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FINITE ELEMENT ANALYSIS OF AUTOMOTIVE INTAKE MANIFOLD USING CAE SOFTWARE

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ABSTRACT: In automotive engineering, an intake manifold or inlet manifold is the part of an engine that supplies the fuel/air mixture to the cylinders.

This project focused on simulation testing of automotive intake manifold design using computer aided engineering software. Finite element random vibration analysis is conducted on excavator intake manifolds designs for material cast iron and aluminium alloy. The purpose of this project is to study the computational maximum stress on the model due to the effect of engine vibrations and pressure pulsation loads. The softwares used are PRO-E 4.0, HYPERMESH-10 and ANSYS-11. Based on the simulation results obtained, the maximum stress of both materials is compared to distinguish which is better in resisting the vibration loads applied.

Keywords: Automotive Intake Manifold, Modal analysis, Intake Manifold Analysis

1. INTRODUCTION

The primary function of the intake manifold is to evenly distribute the combustion mixture (or just air in a direct injection engine) to each intake port in the cylinder head(s). Even distribution is important to optimize the efficiency and performance of the engine. It may also serve as a mount for the carburetor, throttle body, fuel injectors and other components of the engine [1-4].

Due to the downward movement of the pistons and the restriction caused by the throttle valve, in a reciprocating spark ignition piston engine, a partial vacuum (lower than atmospheric pressure) exists in the intake manifold[5-6]. This manifold vacuum can be substantial, and can be used as a source of automobile ancillary power to drive auxiliary systems: power assisted brakes, emission control devices, cruise control, ignition advance, windshield wipers, power windows, ventilation system valves, etc[7-8].

2. DESCRIPTION

In this work static and modal analysis of the intake manifold made of cast iron and aluminium was carried out and is compared.

Length of the intake manifold = 357 mm

Maximum load capacity = 30Mpa

Material Properties:

(i)Cast Iron: Young's modulus = 1.8×10^5 MPa
Poisson's Ratio = 0.40
Density = 7.4×10^{-6} Kg/mm^3

(ii)Aluminium: Young's modulus = 0.7×10^5MPa
Poisson's Ratio = 0.34
Density = 2.7×10^{-6} Kg/mm^3

3. MODELLING AND MESHING

The chosen problem is considered as 3-D solid model. With the dimensional parameters the structure is modeled in Pro-E wildfire3.0 modeling software as shown in Fig.1. The model is meshed for further analysis using a meshing package Hypermesh10 with tetra mesh.

The model consists of 22289 elements and 41238 number of nodes.Fig.3 shows the solid 92 element considered for meshing. FE model of the intake manifold is shown in Fig 2. Appropriate boundary conditions are incorporated in the analysis. The solid 92 is defined by ten nodes having three degrees of freedom (UX, UY and UZ) at each node translations in the nodal X, Y and Z directions. The element has plasticity, creep, swelling, elasticity, stress stiffening, large deflection, large strain, adaptive descent, and initial stress import capabilities.

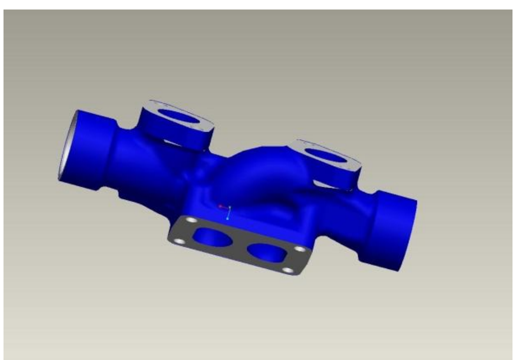


Fig.1: Geometric model of Intake Manifold by using Pro-E 3.0

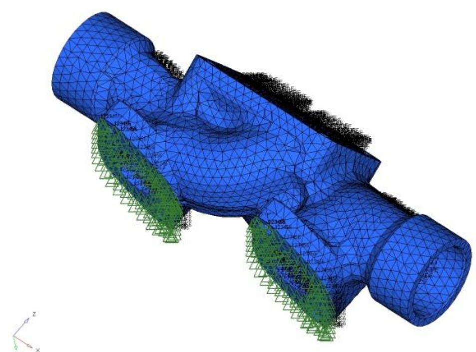


Fig.2: The Finite Element Model by using Hyper mesh10.

