

Stress Pattern Analysis in Intake Manifold

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ABSTRACT: The ignition in the diesel engine takes only if the air to fuel ratio is appropriate and hence air should be compressed to threshold level. Intake manifold assist to maintain the proper flow of air into the engine cylinder head for compression. During the operation the intake manifold is subjected to both thermal and mechanical loads such as pretension load on the bolts and temperature variation loads on the inner and exterior surface of the intake manifold. These loads causes the stresses on the manifold which need to studied and understand the behaviour of the manifold. During the operation the scope of the present work is to study the stress level or patterns in the manifold because of thermochemical load and optimize the design of intake manifold without compromising on factor of safety.

KEYWORDS: Intake manifold, Stress pattern, Temperature distribution.

I. INTRODUCTION

Basically intake manifolds are pretty essential part of an engine which supplies air-fuel mixture into the cylinders. The primary function of intake manifold is to distribute evenly the air-fuel mixture into the cylinder this even distribution improves the performance of the engine The parts and different connections of intake manifold seems very simple but quite things to connect to it and use it is as a manifold.so the first in kind of must obvious part is throttle body and that of course controls the amount of air flow the engine gets when we open that valve inside. And the next thing is that fuel injectors where each of injectors are going to be spraying fuel. There is little notch, from those fuels will be spraying. There is another part which connecting between throttle body and intake manifold is the idle air control valve or IAC. It allows the ECU to manage the idol revolution. The revolution limit is basically what rpm you are going to be spinning at when you are just idling in that throttle is closed. Right in front of plenum there is mounting here and from that adjusts throttle cable. Top of the intake manifold there is the evaporator purge valve which is basically part of emission system and the function of this evaporator purge valve is it allows for evaporated fuel from the gas tank that expanded in the gas tank to be burned off the engine. In the previous era aluminium and cast iron are used for manufacturing of intake manifold. But usage of composite materials and plastic materials providing more efficiency to the engine because of that it gains more popularity. There are many factors for the improvement of engine efficiency and intake manifold is major factor. For the improvement of increasing the efficiency, some of the general modification are required increasing the plenum length for lower engine speed. For the maximum speed the length of plenum should be decreased. There are many other factors like diameter of runner, intake manifold configuration such as spiral, helical, spiral-helical etc.

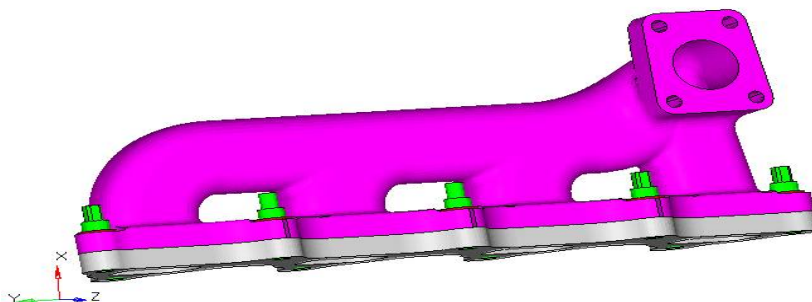


Fig.1 Intake manifold

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II. LITERATURE REVIEW

M.A.Ceviz ,M.akin Discussed about the consequence of plenum length and volume on the performance of SI engine. In the previous studies they concentrated only about the carburetor which work is to mix the air and fuel and supplies that mixture to the intake manifold. In this paper they have conducted engine tests with a purpose of constituting a new changeable length of plenum. After considering all these effects the results exhibit that variable length of plenum increases the engine speed and specifically fuel consumption at higher and lower speed. For the engine speeds which are at lower the length of plenum should be extended. And the engine speeds which are at higher the length of plenum should be shortened.

Xiaokang Ma et.al (2014) They have studied about the how the combustion temperature and NO_x emissions can be reduced in the diesel engine by intake manifold water injection method. This method increases the performance of engine and efficiency of an engine. In this paper researcher Paid more attention on these three effects which are as follows Dilution effect, Thermal effect and Chemical effect.

