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OPTIMISATION AND ANALYSIS OF EXHAUST MANIFOLD

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Abstract: The exhaust manifold is a pipe that conducts the exhaust gases from the combustion chambers to the exhaust pipe. An exhaust manifold is a part of the internal engine that collects the exhaust gases from multiple cylinders into one pipe. Many exhaust manifolds are made from cast iron or nodular iron. Some are made from stainless steel or heavy-gauge steel. The exhaust passages from each port in the manifold join into a common single passage before they reach the manifold flange. An exhaust pipe is connected to the exhaust manifold flange. Exhaust manifold is a part of diesel engines which are required to collect the exhaust gases from the cylinder head and send it to the exhaust system. The exhaust manifold plays an important role in the performance of an engine system. Particularly, the efficiencies of emission and the fuel consumption are nearly related to the exhaust manifold. The manifold may be a casting or fabricated of relatively light material. The purpose of the exhaust manifold is to collect and carry these exhaust gases away from the cylinders with a minimum of back pressure. Exhaust Manifolds are affected by thermal stresses and deformations due the temperature distribution, heat accumulation or dissipation and other related thermal quantities.

The objective of our analysis is to find out the suitable material by comparing thermal stresses and deformations induce by temperature mapping on different materials for exhaust manifold of off-road vehicle diesel engine.

in this process both static and thermal boundary conditions applied, and calculating results of each model with 3 materials and comparing their results After completing static and thermal analysis results, here cfd analysis boundary conditions applied and calculated results like pressure, velocity, and heat transfer rate values. By comparing all results with required graphs and tables, and finally conclude which (material or design or both) has more suitable qualities for our environment and engine.

Tools were used:

Cad tool: solid works

Cae tool: Ansys workbench

1. Introduction

Exhaust manifold

In automotive engineering, an exhaust manifold collects the exhaust gases from multiple cylinders into one pipe. The word manifold comes from the Old English word manigfeald (from the Anglo-Saxon manig and feald) and refers to the folding together of multiple inputs and outputs (in contrast, an inlet or intake manifold supplies air to the cylinders).

Exhaust manifolds are generally simple cast iron or stainless steel units which collect engine exhaust gas from multiple cylinders and deliver it to the exhaust pipe. For many engines, there are aftermarket tubular exhaust manifolds known as headers in American English, as extractor manifolds in British and Australian English, and simply as "tubular manifolds" in British English. These consist of individual exhaust headpipes for each cylinder, which then usually converge into one tube called a collector. Headers that do not have collectors are called zoomie headers.

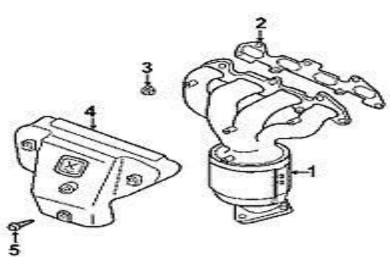

Diagram of an exhaust manifold from a Kia Rio. 1. Manifold; 2. Gasket; 3. Nut; 4. Heat shield; 5. Heat shield bolt

The most common types of aftermarket headers are made of mild steel or stainless steel tubing for the primary tubes along with flat flanges and possibly a larger diameter collector made of a similar material as the primaries. They may be coated with a ceramic-type finish (sometimes both inside and outside), or painted with a heat-resistant finish, or bare. Chrome plated headers are available but these tend to blue after use. Polished stainless steel will also color (usually a yellow tint), but less than chrome in most cases.

Another form of modification used is to insulate a standard or aftermarket manifold. This decreases the amount of heat given off into the engine bay, therefore reducing the intake manifold temperature. There are a few types of thermal insulation but three are particularly common

- Ceramic paint is sprayed or brushed onto the manifold and then cured in an oven. These are usually thin, so have little insulatory properties; however, they reduce engine bay heating by lessening the heat output via radiation.
- A ceramic mixture is bonded to the manifold via thermal spraying to give a tough ceramic coating with very good thermal insulation. This is often used on performance production cars and track-only racers.
- Exhaust wrap is wrapped completely around the manifold. Although this is cheap and fairly simple, it can lead to premature degradation of the manifold.

