

Failure Co-Relation and Strength Optimization of EGR Cooler Housing for Diesel Engine

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ABSTRACT: Now a day, the highly competitive automotive business industry requires manufacturers to pay more attention towards passengers comfort, safety and NOx emission norms. EGR (Exhaust Gas Recirculation) involves diverting a fraction of the exhaust gas into the intake manifold where the recirculated exhaust gas mixes with the incoming air before being inducted into the combustion chamber. EGR reduces NOx because it dilutes the intake charge and lowers the combustion temperature. The traditional development procedure by design modification in CAD software, physical prototyping and testing takes lot of time and money. This has forced designers to pay attention towards development of high quality EGR and its aggregates to function properly using alternative virtual prototyping and numerical simulation in FEA. In this paper, a case study on failure co-relation of EGR housing due to assembly loads (bolt preload) and design optimization from weight and strength point of view is presented using FEA methods. Also its mounting bracket strength evaluation is done for static and dynamic loads acting on it. Analysis of different models of housing by using FEA tool has shown prominent improvement on stress and deformation as compared to the existing design of housing. Compared with original design of EGR housing, maximum displacement in the final design is reduced by 6 times, the structural rigidity and strength is improved by about 75%.

KEYWORDS:- EGR, CAD model, EGR Cooler Housing, FEA, FEA tool.

I. INTRODUCTION

Emission reduction is an important task in the development of internal combustion engines. As increase in the number of vehicle day by day it is important to limit the impact of emission on both the environment and the health of the human. The main combustion products that are contained in engine exhaust gases are carbon dioxide (CO₂), nitrogen oxides (NO_x), particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO) are considered environmentally harmful. This is also reflected in the fact that a government all over the world implies emission norms. Therefore, engine developers work on diminishing these emissions. A way to reduce the formation of NO_x in diesel engines is the use of EGR, recirculated exhaust gas. Part of the exhaust gas is rerouted into the combustion chamber, where it helps to attenuate the formation of NO_x by reducing the local reaction temperature. The amount of EGR that can be used is limited by different factors. One of them is the need for delivering enough fresh air for the combustion to take place; another is the decrease of engine efficiency that can be caused by high amounts of EGR [4].

Currently the automotive industry regularly faces new challenges as the high quality as well as lower cost of components required at the same time. To ensure that such components are designed and manufactured with sufficient quality to withstand a variety of service environments. Material defects and improper design can lead to failure. If a failure occurs in such a component, approach is necessary to identify the failure root cause and to make appropriate design and manufacturing changes in order to prevent failure. Because of systemic analysis and test done in a robust product development process, the vehicles on the roads have less or no failures. This creates a need for structured

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method of identifying the cause of failure. Generally analyzing the entire background information is important before inspecting a failed component. In that, material composition, specification requirements, manufacturing history, heat treatment, operation and service history included. In the service history, careful consideration should be given to details such as mechanical loading type and amplitude, environmental conditions, length of time in service and any anomalous events which may have occurred during the life of the part. Attention should also be given to the frequency of the failures and behaviour of mating components. During this stage the scope of investigation should be defined properly. Once the above information is analysed, the failure conditions are simulated then, based on the behaviour of the component, the relevant action can be made [1].

II. INTRODUCTION TO FINITE ELEMENT ANALYSIS

The finite element analysis is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It consists of a computer model of a material or design that is loaded and analysed for specific results. It is used in new product design and existing product refinement. Basic theme is to make calculations at only limited (Finite) number of points and then interpolate the results for entire domain (surface or volume).

Finite - Any continuous object has infinite degrees of freedom & it's just not possible to solve the problem in this format. Finite Element Method reduces degrees of freedom from Infinite to Finite with the help of Discretization *i.e.* meshing (nodes & elements).

Element - All the calculations are made at limited number of points known as nodes. Entity joining nodes and forming a specific shape such as quadrilateral or triangular etc. is known as Element. To get value of variable (say displacement) anywhere in between the calculations point interpolation function (as per the shape of element) is used.

Analysis - FEA has become a powerful tool for numerical method of wide range of engineering problems. Application range from deformation and stress analysis of automotive, aircraft, building and bridge structures to field analysis of heat flux, fluid flow, magnetic flux and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modelled with relative ease. Several alternative configurations can be tried out on a computer before the first prototype is built. In this method of analysis, a complex region defining a continuum is discretise into simple geometric shapes called finite elements and expressed in terms of unknown values at element corners. An assembly process, duly considering the loading and constraints, results in set of equations. Solution of these equations gives us the approximate behaviour of the continuum.