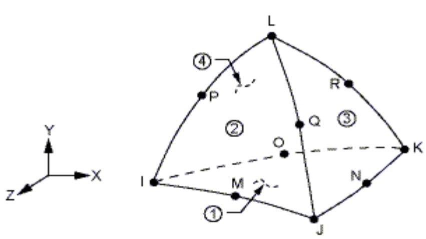


Fig.3: Solid 92 Element

Table 1: QUALITY PARAMETERS

Aspect Ratio	6
Tet collapse	0.7
Length	10
Min angle of trias	20
Max angle of trias	135

4. INTAKE MANIFOLD

4.1 Static Analysis

(i) Cast Iron

Static Analysis of intake manifold made up with cast iron is performed. Displacements in X, Y and Z-directions are shown in Fig.4, Fig.5 and Fig.6 respectively.Fig.7 shows stress in X direction. Stress in Y direction is shown in Fig 8. Fig.9 shows stress in Z direction. The Vonmises stress of the intake manifold shown in Fig.10.

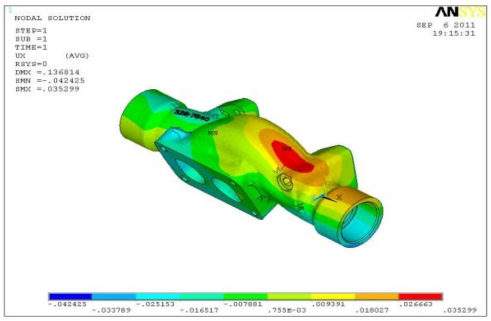


Fig.4: Displacement in X- direction

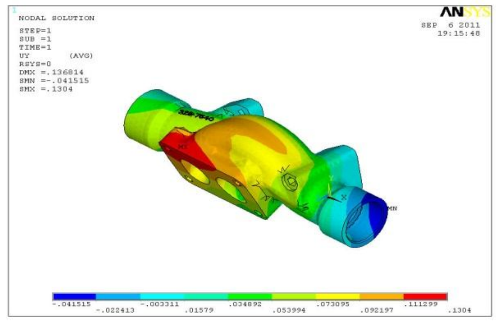


Fig.5: Displacement in Y- direction

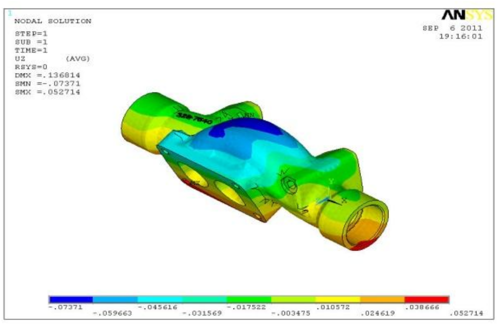


Fig.6: Displacement in Z- direction

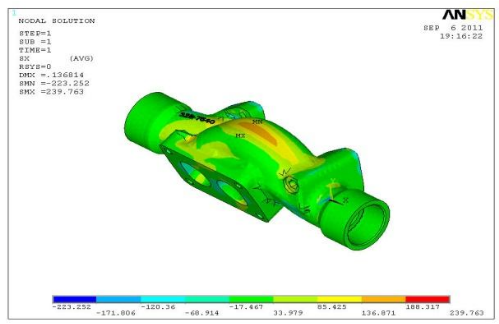


Fig.7: Stress in X direction