The goal of performance exhaust headers is mainly to decrease flow resistance (back pressure), and to increase the volumetric efficiency of an engine, resulting in a gain in power output. The processes occurring can

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be explained by the gas laws, specifically the ideal gas law and the combined gas law

Exhaust manifold is a pipe that conducts the exhaust gases from the combustion chambers to the exhaust pipe. An exhaust manifold is a part of the internal engine that collects the exhaust gases from multiple cylinders into one pipe. Many exhaust manifolds are made from cast iron or nodular iron. Some are made from stainless steel or heavy-gauge steel. The exhaust manifold contains an exhaust port for each exhaust port in the cylinder head, and a flat machined surface on this manifold fits against a matching surface on the exhaust port area in the cylinder head. Some exhaust manifolds have a gasket between the manifold and the cylinder head.

Gaskets are meant to prevent leakage of air/gases between the manifold and cylinder heads. The gaskets are usually made out of copper, asbestos-type material, or paper. In other applications, the machined surface fits directly against the matching surface on the cylinder head. The exhaust passages from each port in the manifold join into a common single passage before they reach the manifold flange. An exhaust pipe is connected to the exhaust manifold flange. On a V-type engine an exhaust manifold is bolted to each cylinder head.

PROBLEM IDENTIFICATION

In recent years the engine operating temperatures of cars, vans and heavy goods vehicles have been increasing because of environmental legislation on emissions and the need to improve engine efficiency. The motor industry worldwide is highly competitive, operating on small margins and large volumes. Therefore, the profitability is highly geared to reductions in design, development and manufacturing costs.

Fig: Defects in End connections due to thermal stress

Automobiles have achieved some success with an approach termed here FEA validation (FEAV) for high temperature components. Moving away from a design process which relied primarily on component testing towards a predictive capability based on standardized material data and computer predicted performance of components has resulted in reductions in development costs and timescale.

Aim of the projects

In this project 2 designs were designed with the help of cad tool creo-2.0 and 3 materials (grey cast iron, steel 440c, en-9) were selected to analysis, analysis process carried with the help of cae tool Ansys workbench,

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in this process both static and thermal boundary conditions applied, and calculating results of each model with 3 materials and comparing their results with required graphs and tables, and finally conclude which (material or design or both) has more suitable qualities to improve the engine efficiency within our environmental conditions and explaining why it is

And also knowing flow parameters like pressure distribution and velocity and heat transfer rate values.

Results to be compared

- Deformation, stress, safety factor(strength)
- Total temperature distribution of the object
- Heat flux values
- Weight of the each object for each material
- Pressure, velocity , heat transfer rate

LITERATURE REVIEW

Dr. VVRLS Gangadharet al., 2017, In this research, an existing model of an engine Exhaust Manifold is modeled in 3D modeling software. Thermal analysis is done for both models using different materials copper, Nickel, Stainless steel and manganese. Analysis is done in ANSYS.

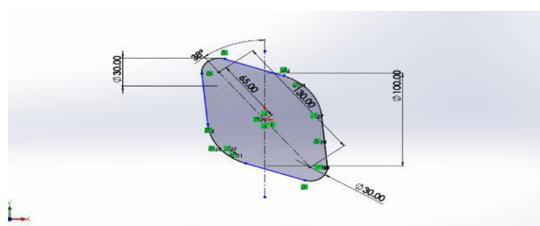
By observing the thermal analysis results, the heat flux (i.e) heat transfer rate is more for Copper when compared with other materials. The heat transfer rate is slightly less for modified model than original model.

Kanupriya Bajpai et al., 2017, In the present work, the performance of a four-stroke four cylinder gasoline engine exhaust manifold have been analyzed using three different fuels - gasoline, alcohol, and LPG for the estimation of flow characteristics, thermal characteristics, and minimum back pressure. The manifold modelling is done in Creo2.0 followed by meshing and analysis in ANSYS.

P Sylvester Selvanathan et al., 2017, This papers aims to analyze the design of an exhaust manifold to establish the significance of various factors involved in designing an exhaust manifold by comparing various existing designs using Computational Fluid Dynamics. The 3 different models are analyzed using CFD software to obtain the velocity vector, static pressure and turbulent kinetic energy along the manifold andthe turbine housing. The simulation data was used to obtain the necessary results using CFD Post.

Design developed by using cad tool (solid works)

Design 1



The above sketch should follow 3 conditions those are the sketcher should be closed and there should be no open end there should be no over lapping. By following these conditions we have to create our model. After completion of sketch click ok and we will get below model.

