Analytical Improving And Thermal Behavior of Exhaust Manifold

Mr. D Anand[1], Mr Rohan[2], Ms Purbasha B[3]
[1, 2, 3]Assistant Professor, Dept of Mechanical Engg
[1, 2, 3] Holy Mary Institute of Technology Science, Telangana.

Abstract- *The exhaust manifold is mounted on the exhaust manifold is mounted on the cylinder head of the engine. It is connected to the catalyst converter at the other end. The exhaust gases emitted from the cylinder come out at temperatures of nearly 8000 C and with pressures ranging from 100 to 500 kPa. The exhaust manifold is subjected to high temperatures and pressures which will lead to thermo mechanical failure. A back pressure is created due to not completely vacating the exhaust system before the gases from the other cylinder is released.*

The exhaust gases emitted from the cylinder come out at temperatures of nearly 8000 C and with pressures ranging from 100 to 500 kPa. The exhaust manifold is subjected to high temperatures and pressures which will lead to thermo mechanical failure. This project aims in redesigning an exhaust manifold by determining Thermal stresses and deflections exhibited under various operating conditions with different materials and temperatures. The objective is to ensure the suitability of the design for a particular material from the view point of reliability and serviceability. Defects in existing manifold are cracks usually occur due to prolonged exposure to extreme temperatures, defects in casting and Heat cycling. High end cad cam software such as Unigraphics and Ansys is used for modeling and analysis. The 3d Model of exhaust manifold is subjected to thermal and structural loads and results are tabulated according to the procedure for the Exhaust manifold.

I. INTRODUCTION

This arrangement will avoid the vibrations being transferred to the exhaust system. In a two stoke engine, the exhaust pipe is provided with a bulge known as expansion chamber. More air and fuel is made to enter the engine cylinder with the exhaust pressure of the gases in the chamber. This improves the power and fuel efficiency. This effect of 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 Kadenacy effect.

FEM software with the International Journal of Mechanical Engineering and Technology (IJMET), ISSN 0976 – 6340(Print), ISSN 0976 – 6359(Online),
Volume 5, Issue 12, December (2014), pp. 16-26 © IAEME 18 temperature field boundary conditions. At last, the modal analysis that considers temperature effect is done. The frequency and vibration mode between cold modal and thermal modals are compared. The result shows that temperature has a great influence on the manifold mode and it is very valuable to product design. in their paper "Modelling and Design of Exhaust Manifold Under Thermo mechanical Loading ", had proposed a thermal stress index (TSI) for designing the exhaust manifold. TSI is a ratio of the elastic effective stress to yield stress. Though TSI does not predict the expected fatigue life quantitatively, it can be easily evaluated. It's merit lies in the quick estimation of the effect of the design parameters at the development stage with comparing the nonlinear fatigue analysis.

II. LITERATURE REVIEW

Taner Gocmez and Udo Deuster in their "Designing Exhaust Manifolds Using Integral Engineering Solutions" focused on the development of a reliable approach to predict failure of exhaust manifolds and on the removal of structural weaknesses through the optimization of design. The failure modes for TMF cracks, vibration and exhaust manifold gaskets are emphasized. Engineering expertise is required to fully utilize this technique as the results strongly depend on defining the problem. This study shows an optimization package, which provides practical solutions to engineering problems through the removal of local structural weaknesses on highly loaded exhaust manifolds.

Bin Zou, Yaqian Hu, Zhien Liu, Fuwu Yan and Chao Wang in their research paper "The Impact of Temperature Effect on Exhaust Manifold Thermal Modal Analysis" discussed the impact of temperature effect on exhaust manifold modal analysis by mapping temperature field from the CFD software and then heat conduction process is analyzed

