ISSN 2249-5460

INTERNATIONAL JOURNAL OF MATHEMATICAL SCIENCES, TECHNOLOGY AND HUMANITIES

www.internationalejournals.com

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International eJournals

International Journal of Mathematical Sciences, Technology and Humanities 61 (2012) 661 – 668

Strength Analysis of Exhaust Manifold of Mpv Two Cylinder Engine

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ABSTRACT

Exhaust manifolds are generally simple cast iron, stainless steel and cast iron (GJV SiMo) units which collect engine exhaust from multiple cylinders and deliver it to the exhaust pipe.

In this project the strength analysis and thermal deformation of cast iron (GJV SiMo) exhaust manifold for two cylinder engine is investigated by finite element analysis (FEA). The software's used are PRO-E 4.0, HYPERMESH-10 and ANSYS-11 the FE model includes the temperature dependent material properties as well as the interactions between exhaust manifold, cylinder head and fasteners. The result of analysis revealed that remarkable thermal deformation and stresses occurred along the longitudinal direction. To analyse the exhaust manifold for the pressure loads and the thermal loads. The stresses in pressure loads, thermal loads and combined loads simulations are below yield strength at elevated temperature.

Keywords: Exhaust Manifold, Modal and Thermal analysis, Finite Element Analysis.

1. INTRODUCTION

Exhaust manifolds are generally simple cast iron or stainless steel units which collect engine exhaust from multiple cylinders and deliver it to the exhaust pipe. For many engines, after market high performance exhaust headers — also known as extractors — are available [1-4]. These consist of individual exhaust head pipes for each cylinder, which then usually converge into one tube called a collector. Headers that do not have collectors are called zoomie headers, and are used exclusively on race cars [5-6].

The most common types of aftermarket headers are made of either ceramic, or stainless steel. Ceramic headers are lighter in weight than stainless steel; however, under extreme temperatures they can crack.

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 [6-8].

2. DESCRIPTION

In this work static and thermal analysis of the exhaust manifold is carried out. In the static analysis, the parameters such as the exhaust gas pressure. In the thermal analysis uniform temperature load is applied.

In this design, we need to design the exhaust manifold in such way that it should withstand for pressure as well as temperature load conditions. Both thickness and the material are studied for this design. The present exhaust manifold that is being used in the two cylinder engines is having lower efficiency so the modified designed exhaust manifold is somewhat more efficient.

Material properties of Cast iron with vermicular graphite GJV SiMo

Young's modulus = 2×10^5 MPa
Poisson's Ratio = 0.29
Density = 7.8×10^{-6} Kg/mm^3
Thermal expansion Coefficient = 9.90×10^{-6}

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 hyper mesh 10 with tetra mesh.

The model consists of 20413 elements. Fig. 2 shows the solid 92 element considered for meshing. FE model of the exhaust manifold is shown in Fig 3. 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, Initial stress import capabilities.

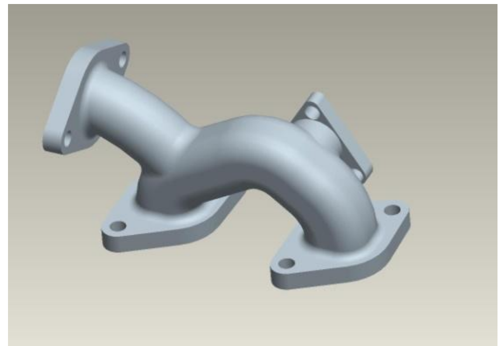

Fig 1: Solid model of Exhaust Manifold

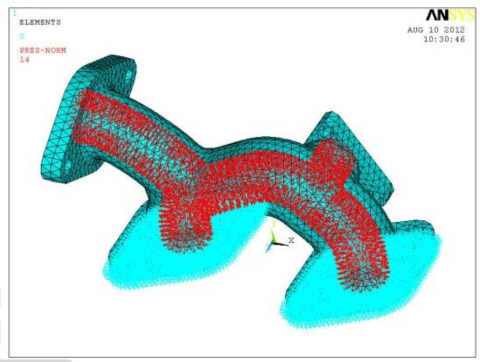

Fig 2: Finite Element model with boundary conditions of Exhaust Manifold

Table 1: Mesh is created in Hyper mesh with following quality parameters

Aspect Ratio	11
Tet collapse	0.11
Length	5
Min. angle of trias	20
Max. angle of trias	125