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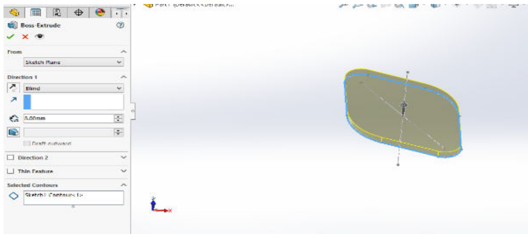
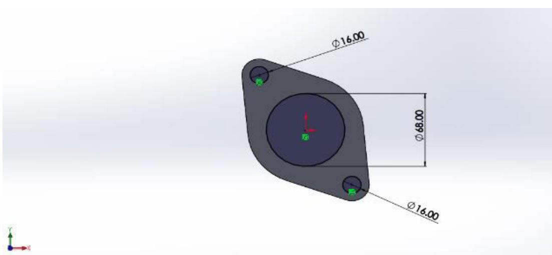
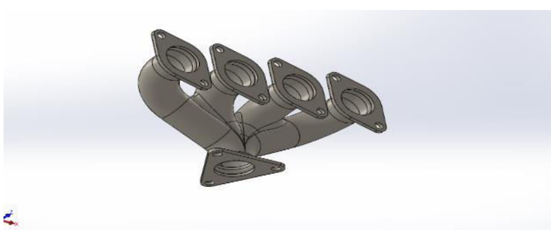


Then extrude it→8mm→ok

After completion of that just click on ok then we will get below model To create holes here we using extrude cut option and the sketch dimensions is shown in below



Cut up to next surface



Exhaust manifold 1st design Final model

Here in order to compare the results, one more design is made by same procedure and the final object is shown in below image, here the both objects were maintain same dimensions but the structure is different to each other

Design 2

Exhaust manifold 2nd design final model

ANSYS PROCESS

Steel

Young's modulus: - 200*10^9 Pa

Poison ratio: 0.28

Density: 7850 Kg/m^3

Yield strength: 250 Mpa

Thermal conductivity: 60.5 w/m-k

Cast iron

Young's modulus: - 11*10^9 Pa

Poison ratio: 0.28

Density: 7200 Kg/m^3

Yield strength: 306 Mpa

Thermal conductivity: 52 w/m-k

Steel 440c

Young's modulus: - 200*10^9 Pa

Poison ratio: 0.28

Density: 7800 Kg/m^3

Yield strength: 450 Mpa

Thermal conductivity: 24.2 w/m-k

En-9

Young's modulus: - 210*10^9 Pa

Poison ratio: 0.28

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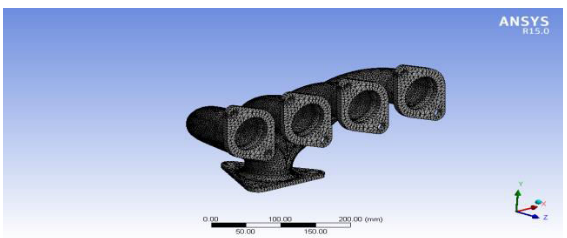
Density: 7850 Kg/m^3

Yield strength: 355 Mpa

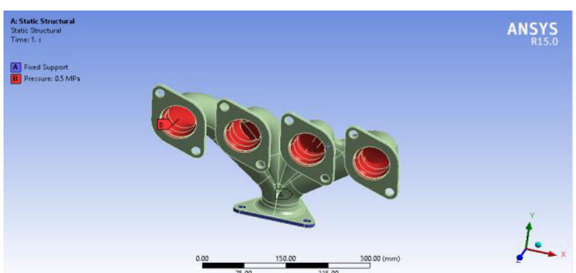
Thermal conductivity: 16.3 w/m-k

Meshing

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.



Boundary conditions



Static structural →supports→fixed support→select bottom surface area and inner circles too

Pressure →0.5 Mpa

After completion of boundary conditions here we have to check results by solving. Just click on solve option and select results like deformation, strain, stress and safety factor values for the object.