David Rathnaraj in his work "Thermo mechanical fatigue analysis of stainless steel exhaust manifolds" had proposed a model based on Isothermal data. Thermal fatigue analysis should be considered in the design process of the exhaust manifold. The durability of exhaust systems, specially corrosion and Thermo Mechanical Fatigue (TMF) resistance, needs to be improved significantly by the use of stainless steel rather than cast iron. The paper focuses on the application of constitutive equation to the thermo mechanical condition of a model based on isothermal data. Using the proposed model, the thermal stress analysis and life prediction of exhaust manifold made of 429EM stainless steel is done. Sweta Jain, AlkaBani Agrawal [5] paper, "Coupled Thermal – Structural Finite Element Analysis for Exhaust Manifold of an Offroad Vehicle Diesel Engine", presents the Sequential Coupled Thermal Structural Analysis to investigate the associated thermal stresses and deformations under simulated operational conditions close to the real situation on different materials.

III. PROBLEM FORMULATION &SOLUTION METHODOLOGY

The exhaust manifold is mounted on the cylinder head of the engine. It is connected tothe catalyst converter at the other end. The exhaust gases emitted from the cylinder come out at temperatures of nearly 800^0C and with pressures ranging from 100 to 500 kPa. The exhaustmanifold is subjected to high temperatures and pressures which will lead to thermo mechanical failure.

METHODOLOGY

This project aims in redesigning an exhaust manifold by determining Thermal stresses and deflections exhibited under various operating conditions with different materials and temperatures.

Perform coupled flied analysis on the exhaust manifold for pressure load and thermal load to find stress and deflection.

Perform thermal analysis on the exhaust manifold for thermal load.

Maximum deflection and stress are calculated at peak response.

IV. MODELING OF EXHAUST MANIFOL

COMPUTER AIDED DESIGN (CAD)

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided drafting describes the process of creating a technical drawing with the use of computer software. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to createa database for manufacturing. CAD output is often in the form of electronic files for print or machining operations.

STEPS INVOLVED IN 3D MODELLING OF EXHAUST MANIFOLD:

D model is designed by using NX cad software. Below is the sketch required to obtain the 3D model of the exhaust manifold. Below image shows the sketch of the exhaust manifold.