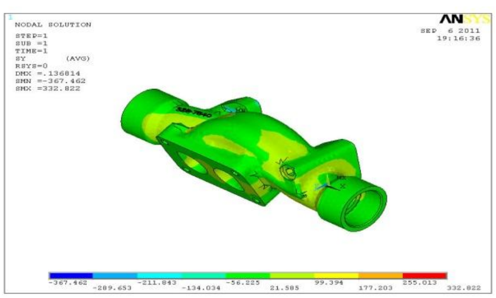


Fig. 8: Stress in Y direction

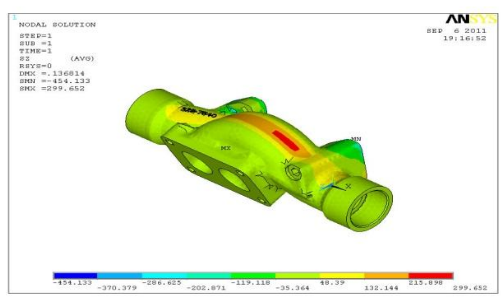


Fig.9: Stress in Z direction

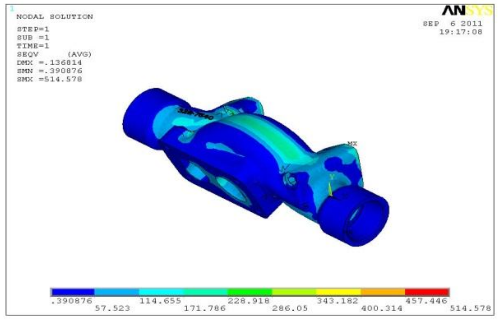


Fig.10: Vonmises Stress

(ii) Aluminium

Static Analysis of intake manifold made up with aluminium is performed. Displacements in X, Y and Z-directions are shown in Fig.11, Fig.12 and Fig.13 respectively.Fig.14 shows stress in X-direction. Stress in Y-direction is shown in Fig 15. Fig.16 shows stress in Z-direction. The vonmises stress of the intake manifold shown in Fig.17.

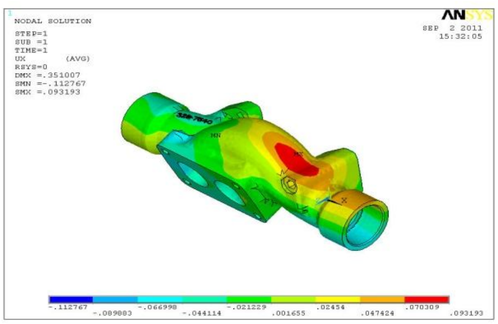


Fig.11: Displacement in X- direction

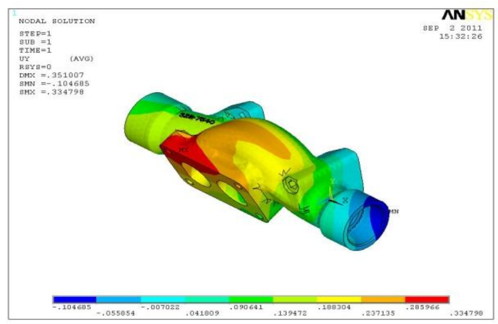


Fig.12: Displacement in Y- direction

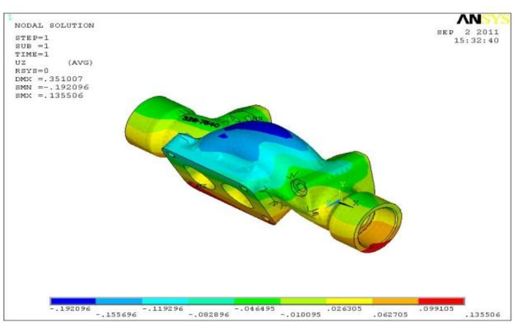


Fig.13: Displacement in Z- direction

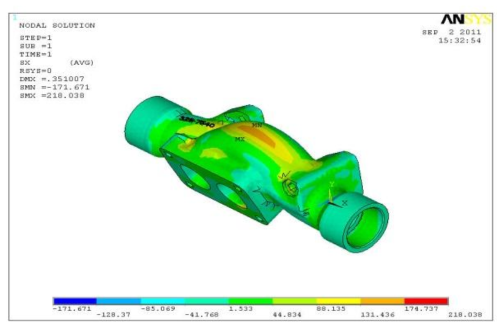
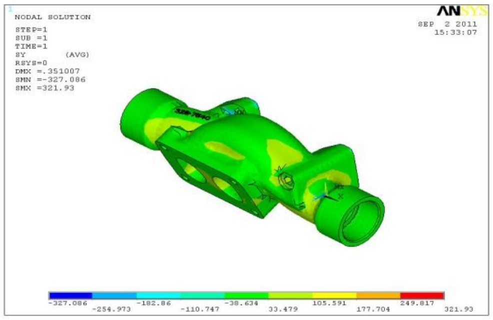