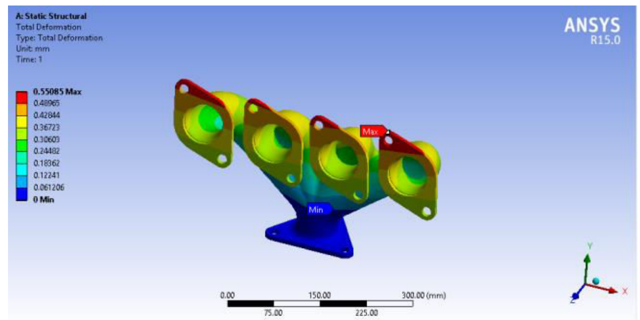
Solution→solve→deformation

Solution→solve→safety factor

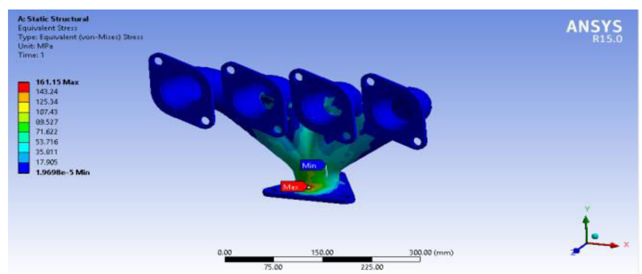
Solution→solve→stress

Steel

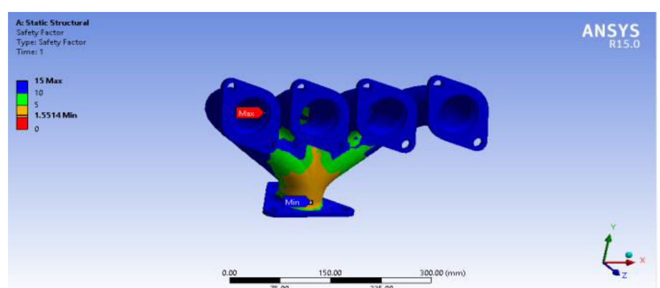
Deformation



Stress



Safety factor



Tables

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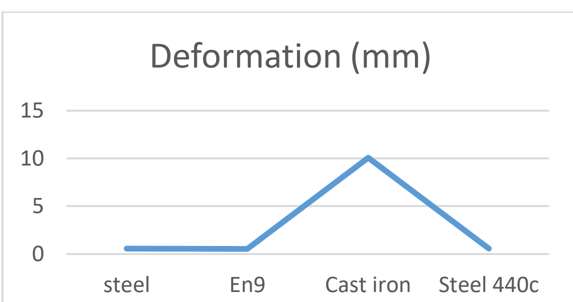
	steel	En9	Cast iron	Steel 440c
Deformation (mm)	0.55085	0.52662	10.09	0.56417
Stress(Mpa)	161.15	161.44	161.73	163.26
Safety factor	1.5514	2.1989	1.892	2.7563

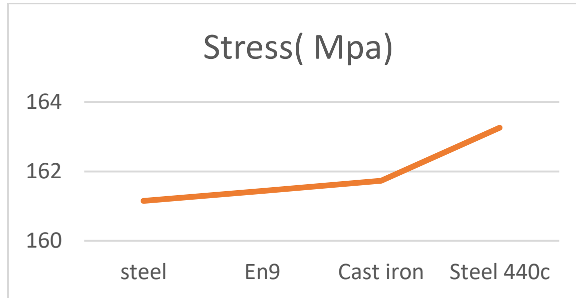
From the static results of each material here observe that, each material has maintain nearly same amount of stress value, and among all steel 440c has 2Mpa higher stress value than other but it doesn’t affect the object due to high yield limit value. Even though it has high stress values and still maintain highest safety factor value than any other material. From the above table all 4 materials are maintaining minimum factor of safety value is greater than 1.5 it means each object can withstand up to 0.5Mpa pressure. Here steel 440c best of all and en-9 took 2nd best and then cast iron and steel materials occupy 3rd and 4th places respectively.