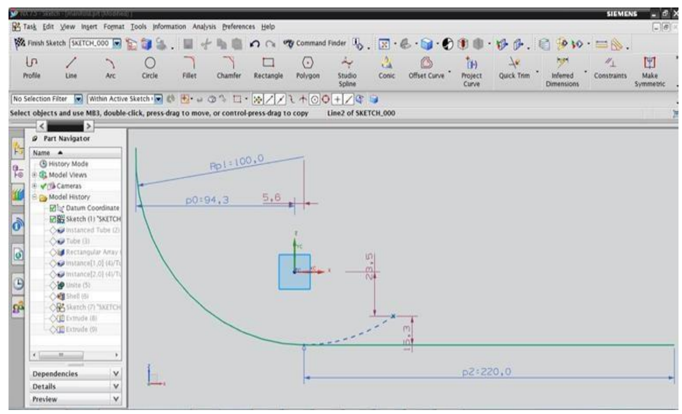

Fig.4.1sketch of the exhaust manifold

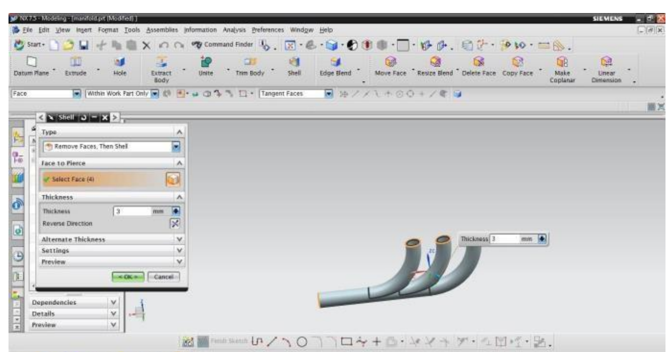

Fig4.2. Shows the Front view of exhaust manifold

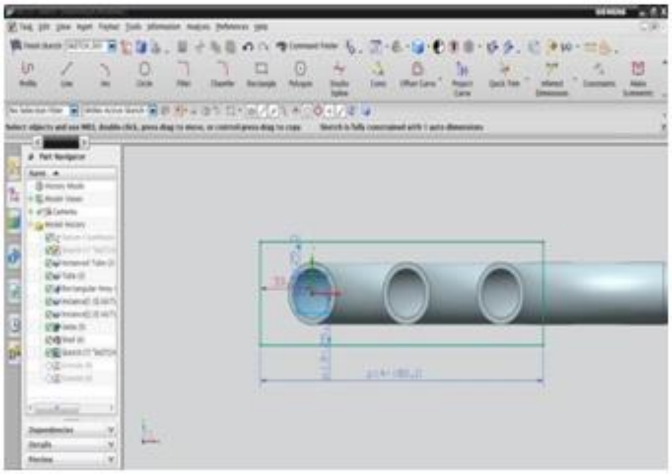

Fig. 4.3extrud option for exhaust house

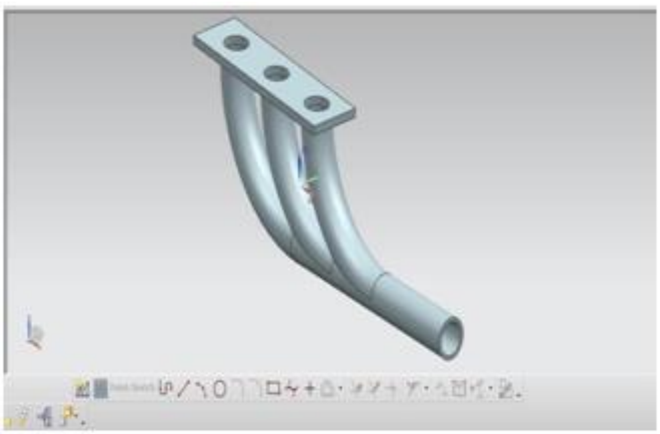

Fig. 4.4 final part

V. ELEMENT DESCRIPTIONS

NODE SOLID87:

SOLID87 is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element has one degree of freedom, temperature, at each node. The element is applicable to a 3-D, steady- state or transient thermal analysis.

NODE SOLID187:

SOLID187 has a quadratic displacement behavior and is well suited to model irregular meshes (such as produced from various CAD/CAM systems). See Solid 187 for a 20-node brick shaped element. The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

The parasolid file is imported into ansys and is meshed with 10 node thermal solid 87 element type. The structure, number of nodes and input summary of the element is given below.

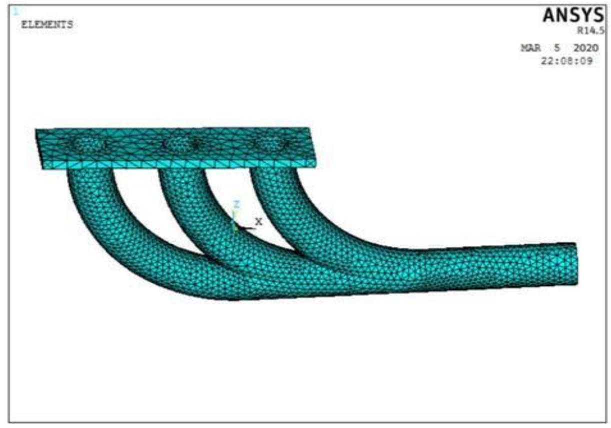

Fig.5.1 shows the Infinite model of the modified exhaust manifold

STRUCTURAL LOADING CONDITIONS

Structural analysis comprises the set of physical laws and mathematics required to studyand predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses.

In structural analysis of modified exhaust manifold, we have to apply structural and thermal loads. The bolts are arrested in all Dof, and pressure load 500000Pa is applied inside of the exhaust pipes (4). Temperature distribution is applied as Thermal loads on modified exhaust manifold from the thermal analysis

LOADS:
Pressure = 500KPa= 500000Pa
Temperature from engine that is 1073K applied inside of manifold tubes..
The bolting locations are arrested in all Dof for modified exhaust manifold.

