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Thermo-mechanical Analysis of a section of an exhaust manifold for automobile applications

[1]Hemanth Kumar K S, [2]Bharath Kumar M M,[3]Girish B Kallihal, [4]Prasanna P Kulkarni

[1,2,3,4]Assistant professor
Mechanical Engineering Department
[1,3,4]STJIT, Ranebennur, Haveri,India
[2]VKIT, Palamakula, Hyderabad, India

***Abstract*: In the present work, a sectional model of the exhaust manifold has been studied to reduce the heat loss by insulating the pipe with different insulating materials. Four different insulating materials were used to increase the thermal resistance of the exhaust manifold so that there would be less heat loss in the manifold. The model with the insulating materials was modeled and discretized. The thermal and structural properties have been assigned to the discretized model and processed for analysis. The heat flux from the exhaust gas is taken as input to the analysis model. Heat loss and temperature difference were taken as output. From the present analysis, it can be said that by using these four materials, the heat loss through the exhaust manifold will be reduced.**

***IndexTerms*—Exhaust Manifold, Glass Wool, Plastic foam, Silica, PUF, Thermal resistance, Heat flux.**

I. INTRODUCTION:

Automotive and energy industries, such as internal combustion engine is used in various fields are an important major transport. Performance, emissions and engine durability and design, choice of material and auto parts, the fatigue life of the heat transfer effect. And the need to improve the performance of the engine is transferred to the heat of the engine cooling system. Automobile exhaust gases in the exhaust system of the engine of the temperature measurement are useful to understand the process. Empty the gas engine at a very high speed and high temperature strength. Outgoing gas silencer in the exhaust system of the automobile exhaust, exhaust system, which is thermal, vibration and fatigue caused by cracks in the muffler in the exhaust system, which led to the disruption of the high temperature of the combustion chamber, the hot parts of the exhaust system in order to study heat transfer analysis to improve the performance of the machine.

II. INSULATING MATERIALS:

Following are the type of Insulating materials used in this work.

1. **Fibrous Insulation**

Composed of air finely divided into interstices by small diameter fibers usually chemically or mechanically bonded and formed into boards, blankets, and hollow cylinders.
Example: Fiber glass, Mineral fiber

2. **Cellular Insulation**

Composed of air or some other gas contained within foam of stable small bubbles and formed into boards, blankets, or hollow cylinders.
Example: Elastomeric foam, Polyurethanes

3. **Granular Insulation**

Composed of air or some other gas in the interstices between small granules and formed into blocks, boards, or hollow cylinders.
Example: Calcium silicate

III. MATERIAL PROPERTIES

Table.1. Properties of Steel used.

Material	Value	Unit
Density	7.9E-09	tonne/mm^3
Young's Modulus	2.1E+05	MPa
Poisson's Ratio	0.3	
Co-efficient of thermal	1.2E-05	mm/mm-K

expansion		
Thermal conductivity	0.0253	W/mm-K

Table.2. Properties of Silica used

Property	Value	Unit
Density	2.42E-09	tonne/mm3
Young's Modulus	7.3E+04	MPa
Poisson's Ratio	0.165	-
Co-efficient of thermal expansion	5.5E-07	mm/mm-K
Thermal conductivity	1.7E-05	W/mm-K

Table.3. Properties of Glass wool used.

Property	Value	Unit
Density	5.1E-10	tonne/mm3
Young's Modulus	5.5E+03	MPa
Poisson's Ratio	0.3	-
Co-efficient of thermal expansion	4.8E-06	mm/mm-K
Thermal conductivity	4E-05	W/mm-K

Table.4. Properties of Plastic foam used.

Property	Value	Unit
Density	6.72E-10	tonne/mm3
Young's Modulus	3.6E3	MPa
Poisson's Ratio	0.21	-
Co-efficient of thermal expansion	7E-05	mm/mm-K
Thermal conductivity	3E-05	W/mm-K

IV. VEHICLE SPECIFICATIONS:

For the present analysis, the engine specifications of Mitsubishi Pajero have been selected. The details of the vehicle specifications are given below.

Table.5. Vehicle Specifications

Sl. No.	Brand	Mitsubishi
1.	Model	Pajero
2.	Generation	Pajero IV
3.	Engine	3.8 i V6 24V MIVEC (250) 5-doors
4.	Power	250 HP/6000 rpm.
5.	Maximum speed	200 km/h
6.	Acceleration 0 - 100 km/h	10.8 sec
7.	Seats	7
8.	Length	4900 mm.
9.	Width	1875 mm.
10.	Height	1870 mm.

