Finite Element Method

Mayur Patil[1] Dhiraj Pujari[2] Omkar Gaikwad[3] Prajwal Satpute[4] Prasad Shelar[5]
[1,2,3,4]TSSM's PVPIT, Bavdhan, Pune, Maharashtra, India

---***---

Abstract - Exhaust Manifold is a very important part of any locomotive vehicle which are required to collect the exhaust gasses coming out from engine and send to exhaust system. The exhaust manifold improves the efficiencies of emission, the fuel consumption and volumetric efficiencies. During this process of exhaust gasses carrying out from engine to exhaust system the exhaust manifold temperatures of 800°C and the pressure varying from 100 KPA to 500 KPA. So now in this paper we have analysis of different materials for exhaust manifolds operating under same loading conditions using FEA. Software used for the modelling and analysis purposes are CREO Parametric and ANSYS Workbench.

Key Words: Exhaust Manifold, Finite Element Method, Model Analysis.

1.INTRODUCTION

The exhaust manifold used in a 4-stroke IC engine which is mounted on the cylinder head of an engine. Exhaust systems generally consist of an exhaust pipe, a manifold, a flexible joint, catalytic converter and mufflers. Exhaust Manifold is a part of diesel engines which are the exhaust gases collect from the cylinder head and send it to the exhaust system. The exhaust manifold plays a main important role in the performance of an engine system. [1-3] The exhaust gases come from the cylinder at temperatures of nearly 800°C and with pressures range from 100 KPA to 500 KPA. [4,5] The exhaust manifold is subjected to high temperatures and pressures which will lead to thermo mechanical failure.

Due to the increasing and decreasing temperatures to the exhaust gases thermal fatigue produced in exhaust manifold. The pressure waves of comes out to exhaust gases during particular times of the cycle subject internal pressure. There will be developed cracks in the exhaust manifold. [1] Particularly, the efficiencies and the fuel consumption are nearly related to the exhaust manifold. The manifold may be a casting or fabricated which is light material. The purpose of the exhaust manifold is to collect and carried out these exhaust gases away from the cylinders with a minimum of back pressure. [3-4] The effect of this using the momentum of the exhaust gases to create a pressure drop in the cylinder and assisting more air and fuel to enter into the cylinder is called Cadency effect. Design of the inlet and exhaust pipes will careful to maximize the effect. Cast Iron is preferred as manifold's material because the cost and ease of manufacture. For Thermal analysis done the calculation of the temperature distribution, heat transfer, thermal gradients and thermal flux. This is followed by stress analysis, to know the thermal stresses. [3]

Fig. 1: Exhaust Manifold of Diesel Engine

To increase the performance and to reduce the weight a great deal of efforts done. The many automotive companies are trying to achieve a goal optimal design of engine. The performance and efficiencies of the depend upon the exhaust manifold. The lower fuel consumption is getting by the proper design of exhaust manifold. A particular conductivity requirement meets to the input in a stress, strain and deformation calculation and to confirm whether material of the component. [2, 5, 6]

2.1 FEM AND MODEL ANALYSIS THEORY

The details about mode shapes, natural frequencies and damping ratios for the investigated structure is provide by Modal analysis. The theoretical calculations on a FE-model and experimental tests on the real structures both can be performed. [4]

The basic equation for typical un-damped modal analysis is classic Eigen value problem. According to mode theory, the structure will be seen by the mass point, rigid body, damper and discrete it as finite number of elastics coupling rigid bodies. Therefore, an infinite multi-degree of freedom system turns into limited multi-degrees of freedom system. The Finite Element Analysis is defined as a numerical analysis technique, which finding approximate solutions to boundary value problems, for partial differential equations. The physical problem which was so far intractable and complex for any closed-bound solution can be analyzed by using this method. This method can be efficiently applied to bodies with irregular geometry. It can take care of any type of complex loading. The general nature of the theory on which it is based has made possible its successful application for the solution of exhaust system. [2]

A reasonable FEM of the whole exhaust system is built with the help of Model analysis. The structure of the exhaust system is complex. Therefore, some simplifications are to be needed before the FEM modeling. [1, 3]

2.2 EXHAUST MANIFOLD DESIGN CONSIDERATIONS

While improving exhaust system performance the many design considerations are required. The exhaust system should be designed for the optimal efficiency. During the exhaust stroke, the piston moves up and the total volume in the cylinder decreases. When exhaust valve opens the high-pressure gas from the cylinder is come to the exhaust manifold. This effect will create an 'exhaust pulse'. This pulse will have High, Medium and Low-pressure heads.

a) High-pressure head – In this a maximum pressure difference in the cylinder and also in outside of the exhaust system.
b) Medium pressure head – The pressure in the cylinder and the outside of system get equal. The exhaust velocity and the pressure difference are decrease.
c) Low pressure head – The ambient atmospheric pressure matches the exhaust gas pressure.

The pressure reduces in the cylinder by to momentum of the high and medium- pressure heads which is less than the atmospheric pressure.

A. Thermal analysis

The temperature distribution; amount of heat gained or lost, thermal gradients and thermal fluxes is calculated by thermal analysis.

– Types Of Thermal Analysis

1) Determine the temperature distribution and total heat flux are done by Steady-state thermal analysis. The loading conditions are steady-state, the temperature changes over time period which is not considered.
2) Determine the temperature distribution and total heat flux done by Transient thermal analysis under conditions that can be vary over a period of time.