RESULTS: Thermal analysis is done to find the temperature distribution on the modified exhaust manifold. These temperatures are applied as the body loads in the structure analysis.

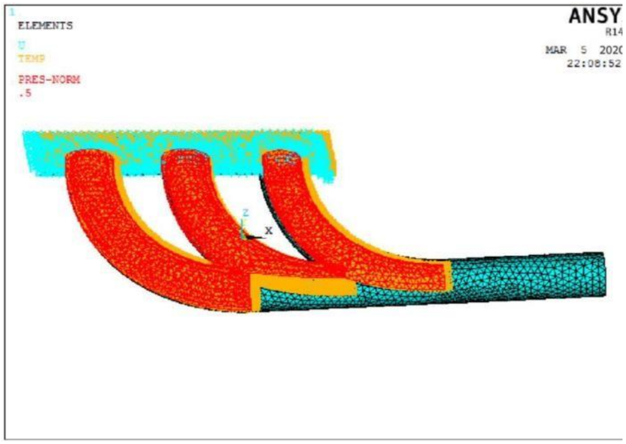

Fig.5.3 temperatures are applied as the body loads in the structure analysis.

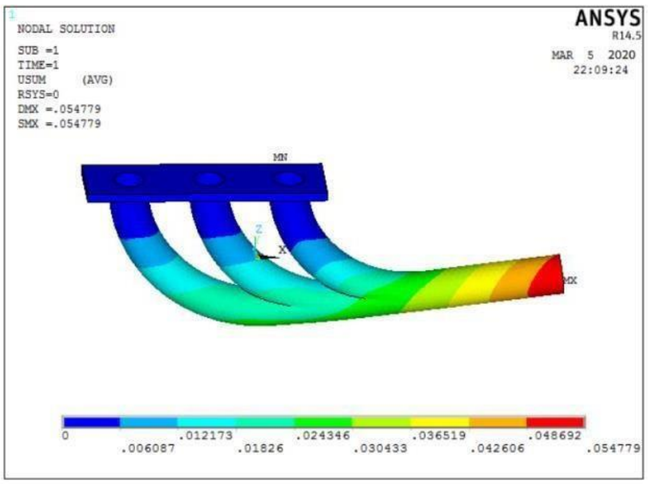

Fig.5.4 Shows the Nodal displacement of exhaust manifold

Von Misses stress

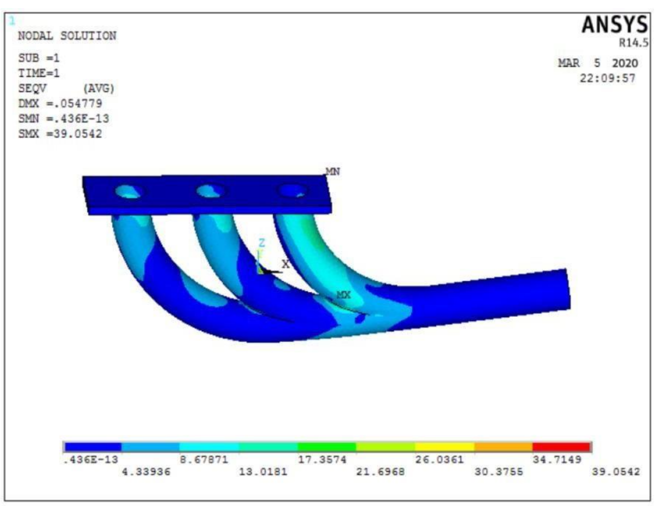

Fig.5.5 Shows the Von Mises stress of exhaust manifold

From the above results it is observed that:

- The Max Deflection 0.054mm observed on the exhaust manifold for operating loading conditions.
- The Max Avg. VonMises Stress observed 39.05Mpa on the segway assembly for operating loading conditions. And the Yield strength of the materials cast iron is 600Mpa.
- **Coupled Field Analysis of Manifold Using Aluminium Material Properties of Exhaust Manifol(Al):**