Graphs

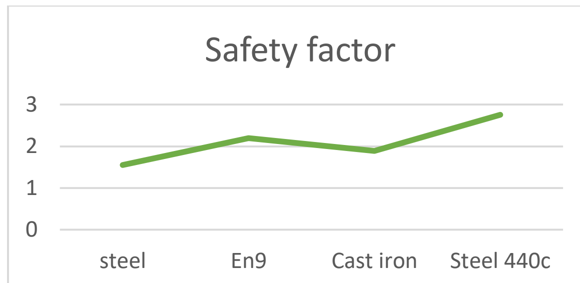
Deformation



Stress



Safety factor

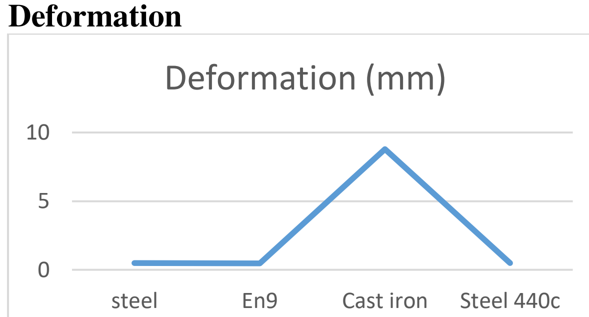


Design 2 results

	steel	En9	Cast iron	Steel 440c
Deformation (mm)	0.48328	0.46058	8.7976	0.48437
Stress(Mpa)	141.42	141.65	141.87	142.86
Safety factor	1.7678	2.5061	2.1568	3.15

Graphs

Deformation



Stress

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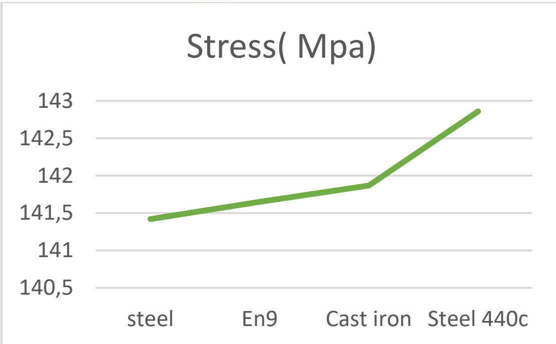
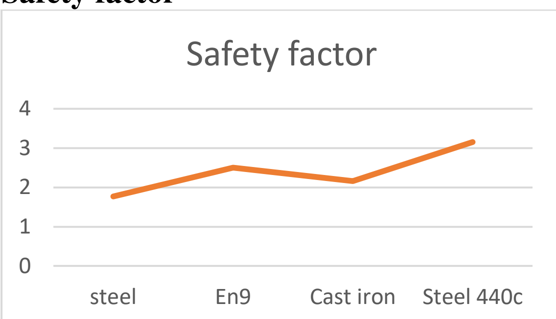
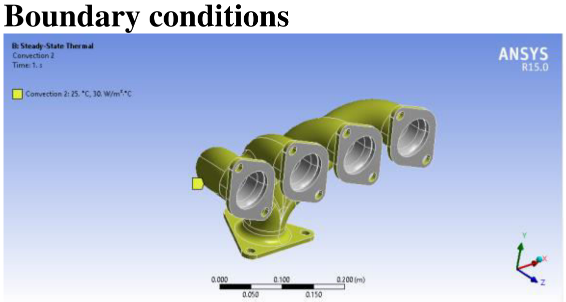


Safety factor



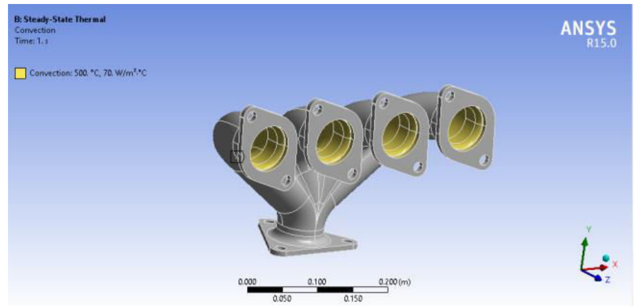
Thermal analysis

Boundary conditions



The thermal mapping is done by solving steady state thermal analysis of the component by using ANSYS Workbench. Outer surface of component is exposed to environment (i.e. air flowing in the chamber or the still air around the engine,) on which constant heat transfer coefficient applied with ambient temperatures 25°C. Outer and inner heat transfer coefficient are assumed respectively 30W/m²°C and 70 W/ m²°C, to calculate thermal loads on the exhaust manifold.