Mohdfaizalhushimet.al(2015) Investigated about air movement inside the intake manifold at different angles which are 30⁰,60⁰,90⁰,120⁰,150⁰,180⁰ using a GT power tool. Air fuel mixture is important for improving engine efficiency. This air fuel mixture is pulled in to the intake manifold before sending it to combustion chamber. They conducted many experiments and simulation by GT power tool. From the investigation of all six angles it can be concluded that the 180⁰ is the best suitable. At this angle the flow of air will be better. From this we can achieve proper mixing of air fuel so that we can achieve maximum engine performance and also efficiency of engine.

Sachinsinglaet.al (2015) Discussed about how the equal velocity can be achieved at the last stage of the runner by making some modification in the intake manifold. In this paper, They have taken intake manifold of Marutiwagor they conducted experiments on manifold. The different velocities and pressure at outlet for inlet velocities are noted down. Later by using ANSYS FLUENT they make a three dimensional model of intake manifold. And simulation is done on a three dimensional model of intake manifold after that they came to conclusion that at the end of the runner they get the uniform velocities at the outlet by comparing with the actual model of manifold and the modified manifold the velocities at the last stage of runner is developed by nearly about 5% to 7%.

S. Karthikeyan et.al (2011) Investigated about the pressure waves. These are simulated by software called AVL boost. The simulation is done for pressure waves of a intake manifold during the improvement of new engine. In a 3 cylinder diesel engine the air flow behaviour at the transient condition is studied. From the investigation they came to conclusion that the results of 3D CFD gives us inappropriate movement of air inside the runner and pressure inside the runner. And it is also experimentally investigated on the engine test bench. They have done experiments on the engine and find out that the pressure at the runner and smoke level of manifold is optimized.

Arvindkumaret.al (2014) Discussed about the manufacture and design modification of intake manifold of 600⁰C .YAMAHA ZF Engine. They have used fiber reinforced plastic instead of using aluminium and cast iron For the manufacture of intake manifold. Normally cast iron and aluminium is used to achieve the best performance and volumetric efficiency. The structure has to be changed for different engine outputs. After usage of fiber reinforced plastic they come to conclusion that the redesigned manifold of FRP causes reduced weight. Charge distribution will be developed.

III.METHODOLOGY

Step 1: Creation of CAD model: The geometry of intake manifold is created in some commercial CAD soft wares like UNIGRAPHICS or SOLID WORKS or SOLID EDGE. The concept of intake manifold geometry is taken from the existing reference model. The reference model dimensions are altered as per the new dimensional requirement. The CAD model generated is exported in the form of neutral file such as IGS, Step, and Para solid.

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Step 2: Creation of FE model

- a) The neutral step file of the intake manifold is imported into the commercial pre-processing tool called as Hypermesh. The imported CAD model is performed with a geometry cleanup process. The geometry cleanup process includes of removing unwanted holes or surfaces, fillets, blends. Geometry cleanup process will also help to recreate patch up the lost surfaces or data. This will normally happen while exporting from CAD software or it may also happen during importing process also. Once the geometry cleanup process completes later discretization or meshing is carried out on the simplified cleaned up geometry.
- b) Selection of elements: The thumb rule for selecting the elements is as follows. If the cross section thickness is uniform and thickness varies from 0.2mm to 20mm it is preferred to have the shell mesh. If the thickness is more than 20mm and also if the cross sections are non-uniform it is preferred to use solid mesh.
- c) In the current project the intake manifold is modelled with a four noded tetra element. The generation of tetra element in a Hypermesh is as follows.
 - Create a three noded tria element on the outer and inner surface of the intake manifold to form an enclosed volume.
 - An average element length of 3mm is maintained throughout the mesh model
 - Element quality
 - Minimum tria angle = 15°
 - Maximum tria angle = 130°
 - Minimum length = 0.50
 - Once the mesh is created the mesh is checked for the edges or cracks. If there are no edges then the model is ready for creating the tetra solid mesh.
 - The tetra element quality is checked for a 0.12 to tetra element collapse. If the value is of each element is more than 0.12 tetra collapse then the element is of good quality.

Step 3: Assigning sections and materials properties to the meshed model

- a) Solid section is created and assigned to the mesh.
- b) Material properties are created with the following parameters and assigned with material name as steel.
 - i. Young's Modulus = 2.1×10^5 Mpa.
 - ii. Density = 7.85×10^{-9} tones/mm³.
 - iii. Poisson's ratio = 0.3.