Thermal conductivity, K (w/m k)	-	113
Density, (kg/m3)	-	2650
Specific heat, c (J/Kg k)	-	960
Poisson’s ratio, v	-	0.3
Elastic modulus, E (GPa)	-	71
Bulk temperature	-	26

NODE SOLID187:

SOLID187 has a quadratic displacement behavior and is well suited to model irregularmeshes (such as produced from various CAD/CAM systems). See Solid 187 for a 20-node brickshaped element. The element is defined by ten nodes having three degrees of freedom at each node:

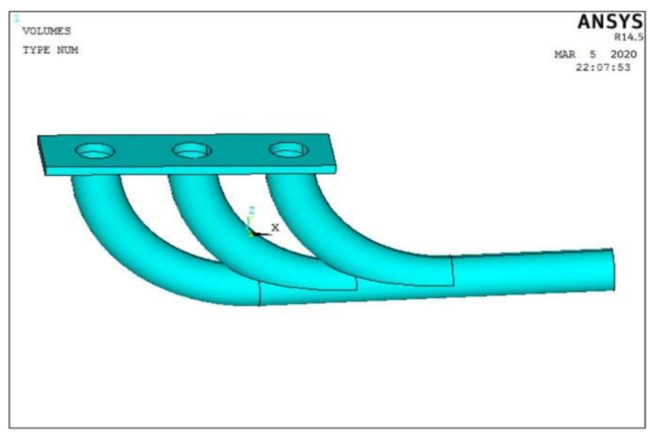

Fig.5.6 shows the Infinite model of the modified exhaust manifold

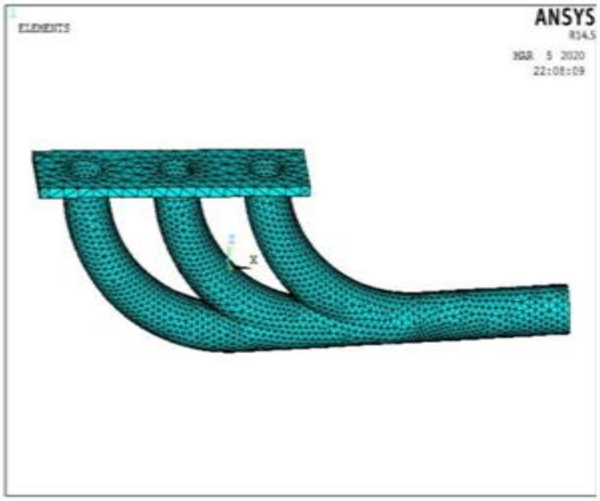

Fig.5.7 shows the finite model of the modified exhaust manifold

APPLYING THE BOUNDARY CONDITIONS

In thermal analysis of modified exhaust manifold, we have to apply thermal loads. Temperature 1073K is applied inside of exhaust pipes (4), and convection is applied on modified exhaust manifold.

5.4 STRUCTURAL LOADING CONDITIONS

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses.

In structural analysis of modified exhaust manifold, we have to apply structural and thermal loads. The bolts are arrested in all Dof, and pressure load 500000Pa is applied inside of the exhaust pipes (4). Temperature distribution is applied as Thermal loads on modified exhaust manifold from the thermal analysis

Nodal temperature:

LOADS:

- Pressure = 500KPa= 500000Pa
- Temperature from Thermal analysis result.
- The bolting locations are arrested in all Dof for modified exhaust manifold.

RESULTS: Thermal analysis is done to find the temperature distribution on the modified exhaust manifold. These temperatures are applied as the body loads in the structure analysis.