11.	Wheelbase	2780 mm.
12.	Model Engine	Mitsubishi 6G75
13.	Position of engine	Front, longitudinal
14.	Engine displacement	3828 cm^3
15.	Torque	329 Nm/2750 rpm.
16.	Fuel System	Multi-point injection
17.	Position of cylinders	V engine
18.	Number of cylinders	6
19.	Bore	95 mm.
20.	Stroke	90 mm.
21.	Compression ratio	9.8
22.	Number of valves per cylinder	4
23.	Fuel Type	Petrol (Gasoline)

V. CAD MODELS:

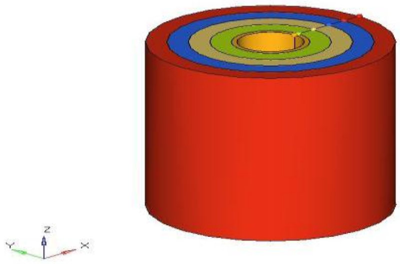

Fig.1. CAD Model of the exhaust manifold section

Figure shows the CAD model generated using CATIA v5. The dimensions selected in the previous step have been used for modelling. It shows that a steel pipe is in the centre of the model and four insulating materials (i.e., Silica, Glass Wool, Poly Urethane Foam and Plastic foam) have been modelled around the steel pipe. All dimensions used are in mm.

VI. MESHED MODEL:

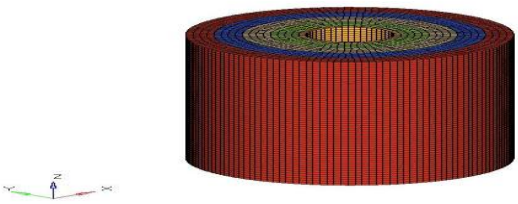

Fig.2. FE Model of the Exhaust manifold section

Table.6. Meshed result of Exhaust Manifold section.

Total No of Nodes	444081
Total No of Elements	439200

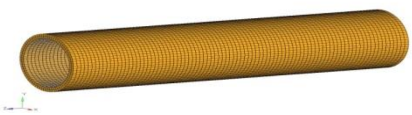

Fig.3. FE Model of the steel pipe

Table.7. Meshed result of STEEL section

Total No of Nodes	20748

Total No of Elements	20520

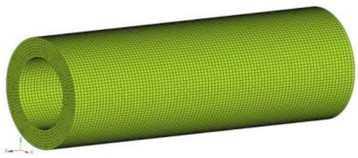

Fig.4: FE Model of Silica insulation

Table.7. Meshed result of SILICA section

Total No of Nodes	71890
Total No of Elements	64260

Fig.5: FE Model of Glass Wool Insulation

Table.7. Meshed result of Exhaust Manifold section

Total No of Nodes	104468
Total No of Elements	92700

Fig.6: FE Model of PUF insulation

Table.8. Meshed result of Exhaust Manifold section

Total No of Nodes	133770
Total No of Elements	117900

V.LOADS AND BOUNDARY CONDITIONS

1. Thermal loading:

Below Figure shows the thermal boundary conditions and load applied to the model. The heat flux calculated from the previous section has been applied on the inner radius of the steel pipe and the BCs have been applied to the outer edges of the model. This closely simulates the effect of the exhaust gases flowing in the steel exhaust manifold section.

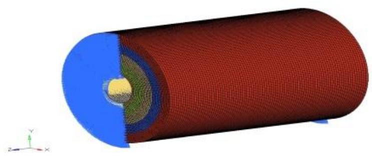

Fig.8: Thermal Loads and Boundary conditions of the exhaust manifold section

2. Buckling Analysis:

Below Figure shows the structural boundary conditions and the pressure load from the exhaust gases applied on the steel pipe. the total volume of the exhaust gases flowing through the steel pipe exerts a pressure on the inner walls of the steel pipe. The purpose of this simulation is to determine the structural strength of the steel pipe and the insulation around it.