III. INTRODUCTION TO EGR COMPONENTS

Housing:

Purpose:-Housing is a part of core. Is used as shell, It conducts the coolant which is remove the heat from the gas filled tubes.

Diffuser:

Purpose:-Diffuser is used to guide the entry and exit of Exhaust gas, It conducts the gas maintained the smooth flow of gases at inlet and outlet of the cooler.

Header:

Purpose:-Header is used to hold the tubes.
EGR components Show in Fig.1

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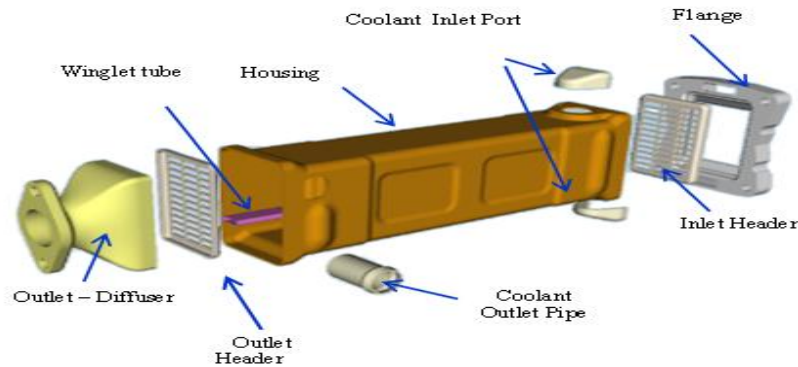


Fig. 1 Basic Components of EGR

IV. PROBLEM STATEMENT

The housing plays a very important role in the automotive EGR cooler system. Housing is used as shell, it conducts the coolant to remove the heat from the gas filled tubes. The main function is to withstand the forces and vibrations during running condition of vehicle. The Existing housing design is failing at the mounting bosses while applying bolt torque during the assembly process. To avoid failure in housing add the boss thickness and introducing the ribs that will support the bosses.

V. METHODOLOGY

The structural analysis for the housing will be done as follows:

1. CAD modeling of the housing, in CATIA software.
2. Pre-processing in a FE software
 - Discretization of the geometry, using solid elements.
 - Application of the boundary conditions.
3. Solution for structural analysis.
4. Post-processing – viewing displacements, stresses and interpreting the results.
5. Stresses and displacement optimized

CAD modal

In the process of design optimization various EGR cooler models were models using solid works software. The entire process of design to simulation, analysis, prototyping and manufacturing, today is solely depends on end to end computer aided engineering solutions. CATIA V5 is versatile and user friendly software, capable of performing variety of tasks not withstanding its complexity with ease. CAD modal shown in Fig.2

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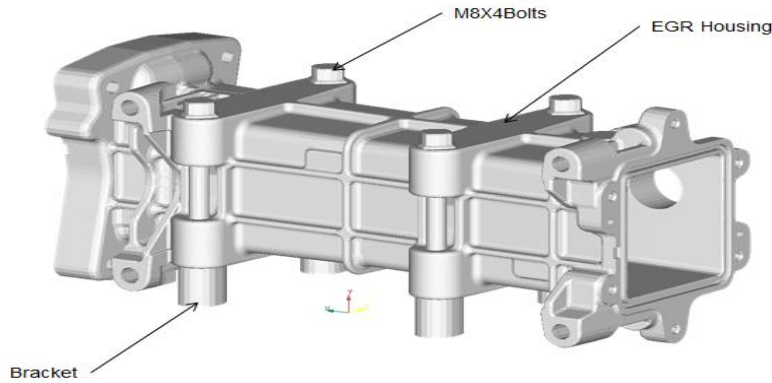


Fig. 2 CAD model of Housing

For liner static analysis we used MSC-Nastran SOL101 also Hypermesh software is used for pre-processing (meshing) of same modal. For meshing 3D tetrahedral elements are used. After meshing we applied Loads and Boundary condition according to actual assembly of EGR cooler by using bolts. During assembly there is torsion load on bolt and this load can be converted into pre-tension it comes about 25735 N. All DOF of mounting bracket are lock and it is shown in Fig.3.