Step 4: Boundary and loading condition

The intake manifold is bolted to the engine head. Here in the current work the engine head is modelled as a rigid plate which will never deform. This rigid plate is fixed in all 6DOF. And load transfer will takes place from intake manifold to the rigid plate through the bolts.

Loads: pretention loads are applied on the bolts cross section.

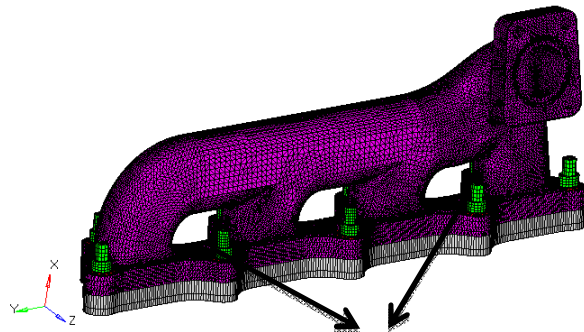
- Apply room temperature on the intake manifold: 30°C .
- Pretension load applied on bolts: 6250N.
- Apply operating temperature on the intake manifold.

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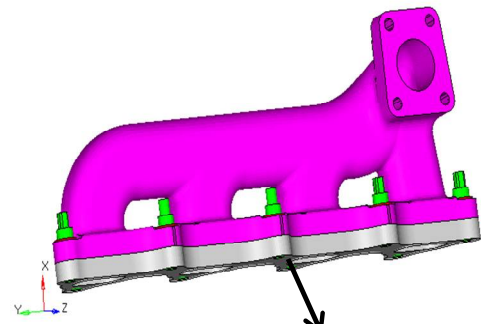
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9 bolts fixed to engine head

Fig 2 Loads applied on bolts



Fixed in all dof

Fig 3 boundary conditions

Step 5: Setting of the abaqus solver deck

Once the cleanup meshing tetra element generation and boundary and loads are defined. The model is ready for submitting the analysis run. Static analysis cards are defined to the FE model and it is exported as Abaqus solver deck file.

Step 6: Submitting the abaqus run

The exported abaqus deck file is imported into an abaqus solver and the following command is executed to submit the run.

Step 7: Post processing

The results obtained from the abaqus solver are post processed for the stresses and displacements. The post processing is discussed in the section "Results & discussion".

IV. RESULTS AND DISCUSSION

For aluminium intake manifold

The virtual simulation of intake manifold is carried out in 3 steps.

Step 1: Intake manifold is subjected to room temperature of 30⁰c.

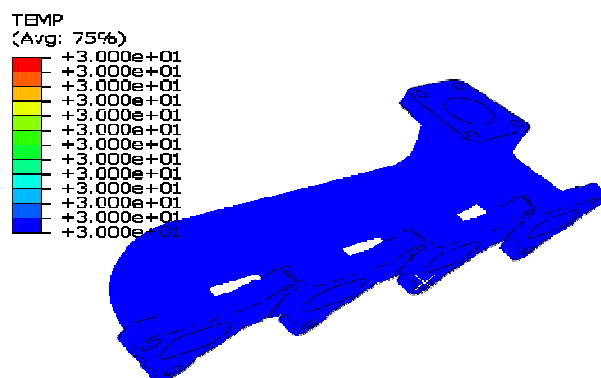


Fig 4.1 Initial temperature distribution.

Step.2 Intake manifold is assembled to the engine head with a bolt. The bolts are subjected to a torque of 10000N/mm. And the stress plots are as discussed below.