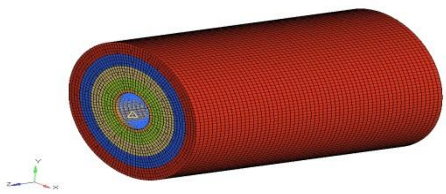

Fig.9: Structural Loads and Boundary Conditions of the exhaust manifold section

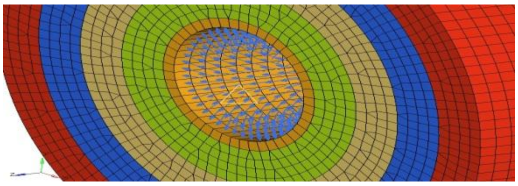

Fig.10: Structural Loads and Boundary Conditions of the exhaust manifold section

VI.RESULTS AND DISCUSSION

1. THERMAL ANALYSIS

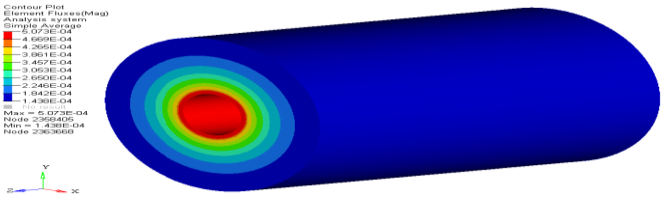

Fig.11: Variation of heat flux in the exhaust manifold section

Above Fig shows the heat flux distribution in the exhaust manifold section. It can be seen that the maximum heat flux is inside thesteel pipe because of the exhaust gases and decreases when nearing the atmosphere. Minimum heat flux is seen on the outer surface of the pipe section. This shows that the heat flux is reducing due to the change in thermal conductivity of the insulating materials

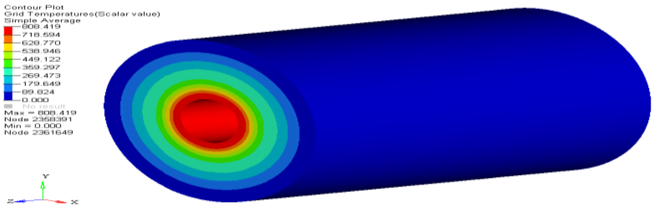

Fig.12: Temperature distribution in the exhaust manifold section

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Above Figshows the temperature distribution in the exhaust manifold section. The maximum temperature is seen on the inner wall of the steel pipe because of the exhaust gases flowing through it. The temperature varies from a high value of 808.4°C near the steel pipe to a low value of around 35°C near the outer surface of the insulation.

2. STATIC ANALYSIS

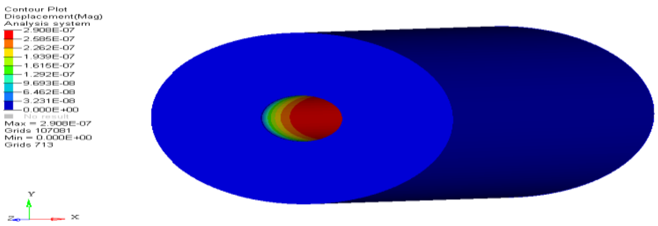

Fig.13: Displacement plot of for the structural loads applied on the exhaust manifold section.

Above Figshows the displacement plot for the structural load applied to the exhaust manifold section. The maximum displacement is seen to be 2.9E-07 mm which is very much less to cause any serious damage to the structure.

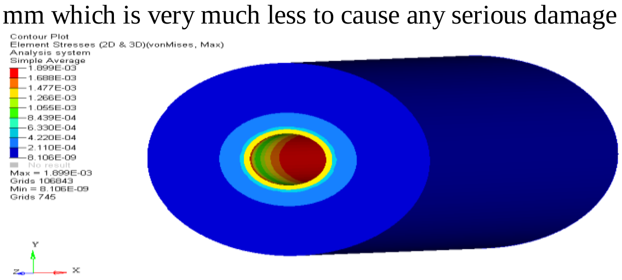

Fig.14: Stress plot for the structural loads applied on the exhaust manifold section

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Fig.14shows the stress plot for the structural load applied on the exhaust manifold section. It shows that the maximum stress developed in the model is 1.89E-03 MPa which is very much less than the yield strength of the steel pipe. Hence we can say that the structure is safe for use under the present conditions

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3. BUCKLING ANALYSIS

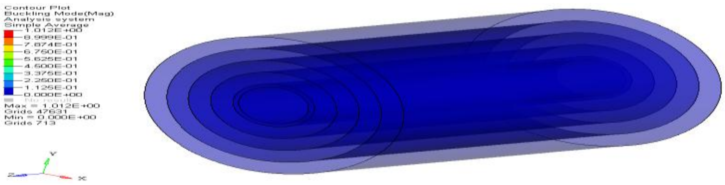

Fig.15: Buckling plot for the exhaust manifold section

Fig.15shows the buckling modes for the structural load applied on the exhaust manifold section. The buckling factor calculated for this structure is 4.68E+07 which is greater than 1. Hence we can say that the load applied on the structure does not cause any buckling and is safe for the applied loads.

VII.CONCLUSION

In the present work following conclusions can be reached.

- The thermal loads applied to the manifold section shows that the temperature distribution is uniform and within the limits of the insulating materials.
- The heat flux developed in the model due to the heat loads is seen to be decreasing with a high value near the center and a low value at the edge of the insulation.
- The pressure applied on the steel pipe show that the displacement is negligible and does not affect the performance of the pipe.
- The stress developed in the pipe section is well within the yield limit of the materials and is safe to work under the given conditions.
- The buckling factor calculated for the model is higher than 1 and can be said to be safe under the present conditions.

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