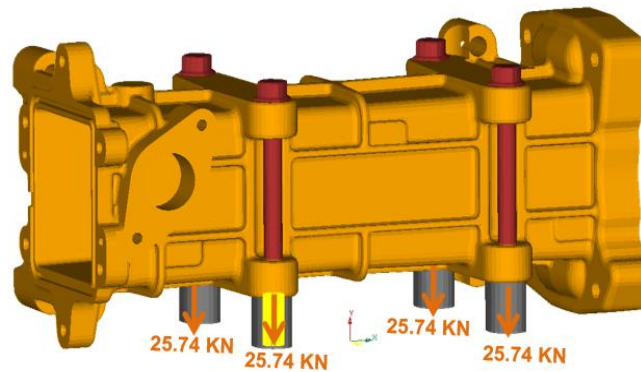


Fig. 3 Loads on Housing

The Assembly bolt torque of 35Nm is converted in to force using the formula

$$F = M / (0.17 \times d)$$

Where,

F = Force (N),

M = Moment (N-mm)

d = Diameter of bolt (mm)

Preload Apply Method:

Special command in commercial software

Most of the commercial software's have special command for applying bolt torque either by directly specifying the torque or otherwise equivalent axial force produced due to torque. To calculate equivalent compressive axial force, standard formulas available in design data book these can be used.

$$M = K * F * d \quad (K = 0.15 \text{ to } 0.2)$$

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VI. MATERIALS PROPERTIES

The material properties of Hosing, Bracket, and Bolt as shown in Table 1 were aluminium, which is usually used in pressure die casting material.

Table 1 – Mechanical Materials properties

Material:	Aluminium	Cast Iron	Steel
Parts:	Housing	Bracket	Bolt
Young's modulus E [MPa]:	6.8 E4	1.69 E5	2.1 E5
Poisson's ratio v [-]:	0.33	0.3	0.30
Mass density ρ [ton/mm ³]:	2.7 E-9	7.1 E-9	7.8 E-9
Thermal Exp. Co. α[mm/K]:	2.4 E-5	2.4 E-5	2.1 E-5

VII. RESULTS AND DISCUSSION

Maximum deflections and stresses developed:-

In Existing model it's found that, at mounting bosses higher stress developed beyond permissible limit of material followed by deflection of bosses it undergoes failure. By analyse the model it's found that maximum deflection occurs at about 0.63mm and maximum stress near about 283 MPa.

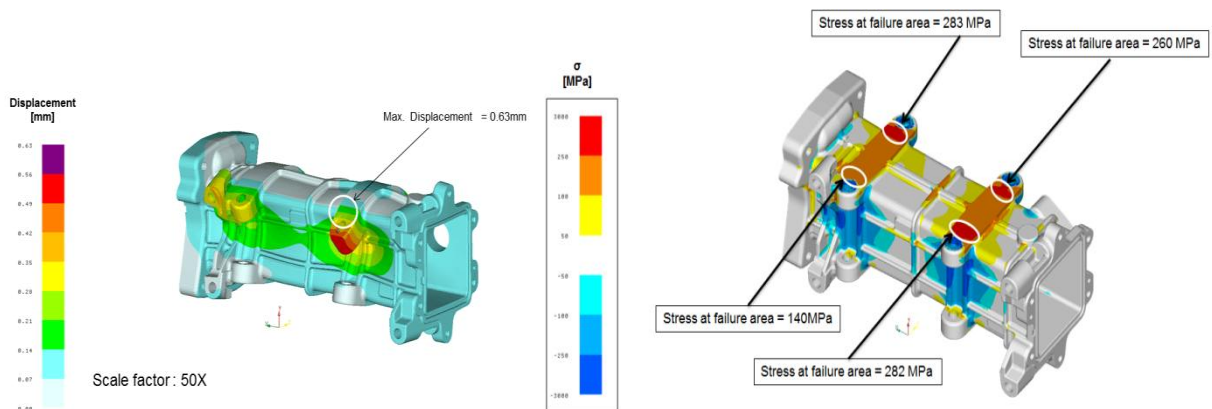


Fig.4a) Deformation in housing at model1

b) Principal Stress plot in housing at model1

Further this maximum stress co-relate with actual component of EGR cooler as shown in fig.5.

