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DESIGN AND ANALYSIS OF FOUR CYLINDER DIESEL ENGINE EXHAUST MANIFOLD

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Abstract: Exhaust manifold is an important component in an exhaust system of engine. It connects to each exhaust port on the engine's cylinder head, and it funnels the hot exhaust down into one simple exhaust pipe. With the help of the exhaust manifold gaskets, it also prevents the toxic exhaust fumes from sneaking into the vehicle and harming the occupants. This paper is related to design and finite element analysis of exhaust manifold of 4 cylinder diesel engine. Engine capacity is 5678cc. The finite element analysis in ANSYS software by using materials based on their composition viz. FG220MoCr and SG500/7. In FEA we find out the thermal as well as static structural properties material. Finally the results are validated through experimentation on thermal analysis of material strength, Izod-Charpy impact testing, and Metallurgical Microscope.

Keywords: Design, Analysis, FEA

I. INTRODUCTION

The exhaust manifold mounted on the cylinder head of an engine collects a gas exhausted from an engine, and sends it to a catalyst converter. The exhaust manifold plays an important role in the performance of an engine system. Particularly, the efficiencies of emission and fuel consumption are closely related to the exhaust manifold. The exhaust manifold is under a thermal fatigue produced by increasing and decreasing temperature, which leads to a crack of the exhaust manifold.

Well-designed exhaust systems collect exhaust gases from engine cylinders and discharge them as quickly and silently as possible. Primary system design considerations include minimizing resistance to gas flow (back pressure) and keeping it within the limits specified for the particular engine model and rating to provide maximum efficiency. Reducing exhaust noise emission to meet local regulations and application requirements. Providing adequate clearance between exhaust system components and engine components, machine structures, engine bays, enclosures and building structures to reduce the impact of high exhaust temperatures on such items. Ensuring the system does not overstress engine components such as turbochargers and manifolds with excess weight. Overstressing can shorten the life of engine components. Ensuring the exhaust system components are able to reject heat energy as intended by the original design. “Dry” turbochargers and manifolds should not be wrapped or shielded without Cat components or Caterpillar approval.

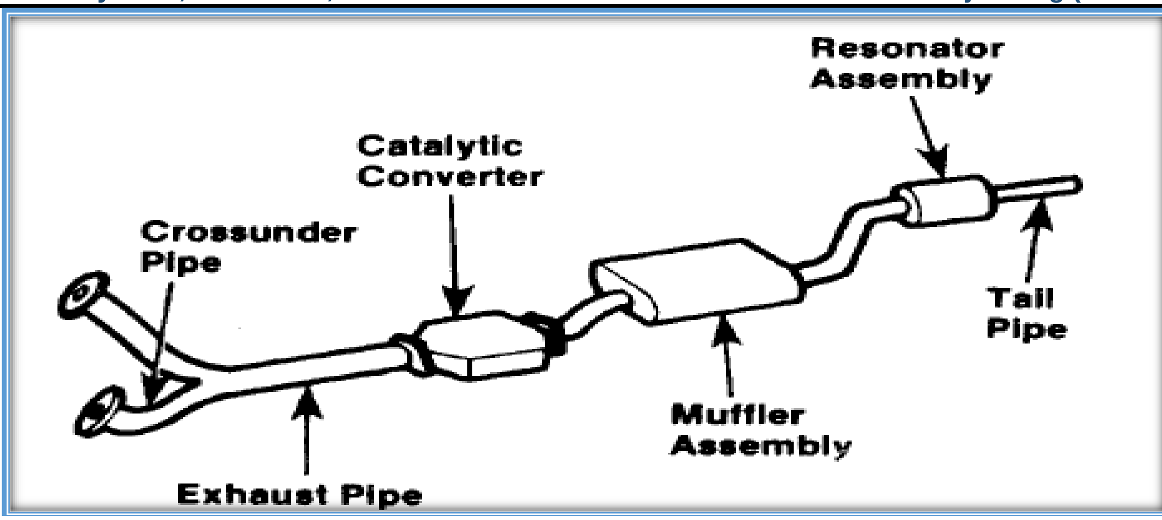

Fig. 1.1 Typical Exhaust System

The exhaust manifold collects the burned gases as they are expelled from the engine cylinders and directs them to the exhaust pipe. The manifold is designed to give minimum back pressure and turbulence. Exhaust system should be designed keeping in mind the allowable back pressure will be half of the maximum permissible. Restriction of backpressure is generally due to pipe size, silencer, and system configuration. Cat products utilize dry, water cooled and air shielded water cooled (ASWC) manifold designs, based on application and design requirements. Dry manifolds are the preferred manifold design. They are cost effective and by providing the maximum possible exhaust energy to the turbocharger, they offer the highest overall efficiency. Dry manifolds, however, also radiate the most heat and reach the highest surface temperatures.