Inner Boundary Conditions



Convection→ select all inner areas→bulk temperature→500*c

Coefficient of film→70 w/m^2,*c

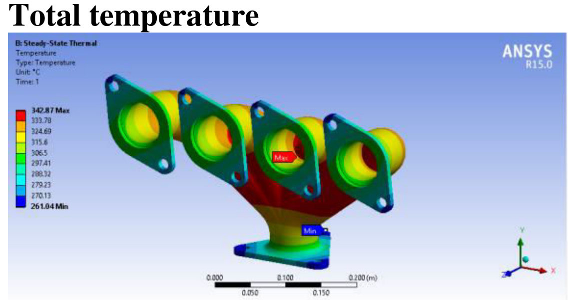
Convection→ select all inner areas→bulk temperature→25*c

Coefficient of film→30 w/m^2,*c

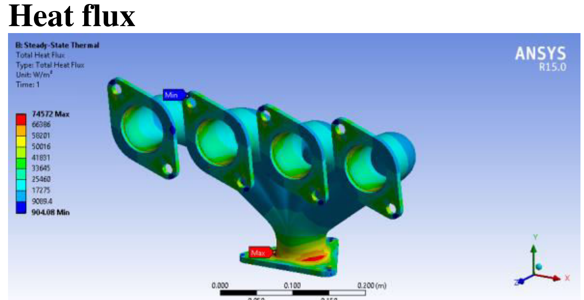
Design 1

Steel

Total temperature



Heat flux



Tables

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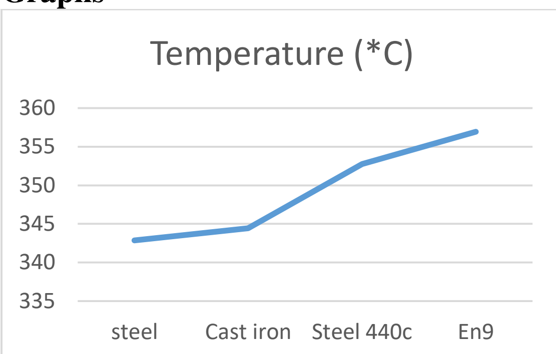
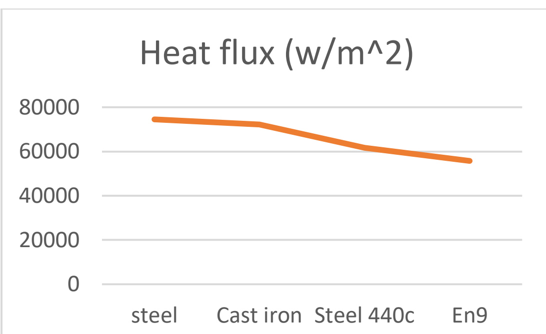
	steel	Cast iron	Steel 440c	En9
Temperature (*C)	342.87	344.44	352.77	356.92
Heat flux (w/m^2)	74572	72271	61731	55811

Graphs

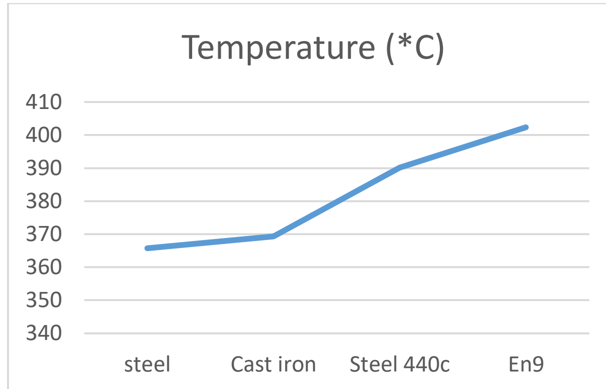




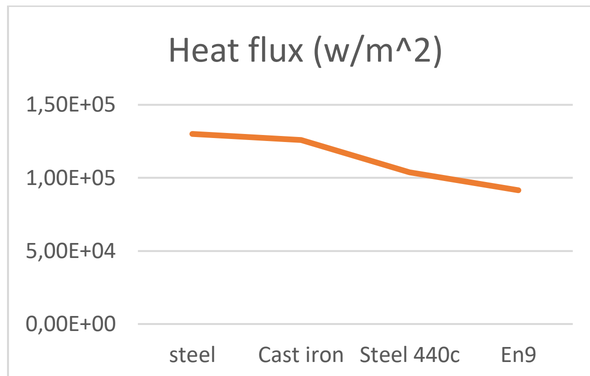
Design 2 results

	steel	Cast iron	Steel 440c	En9
Temperature (*C)	365.69	369.28	390.17	402.3
Heat flux (w/m^2)	1.3015e5	1.2604e5	1.0376e5	9164