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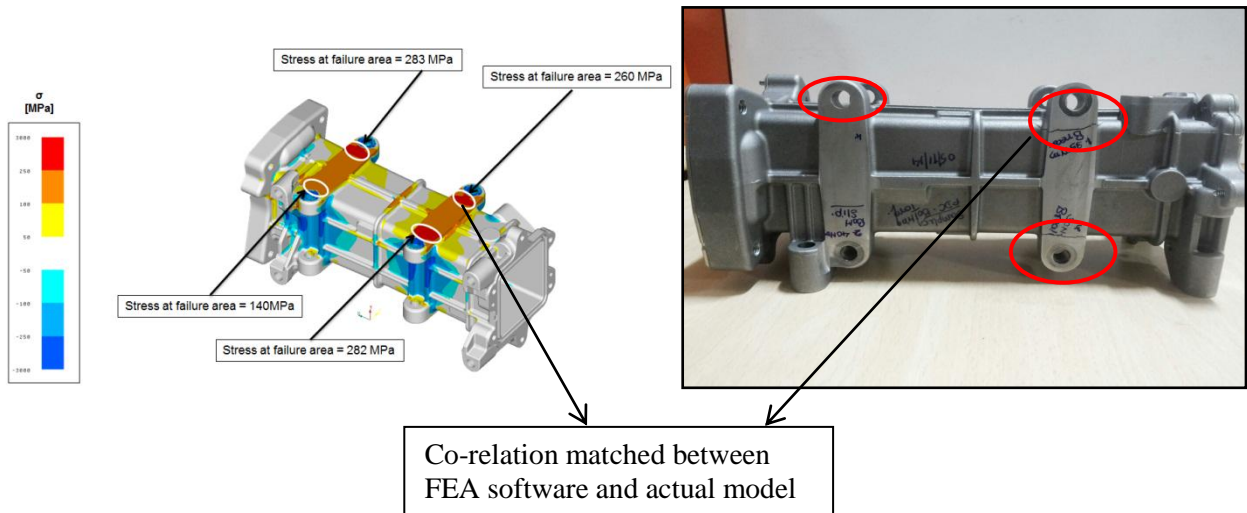


Fig.5 FEA and Failure model

Table 2 – Variation in stress, displacement and mass with same pre-load condition

Model	Max principle stress(MPa)	Max Displacement(mm)	Mass(Kg)
1	283	0.63	1.385
2	152	0.36	1.466
3	53	0.11	1.534
4	50	0.13	1.528
5	45	0.11	1.550
6	53	0.12	1.520

From above table conclusion that first two designs are above permissible limit of principle stress remaining four designs gives optimum permissible limit. Analysis of housing is done by adding minimum weight to bring optimum value of displacement with manufacturing feasibility.

From above table conclusion is model 6 is optimum in all respect and circular shape of bosses changed to square, thickness changed from 25.5mm to 15mm also the rib thickness changed to 6mm. Two ribs added between the mounting bosses with height of 5mm which consist of three horizontal ribs for strength purpose.

After analysing model 6, maximum deflection occurred 0.12mm and maximum stress at bosses area is 45 MPa as shown in fig.6

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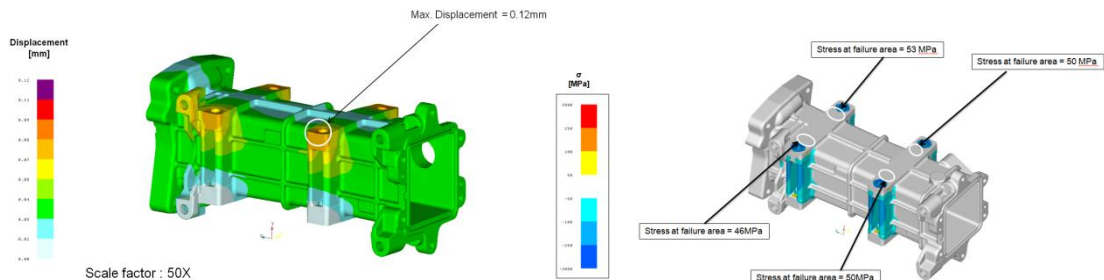


Fig.6a) Deformation in housing at model6b) Principal Stress plot in housing at model6

VIII. CONCLUSION

Analysis of housing for different loading conditions gives area of failure in the housing which is modified. By FEA analysis of mounting condition, the values such as maximum stresses and deflections acquired. These values are optimized with the help of FEA software. Failure location matched with its higher stress region in FEA results. This is achieved by increasing bosses thickness and introducing the ribs that support the bosses, so to reduce the maximum stress and deflections to avoid the failure. As compared to original design of EGR housing, maximum displacement in the final design is reduced by 6 times, the structural rigidity and strength is improved up to 80%.

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