1.1 Problem Statement

As power and torque increases the temperature of exhaust gases increases, this high temp fails the exhaust manifold with current material FG220MoCr. Hence selecting new material without compromising functionality of Exhaust Manifold. Also thermal stresses should be kept minimum.

1.2 Objectives

- To design of an exhaust manifold for the new proposed material.
- To analyze of the designed exhaust manifold using ANSYS 14.5.
- To Study the parameter like von misses stress, von misses strain and displacements were obtained from computational analysis software.
- To analyze an exhaust manifold without compromising properties of material.

1.3 Scope

- Material of the Exhaust Manifold can be changed for better performance.
- Analysis is also important factor for which can be considered for the research.

1.4 Methodology

First collect the information about project and also literature survey then design, developed the given project.

II. LITERATURE SURVEY

Jianbing Cai, Gaiqi Li, Jianhua Li, Yi Hu [2017] the fuel manifold is an important accessory through which the fuel enters in combustor, fuel is measured after entering in fuel control system. The component test results of fuel manifolds show that , when the starting fuel supply is given and the primary fuel manifold relative unfold pressure is at constant, the adjustment of the secondary fuel manifold turn-on pressure has effects on fuel flow through the secondary fuel manifold and the time of fuel into the combustion chamber. The verification test of the secondary fuel manifold unfold pressure influence on engine starting performance has been conducted, showing that the unfold pressure variation of the secondary fuel manifold has great influence on the engine start performance. The test research results have important guidance and reference meaning for confirming the secondary fuel manifold unfolds pressure. [1]

Yuto Otoguroa, Kenji Takizawaa, Tayfun E. Tezduyarb, Kenichiro Nagaokaa, Sen Mei [2018] the computational challenges encountered in turbocharger turbine and exhaust manifold flow analysis. The core computational method is the Space–Time Variational Multiscale (ST-VMS) method, and the other key methods are the ST Iso geometric Analysis (ST-IGA), ST Slip Interface (ST-SI) method, ST/NURBS Mesh Update Method (STNMUM), and a general-purpose NURBS mesh generation method for complex geometries. The ST framework, in a general context, provides higher-order accuracy. The VMS feature of the ST-VMS addresses the computational challenges associated with the multiscale nature of the unsteady flow in the manifold and turbine, and the moving-mesh feature of the ST framework enables high-resolution computation near the rotor surface. The ST-SI enables moving mesh computation of the spinning rotor. The mesh covering the rotor spins with it, and the SI between the spinning mesh and the rest of the mesh accurately connects the two sides of the solution. The ST-IGA enables more accurate representation of the turbine and manifold geometries and increased accuracy in the flow solution. The STNMUM enables exact representation of the mesh rotation. The general-purpose NURBS mesh generation method makes it easier to deal with the complex geometries we have here. An SI also provides mesh generation flexibility in a general context by accurately connecting the two sides of the solution computed over nonmatching meshes. That is enabling us to use nonmatching NURBS meshes here. Stabilization parameters and element length definitions play a significant role in the ST-VMS and ST-SI. For the ST-VMS, we use the stabilization parameters introduced recently, and for the ST-SI, the element length definition we are introducing here. The model we actually compute with includes the exhaust gas purifier, which makes the turbine outflow conditions more realistic. We compute the flow for a full intake/exhaust cycle, which is much longer than the turbine rotation cycle because of high rotation speeds, and the long duration required is an additional computational challenge. The computation demonstrates that the methods we use here are very effective in this class of challenging flow analyses. [2]

Simone Sissa, Matteo Giacopini, Roberto Rosi [2014] this paper aims at estimating the low-cycle and high-cycle fatigue life of a turbocharged Diesel engine exhaust manifold. First, a decoupled thermo-structural Finite Element analysis has been performed to investigate low-cycle fatigue phenomena due to the thermal loadings applied to the exhaust manifold. High/low temperature cycles causes stress-strain hysteresis loops in the manifold material whose related dissipated energy can be directly correlated to low-cycle thermal fatigue. Afterwards, a dynamic harmonic analysis has been performed aiming at investigating the existence of high-cycle fatigue phenomena due to vibrational loading applied to the exhaust manifold during the duty cycle. Three direction acceleration experimental loadings have been applied to the model. An ad-hoc methodology has been developed to superimpose thermo-structural results to dynamic harmonic analysis results. In particular, quasi-static thermo-structural results have been employed to identify the mean stress values of vibration fatigue cycles, while alternate stress values have been derived from harmonic analysis. Different combinations of frequencies and phases of the acceleration input signals have been considered to create different high-cycle fatigue loadings. Each cyclic load case has been processed employing the multiaxial Dang Van fatigue criterion. [3]