Graphs
Total temperature



Heat flux



Cfd analysis

Here inlet mass flow rate value is 0.000424kg/s, and temperature applied 900K, after applying these values solving it, and below images shows final results

Heat transfer rate
Design1

```
                  Area-Weighted Average
        Wall Func. Heat Tran. Coef.                  (w/m2-k)
-------------------------------- --------------------
                wall-3-freeparts                63.486963
```

Design2

```
                  Area-Weighted Average
Wall Adjacent Heat Transfer Coef.                  (w/m2-k)
-------------------------------- --------------------
                wall-3-freeparts                64.967358
```

CONCLUSION

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In this is thesis two exhaust manifold objects were designed by using cad tool (solid works) and then imported into cae tool Ansys workbench here, in this process both static and thermal boundary conditions were applied on each model and calculated results like deformation, stress, safety factor and heat flux values for real time boundary conditions. Here steel material consider to be as an existing material and steel440c, cast iron, en-9 materials were chosen materials to improve the performance of the object. Here 0.5Mpa pressure consider as real time boundary condition in static analysis.

From static analysis results here 2nd design has got better performance than 1st design. In this case 2nd design can reduce up to 20Mpa of total stress value on the object on each material respectively it means approximately 12.5% of total stress will be reduced compare to design1. Strength will increases nearly 15%, by comparing both models 2nd design can give better results than 1st design.

In thermal Outer surface of component is exposed to environment (i.e. air flowing in the chamber or the still air around the engine,) on which constant heat transfer coefficient applied with ambient temperature 25°C, Outer and inner heat transfer coefficient are assumed respectively 30W/m² °C and 70 W/ m² °C, to calculate thermal loads on the exhaust manifold.

From thermal analysis results it is clearly shown that compare to design1, design2 has high heat transfer rate and total temperature distribution also. And also all these temperature values under melting point limit only

By knowing cfd analysis results the pressure on walls is completely under yield limit conditions, so that our object is safe at applied load, and also steel 440c has less outlet temperature values compare to steel, and the heat transfer rate values are increased.

Exhaust manifold materials must have good fatigue strength under repeated thermal stress and be resistant to corrosion, based on this point here thesis can be concluded here design2 with steel 440c materials due to high fatigue strength values.

Advantages of design2

- This design can withstand high amount of thermal stresses without breakage
- It increases the overall heat transfer rate values compare to design1
- Due to high strength object durability can increases.

Disadvantages of design2

- Slightly weight can increases compare to design1

REFERENCES

[1] Swathi Satish, Mani Prithiviraj and Sridhar Hari, "Comparison of predictions obtained on an exhaust manifold analysis using conformal and indirect mapped interface", International Congress on Computational Mechanics and Simulation, IIT Hyderabad, 10 –12 December 2012.

[2] J.DavidRathnaraj, "Thermo mechanical fatigue analysis of stainless steel exhaust manifolds", IRACST – Engineering Science and Technology, Vol 2, No. 2, April 2012, PP 265 – 267.

[3] M.Rajasekhar Reddy, DrK.Madhava Reddy, "Design And Optimization Of Exhaust Muffler In Automobiles", International Journal of Engineering Research and Applications, Vol 2, Issue 5,Sept-Oct 2012, PP 395 – 398.

[4] Sweta Jain, AlkaBaniAgrawal, "Coupled Thermal – Structural Finite Element

Analysis for Exhaust Manifold of an Off-road Vehicle Diesel Engine",
International Journal of Soft Computing and Engineering, Vol 3, Issue 4, September 2013, PP 226-230.
[5] Bin Zou, Yaqian Hu,ZhienLiu, Fuwu Yan and Chao Wang, "The Impact of Temperature Effect on Exhaust Manifold Thermal Modal Analysis", Research Journal of Applied Sciences Engineering and Technology, August 20, 2013, PP 2824-2829
[6] Olsson F, "Principkonstruktion", Institution for Maskinkonstruktion, Lunds Tekniska Hogs kola, 1995.