Nodal displacements:

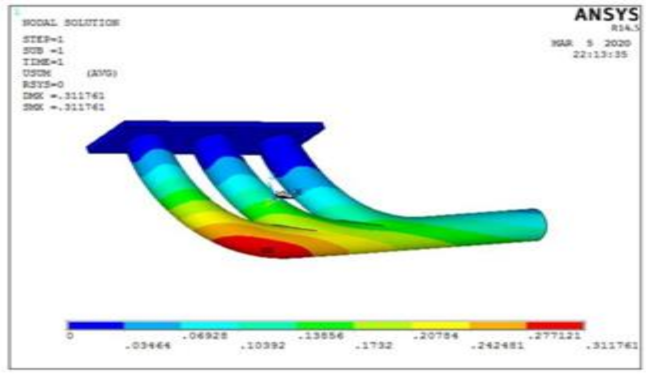

Fig.5.9 Shows the Nodal displacements on exhaust manifold

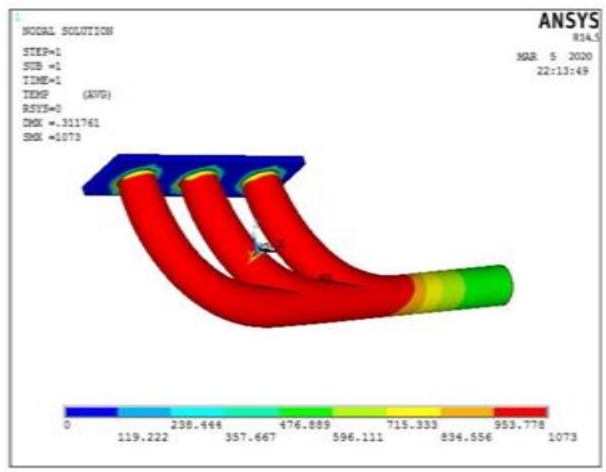

Fig.5.10 Shows the temperature distribution on exhaust manifold

Von Mises stress:

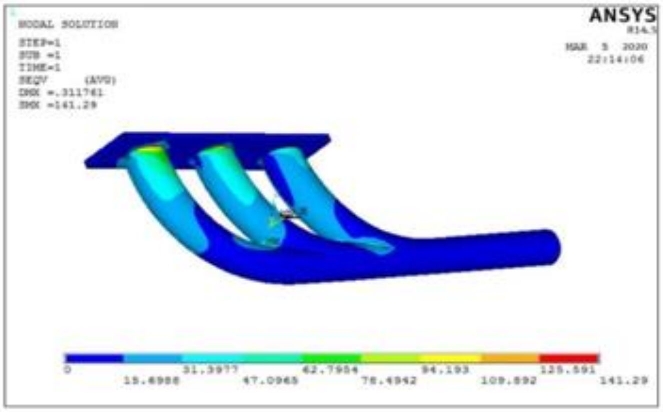

Fig.5.11 Shows the Von Mises stress of exhaust manifold

From the above results it is observed that:

The Max Deflection 0.054mm observed on the exhaust manifold for operating loading conditions. The Max Avg. Von-Mises Stress observed 141.29Mpa on the segway assembly for operating loading conditions. And the Yield strength of the materials Aluminium is 180Mpa**.**

VI. CONCLUSION AND FUTURE SCOPE

CONCLUSION

In this project we studied couple field analysis of exhaust manifold at maximum temperature and pressure condition by using aluminium and castiron materials. Thermal vonmises stress observed 141.29Mpa on the segway assembly for operating loading conditions. And the Yield strength of the materials Aluminium is 180Mpa . Here 21.5 % stress less formed for Aluminium that of yield strength.

Thermal vonmises stress observed 39.05Mpa on the segway assembly for operating loading conditions. And the Yield strength of the materials cast iron is 600Mpa . Here 93.49 % stress less formed for Cast iron that of yield strength.

Compare both results, cast iron formed less thermal stresses during loading conditions on manifold. Thats why cast iron is a best material for manifold.

FUTURE SCOPE

The scope of this project is to re-design an exhaust manifold by determining the thermal stresses and deflections exhibited under various operating conditions with different materials and temperatures. The main objective is to ensure the suitability of the design for a particular material from the view point of reliability and serviceability. Existing manifolds fails under the operating temperatures and pressure loadings. In this project we develop a design to ensure the best suited design and material for the given operating conditions. Manifold behavior of cast iron can be compared with the metal matrix composites and best suited design can be selected.

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