Fig.14: Stress in X direction



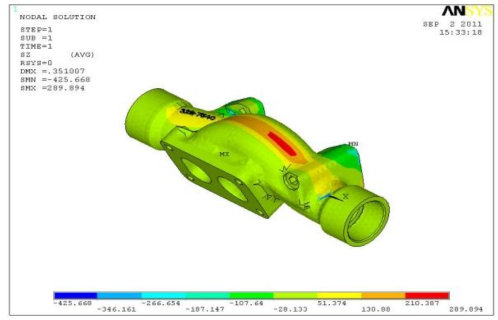


Fig.15: Stress in Y direction

Fig.16: Stress in Z direction

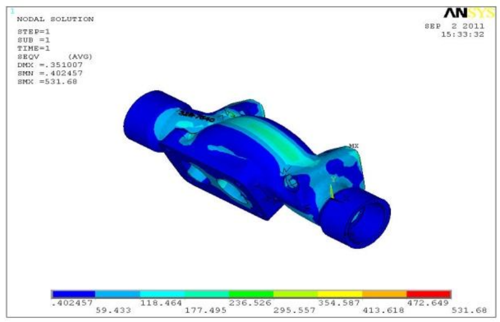
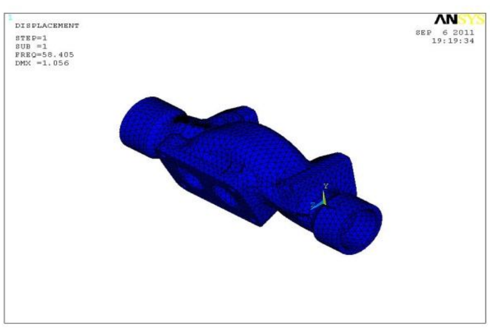


Fig.17: Vonmises Stress

4.2. Modal Analysis

i) Cast Iron

Natural frequencies and mode shapes of intake manifold made up of cast iron is performed. Fig.18 shows mode shape 1 of the intake manifold. Mode shape 2 of intake manifold is shown in Fig.19.Mode shape 3, 4, 5 & 6 of intake manifold made up with cast iron is shown in figures 20,21,22,23 respectively.



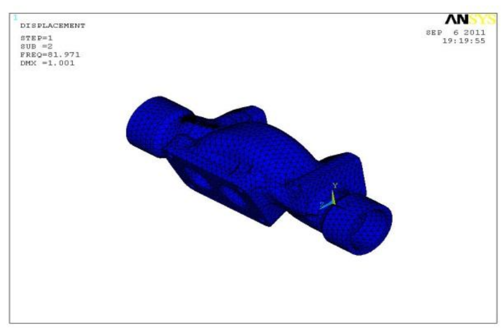


Fig.18: Mode shape 1

Fig.19: Mode shape 2

Fig. 20: Mode shape 3

Fig.21: Mode shape 4

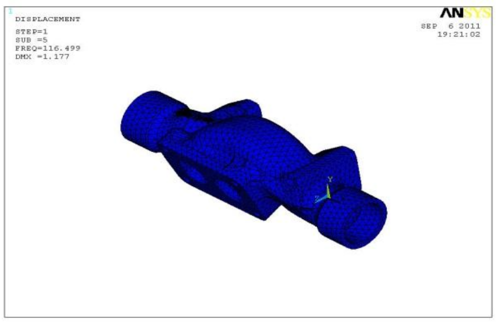


Fig. 22: Mode shape 5

Fig. 23: Mode shape 6

(ii) Aluminium

Natural frequencies and mode shapes of intake manifold made up of aluminium is performed. Fig.24 shows mode shape 1 of the intake manifold. Mode shape 2 of intake manifold is shown in Fig.25.Mode shape 3, 4, 5 & 6 of intake manifold made up with cast iron is shown in figures 26,27,28,29 respectively.