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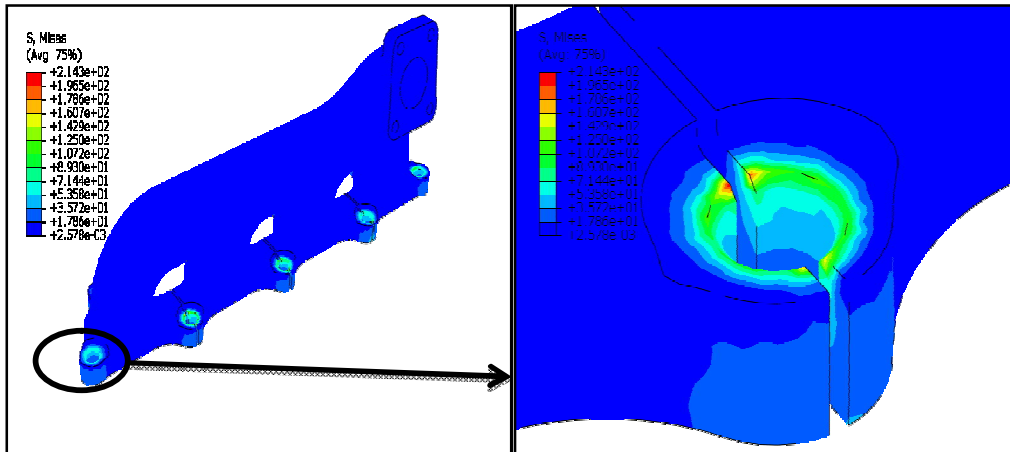


Fig. 4.2 Stress distributions on manifold after pre-tensioning at room temperature

Initially the intake manifold is in ideal condition there is no stress distribution in the manifold. When engine is assembled to engine head with the bolts then there is stress distribution occurs in manifold and bolt due to pre-tension load at room temperature

Step 3: The intake manifold along with the pretension load is applied with an operating temperature of 255⁰ c to 746⁰c and then stress counter plots are displayed as follow.

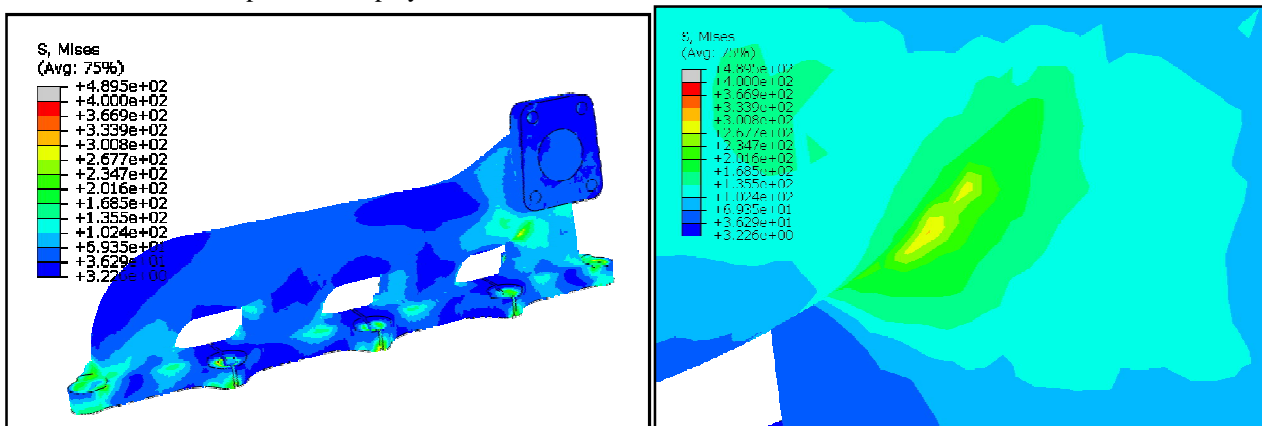


Fig.4.3Stress distributions on manifold during operation.

Above figure represents stress distribution on manifold due to temperature gradient during operating condition. The maximum von mises stress observed is 485Mpa. The observed stress in this region is negligible At this condition the operating temperature is 255⁰c to 740⁰c. Now in this analysis we consider the stress which is of 300Mpa. These stresses should be considered as critical stresses these stresses can be minimized by giving extra fillets at critical stress region and some modifications in the manifold.

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Temperature distribution during operation.

Temperature ranges from 30⁰c to 743⁰c.