Cristiana Delprete, Raffaella Sesana, Andrea Vercelli, [2010] Some mechanical components are subjected to thermo-mechanical fatigue, which occurs when both thermal and mechanical loads vary with time. Due to the complexity of the components geometry, stresses and strains field becomes multiaxial, worsening the fatigue resistance. In this paper several damage models are applied and compared on a case study, an automotive exhaust manifold simulacrum replying the material and the geometrical features of the commercial component. A complete thermo-structural FE analysis has been run and results have been post-processed by means of a numerical code implementing several multiaxial damage models available in literature and based both on a critical plane approach

(Kandil-Brown-Miller, Fatemi-Socie) and strain-based models (Von Mises, ASME Code and Sonsino-Grubisic). The model calibration has been carried out by means of literature experimental data referred to commercial exhaust manifolds of similar geometry and material. [4]

Hailong Zhao, Carlos C. Engler-Pinto Jr. , Jacob Zinde , Larry Godlewski , Yinhui Zhang , Qiang Feng , Mei Lib [2015] in this study, Out-of-phase thermomechanical fatigue (OP-TMF) tests between 600qC and 950qC have been conducted for three cast austenitic alloys with different metal-carbide (MC) morphologies: dense skeleton, sparse skeleton and blocky carbides. The alloy with dense skeleton-like MC exhibited longer TMF life than the other two, even though their chemical composition and casting process were similar. Fractographic analysis indicated that the fatigue cracks initiated from the specimen surface for all the alloys in this study. The morphology of Nb(C, N) has an obvious effect on inelastic deformation. Alloys with skeleton-like Nb(C, N) precipitates have better ductility as compared to alloys with isolated blocky precipitates. Dense skeleton-like Nb(C, N) is found to delay OP-TMF crack initiation and propagation, resulting in longer TMF lives. [5]

Davide Gabellone, Stefano Plano [2014] Due to the more stringent and upcoming laws in terms of environment protection field, the required temperatures in combustion chamber need to be higher in order to reduce particles emissions. This target is reached by engine downsizing (see FIAT and Ford) together with the application of turbochargers, but the new altered conditions lead to a design of exhaust gas manifold that has to take into account an improvement in terms of temperature up to 1050°C. Above all, materials characterization has to be carried out in order to represent, as close as possible, real operative conditions. Usually, materials for exhaust gas manifold are characterized from HCF, LCF and TMF point of view by testing on cylindrical specimens, but this way it's not possible to detect the effect given by rolling process. In these last years CRF has designed and developed a particular kind of anti-buckling in order to allow LCF and TMF characterization on flat specimen at high temperatures with fully reversed strain cycle. This paper will show the results of LCF characterization carried out on flat specimen (th=1.5 [mm]) in strain ratio condition $R\varepsilon=-1$ at temperatures of 600[°C] and 800[°C]. Furthermore, results of several TMF tests will be showed. [6]

III. DESIGN

In this project work we consider the configuration of Heavy load genset 4-cylinder diesel engine to calculate the theoretical static result:

TABLE 1

Specification of 4 Cylinder Diesel Engine

Sr. No.	Type	4 Cylinder Diesel Engine (Value)
1	Capacity of engine	5678cc
2	Number of cylinder	6
3	Bore × Stroke	97mm × 128 mm
4	Type of Injection	DI
5	Prime power	115 kw @ 1500 rpm.
6	Maximum Torque	732 Nm @ 1500 rpm.
7	Compression Ratio	17.5:1

The designed 3D models of exhaust manifolds in ctaia software as shown in below figure:

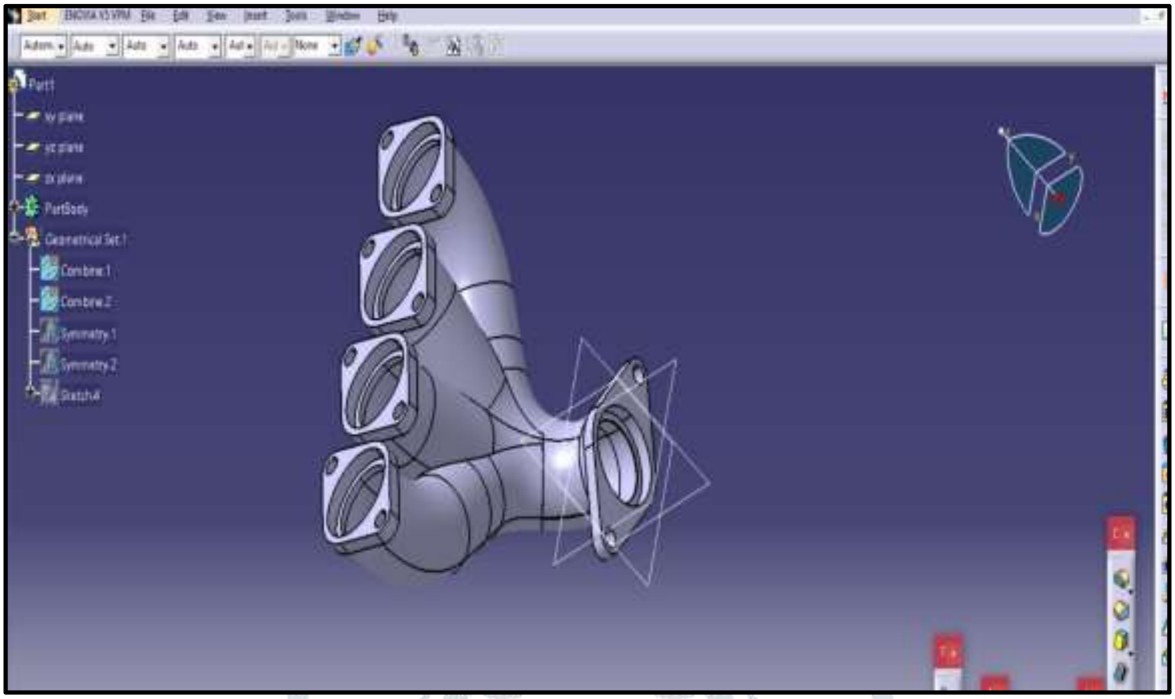

Fig. No. 3.1 3D Model of Exhaust manifold in Catia Software

IV. EXPERIMENTAL WORK

4.1 Impact Test

Notched-bar impact test of metals provides information on failure mode under high velocity loading conditions leading sudden fracture where a sharp stress raiser (notch) is present. The energy absorbed at fracture is generally related to the area under the stress-strain curve which is termed as toughness in some references. Brittle materials have a small area under the stress-strain curve (due to its limited toughness) and as a result, little energy is absorbed during impact failure. As plastic deformation capability of the materials (ductility) increases, the area under the curve also increases and absorbed energy and respectively toughness increase. The fracture surfaces for low energy impact failures, indicating brittle behaviour, are relatively smooth and have crystalline appearance in the metals. On the contrary, those for high energy fractures have regions of shear where the fracture surface is inclined about 45° to the tensile stress, and have rougher and more highly deformed appearance, called fibrous fracture.

V. CONCLUSION

In this project I have conclude that, both results are as follows:

i) Finite Element Analysis

- The maximum displacements appears for new material is less than the original material.

ii) Experimental Test Analysis

- Hardness of new material is high than the original material.