B. Structural Analysis

The fields of mechanics and dynamics is incorporating with Structural analysis and also many theories of failure. The structure, geometrical features and support conditions on which the loads acting which is to be considered for doing structural analysis. The exhaust manifold has to be specified their material properties. The structural analysis is obtained reactions at the supports, displacement values and stress values.

C. Modal Analysis

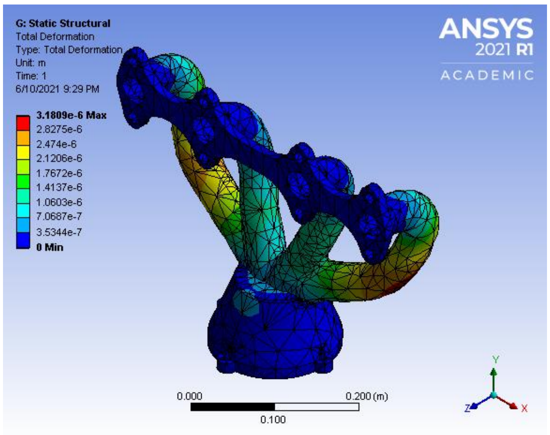

Fig. 2: Model Analysis of Exhaust Manifold

From Modal analysis the natural frequencies and mode shapes in the frequency range are found. A total 6 natural frequencies are observed in the frequency range which from the modal analysis. The listed mass participation of each of these 6 frequencies. Mode shapes of these frequencies are to be plotted. At different frequencies the maximum mass participation in X/Y/Z direction. [1, 2, 4, 6]

2.3 MANIFOLD MATERIAL

Automobile engine is always exposed to hot gases of exhaust Manifold. The exhaust manifold material includes thermal fatigue strength which is to be required to the high temperature exhaust gases, oxidation resistance, good fabrication properties and low thermal capacity to perform the catalytic function. The components to elevated temperature service are complex for proper material section. The operating temperature and peak skin temperatures are the major factors limiting materials, for the proper material selection many other variables contribute. In addition to considered operating working temperatures, mechanical and thermal loading conditions in the component's working environment. The operating temperature of a component exceeds to 600 F, the range of service such as degradation of mechanical properties. The higher temperature, the greater the number of degradation mechanisms at work, but the alloying additions can be effective to sustaining many material properties. [3]

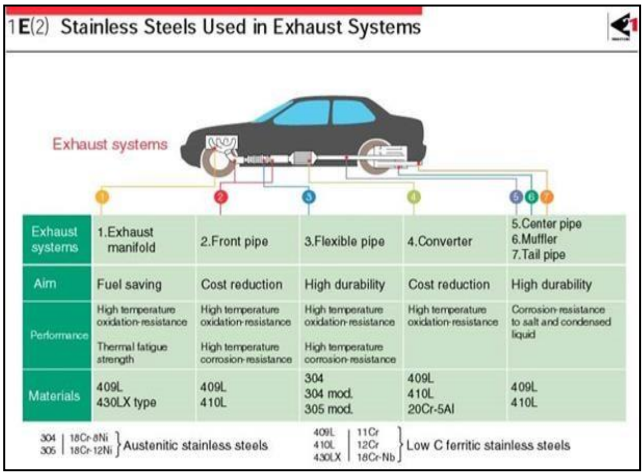

Fig.3: Materials for exhaust system

Alloy	Application
Ti-6Al-4V	Spring suspension, bumper, exhaust valves, connecting rods
Timetal @LCB	Used for suspension spring
Gr-4, Ti-6Al-4V	Body, fuselage
Gr-2, Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo-0.1Si	Exhaust valves
Gr-2	Exhaust system

Fig.4: Materials for exhaust system

The Maximum temperature of engine exhaust manifold is around 800-950°C. So selected material should be able to handle temperatures in this range. There are also various other corrosion factors like high temperature oxidation, high service temperature, high fatigue strength, high fracture toughness. The engine performance parameters are failure in the exhaust system can cause loss of back pressure. The mechanical properties of Ferritic Stainless steel and Titanium Alloy are sensitively dependent on the temperature and relevant to be used as a manufacturing material in fabrication. [3-5].

REFERENCES

1. Gopal, MMM Kumara Varma, Dr. L Suresh Kumar, International Journal of Engineering Trends and Technology (IJETT) – Volume17 Number 10–Nov2014.
2. My laudy Dr.S.Rajadurai, R.Kavin, Rejinjose, Prabhakaran, Rajeshraman, A System Approach to Dynamic Characteristics of Hanger Rod in Exhaust System.
3. Gopaal, M M M Kumara Varma, Dr. L Suresh Kumar, Thermal And Structural Analysis Of An Exhaust Manifold Of A Multi Cylinder Engine-2014.
4. Aakash Mutkule Aksahay Satpute Shubham Koshatwar, Saurabh Dharmadhikari, Thermal And Structural Analysis Of Exhaust Manifold Using Fea Approach.
5. Ir Noorazizi Mohd Samsuddin, Technique for Hanger Location of Vehicle Exhaust System Using Finite Element Method-2014.
6. Cheekoti Shekar,K.Aparna, G.Vinod Reddy, Exhaust Manifold Optimization of Multi-Cylinder Petrol Engine by Using FEM and CFD Analysis.
7. Henrik Ekholm, Bjorn Zettervall, Model analysis on an exhaust manifold to define a catalyst FE-Model, 2008.
8. S.B.Borole, Dr. G.V.Shah, Design Modification and Analysis of Engine Exhaust Manifold, 2016.
9. Ewins D. J. Model testing: Theory, practice and application, 2000.