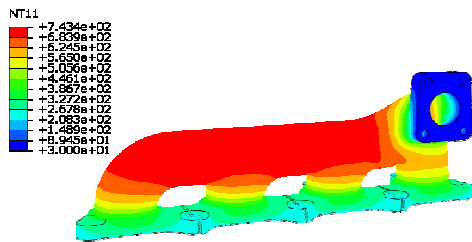


Fig.4.4 Temperature distribution

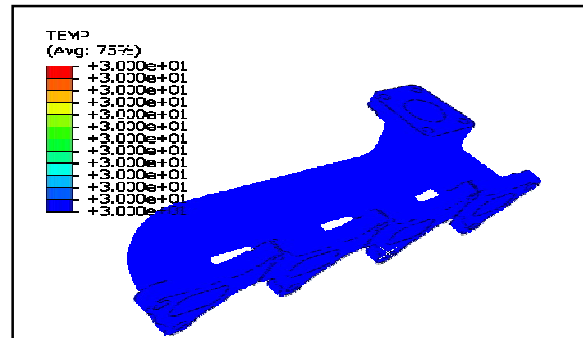


Figure 4.5 Temperatures after stopping

At some interval of time, the intake manifold attains temperature of 30⁰C, as the operation completes.

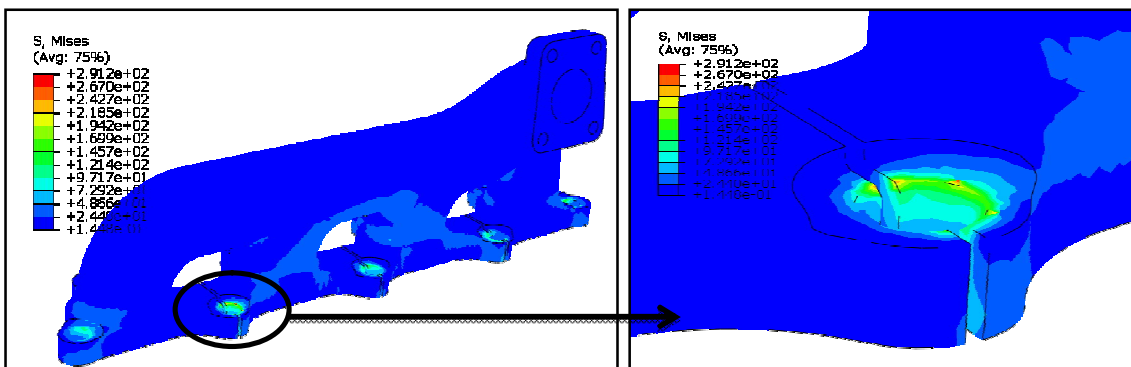


Fig.4.6 Maximum von mises stress observed after one cycle of operation

The maximum von mises stress observed in this figure is 194 Mpa. This stress observed after one cycle of operation room temperature + pretension load+ operating temperature and then stopping the engine.

For cast iron intake manifold.

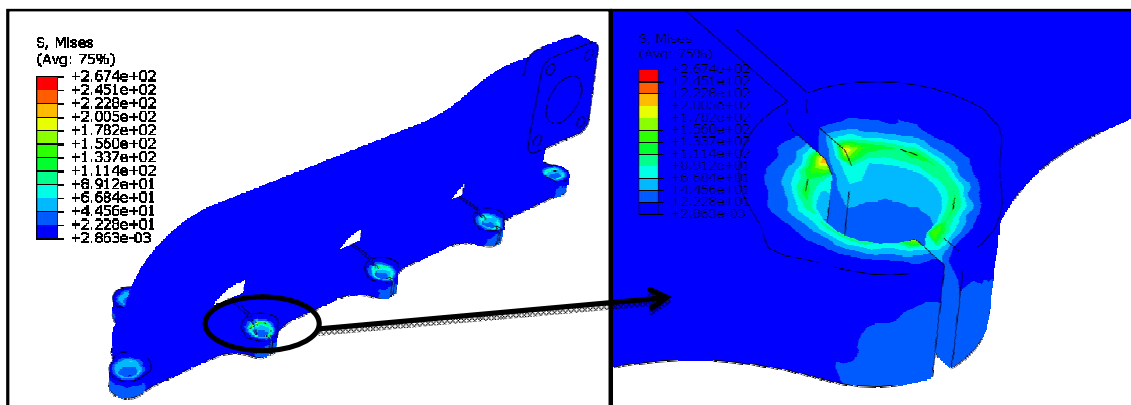


Fig 4.7 Stress observed after bolt pre-tensioning

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When the manifold is assembled to the engine the stresses forms at the bolt section due to pre tension load. The bolts are subjected to a torque at room temperature. The stresses developed at the bolt section 200Mpa are shown in Fig