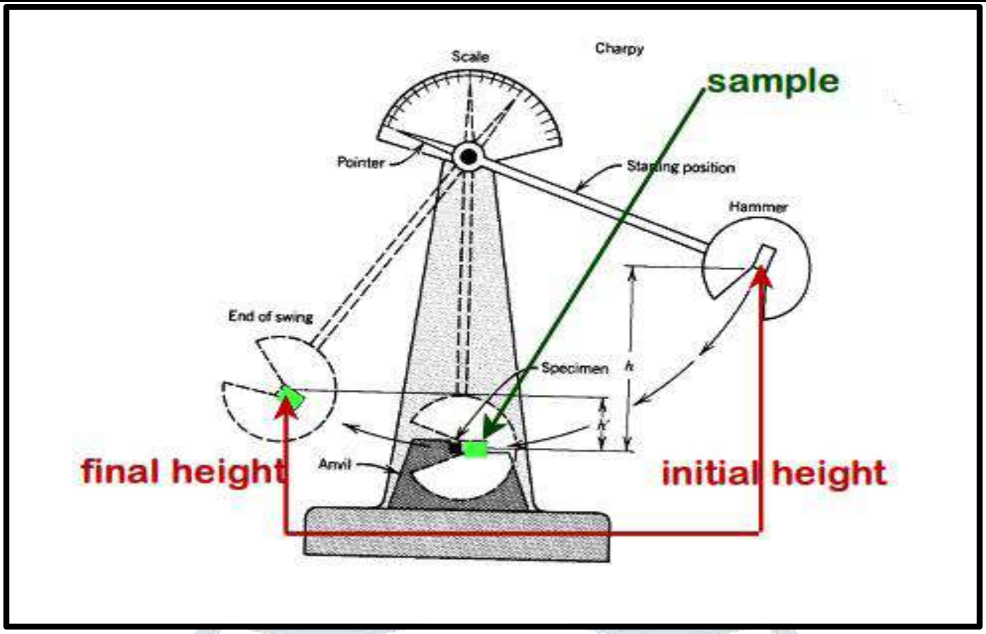

Fig. 4.1 Schematic Diagram of Experimental Setup for Impact Test

4.2 Microstructure of Material

4.2.1 FG220MoCr

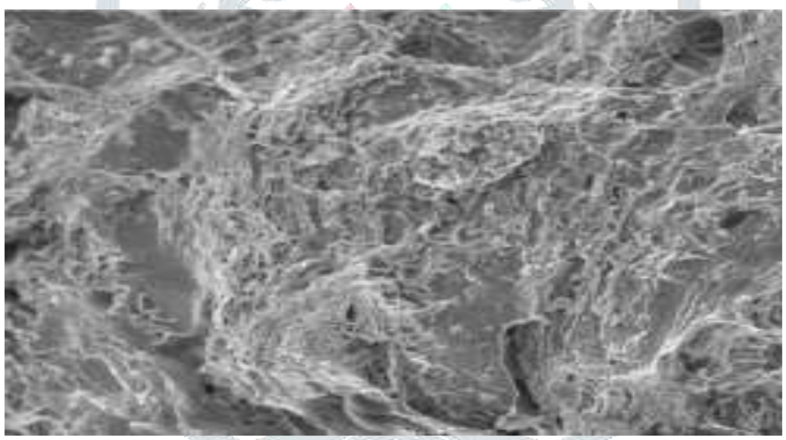

Fig.4.2 Microstructure of FG220MoCr Mag: 100 X

Comments: It Shows graphite flake in the ferritic matrix with dark band of pearlite of the cell boundaries. Over all dendritic pattern. Flake size is ASTM B TYPE size is about ASTM 3. Large casting defect (shrinkage pore, Figure No: - 7.1) was observed in the final fracture portion of this sample.

4.3.2 SG500/7

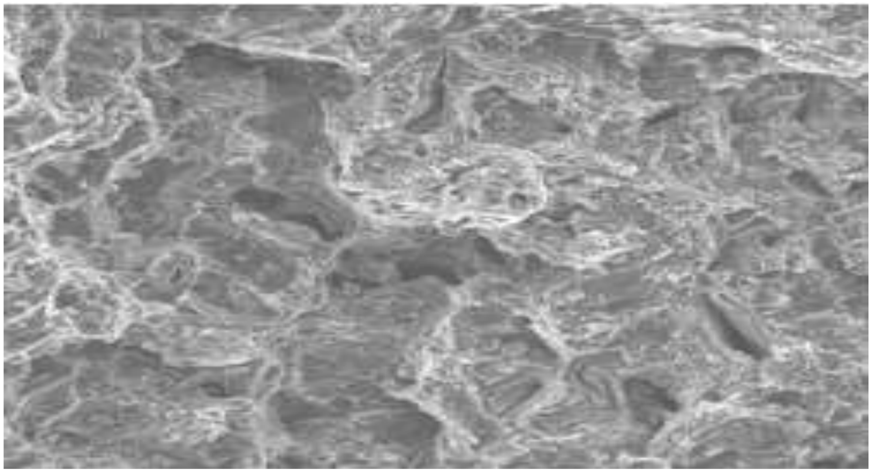

Fig. No. 4.3 Microstructure of SG500/7 Material (Mag:100X)

VI. FUTURE SCOPE

- This study indicates fatigue analysis of exhaust manifold for various material and suggest the new material for manufacturing of exhaust manifold.
- In the near future, the next step in this work is to consider that the applications in different area of exhaust manifold.

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