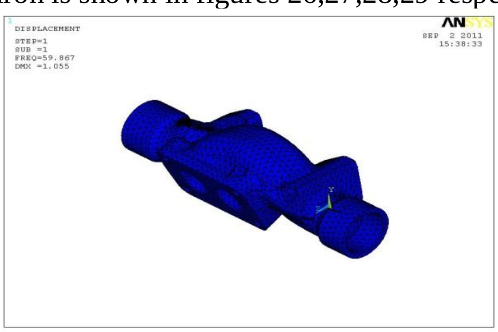


Fig.24: Mode shape 1

Fig.25: Mode shape 2

Fig.26: Mode shape 3

Fig.27: Mode shape 4

Fig.28: Mode shape 5

Fig. 29: Mode shape 6

5. RESULTS & DISCUSSION

Table 2 shows displacement and stresses of the intake manifold made up with cast iron by static analysis, which shows displacement in X-direction-direction and Z-direction are 0.424 mm, 0.130 mm, and 0.73 mm respectively. Stresses in X, Yand Z-directions are found as 239.736MPa, 367.462MPa, 454.133MPa respectively. The vonmises stress found as 541.578 MPa. Table 3 shows displacement and stresses of the intake manifold made up with aluminium by static analysis, which shows displacement in X-direction, Y-direction and Z-direction are 0.1227 mm, 0.3347 mm, 0.1920 mm respectively. Stresses in X, Yand Z-directions are 218.038MPa, 327.086MPa, 425.668MPa respectively. Vonmises stress is found as 531.68MPa. Table 4 shows the natural frequencies of the intake manifold made up with cast iron by modal analysis, Table 5 shows the natural frequencies of the intake manifold made up with aluminium by modal analysis.

Table 2
Static Analysis of Cast Iron

Name: Static Analysis	Cast Iron
Displacement in X- direction ,mm	0.424
Displacement in Y-direction ,mm	0.130
Displacement in Z-direction ,mm	0.073
Stress in X-direction, MPa	239.736
Stress in Y-direction , MPa	367.462
Stress in Z-direction , MPa	454.133
Vonmises Stress , MPa	541.578

Table 3
Static Analysis of Aluminium

Name: Static Analysis	Aluminium
Displacement in X- direction ,mm	0.1227
Displacement in Y-direction ,mm	0.3347
Displacement in Z-direction ,mm	0.1920
Stress in X-direction, MPa	218.038
Stress in Y-direction , MPa	327.086
Stress in Z-direction , MPa	425.668
Vonmises Stress , MPa	531.68

Table 4
Modal Analysis of Cast Iron

Name: Modal analysis	Frequency (Hz)
Mode shape 1	58.405
Mode shape 2	81.971
Mode shape 3	88.68
Mode shape 4	101.236
Mode shape 5	116.499
Mode shape 6	137.289

Table 5
Modal Analysis of Aluminium

Name :modal analysis	Frequency (Hz)
Mode shape 1	59.867
Mode shape 2	84.428
Mode shape 3	91.57
Mode shape 4	104.748
Mode shape 5	119.512
Mode shape 6	140.966

6. CONCLUSION

The following conclusions are drawn from the present work.
1. The maximum deflection induced is 0.424mm in case of cast iron, which is higher than 0.3347mm obtained for aluminium.
2. The maximum stress induced is 541.578 MPa in case of cast iron, which is higher than the maximum stress induced as 531.68 MPa obtained for aluminium.
3. The natural frequencies obtained for cast iron is lesser than the aluminium.
4. Hence comparing all these conditions it may be considered that design of aluminium is better for manufacturing of intake manifold.

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