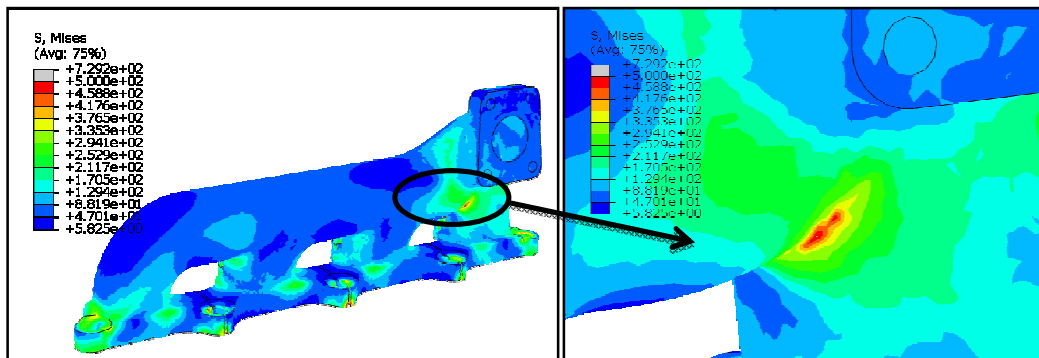


Fig 4.8 stresses observed during operating temperature

The maximum von mises stress observed is 729Mpa the observed stress at this region is negligible. The operating temperature is 255⁰c to 740⁰c. Now in this analysis we consider the stress which is of 458Mpa. This stress should be considered as critical stresses these stresses can be minimized by giving extra fillets at critical stress region and some modifications in the manifold.

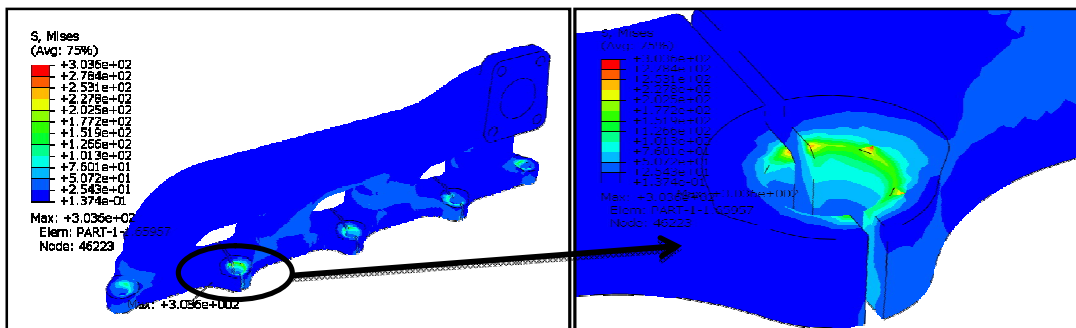


Fig 4.9 Stresses observed after one cycle of operation

The maximum von mises stress obtained is 253Mpa. Which is taken after room temperature + pre-tension load + operating temperature and then stopping the engine.

Table 1 mass reduction and stress comparison table

Sl.No	Mass(kg)	Material	Pretension Load	Operating temperature	YS(MPA)	Max Stress	FOS	% mass reduction
	M		N	°C		Von-Mises		
LC1	3.68	Cast Iron	6250	255°C - 743°C	669	458	1.46	0%
LC2	1.27	Aluminium	6250	255°C - 743°C	669	300	2.23	66%

Since the density of the aluminium is 66% less than the cast iron. The weight of the product for a given volume will be reduced by 66% of the cast iron product

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V. CONCLUSION

- The maximum stress observed in the intake manifold for the worst condition is 458Mpa considering cast iron as a material. And maximum stress considering aluminium as material is 300mpa. So from the results the intake manifold with aluminium as material is best with respect to strength to weight ratio.
- The structure is safe in both the cases (cast iron and aluminium) but aluminium is preferred for the manufacturing considering the strength to weight ratio. But the cost of the aluminium is higher than the cast iron so from the cost point of view cast iron intake manifold can be considered as other option to manufacture the product.

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