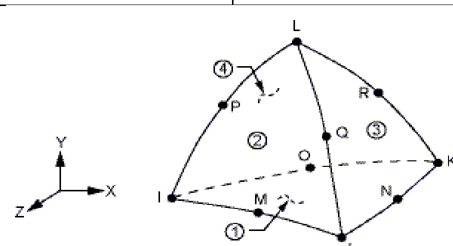

Fig 3: Solid 92 Element

Name	Results as per Analysis	Allowable stresses and deflection	Reference figure
Displacement in X-direction, mm	0.0833	2.0	4
Displacement in Y-direction, mm	0.0824	2.0	5
Displacement in Z-direction, mm	0.0273	2.0	6
Stress in X-direction, MPa	152.584	528	7
Stress in Y-direction, MPa	130.685	528	8
Stress in Z-direction, MPa	219.028	528	9
Vonmises stress, MPa	217.415	528	10

4. EXHAUST MANIFOLD

Table 2: Static Analysis of Exhaust Manifold

Static Analysis: Static analysis was carried out to know the strength of the exhaust manifold by applying the internal pressure.

Thermal Analysis: Thermal analysis was carried out to know the thermal stresses of the exhaust manifold by applying uniform temperature.

Combined load Analysis: Combination of internal pressure and uniform temperature is applied to find stresses.

5. RESULTS & DISCUSSION

5.1 Static Analysis:

Static Analysis of exhaust manifold made up with Cast iron with vermicular graphite GJV SiMo 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 exhaust manifold shown in Fig.10

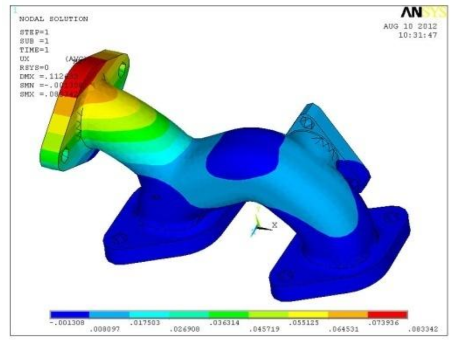

Fig. 4: Displacement in X- direction

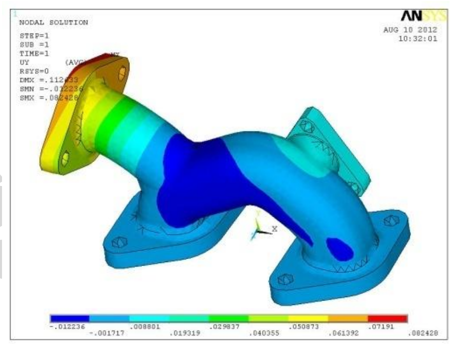

Fig. 5: Displacement in Y- direction

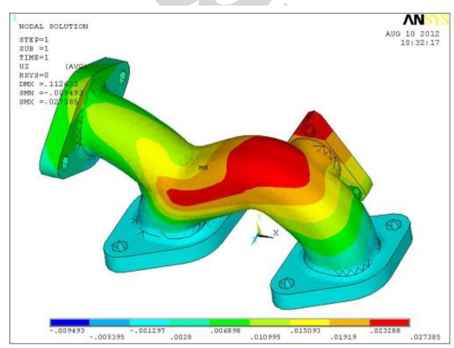

Fig. 6: Displacement in Z- direction

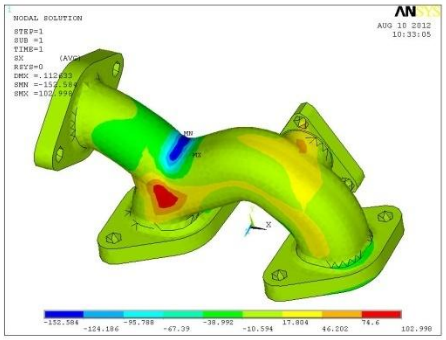

Fig. 7: Stress in X direction

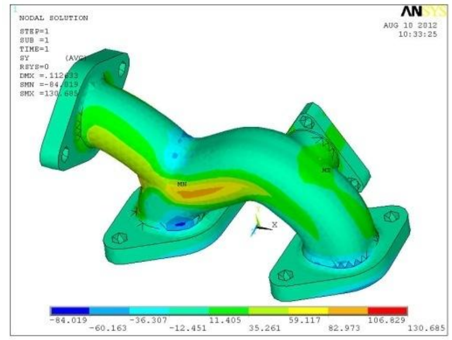

Fig. 8: Stress in Y direction

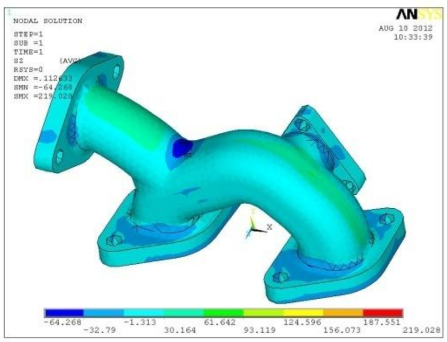

Fig.9: Stress in Z direction

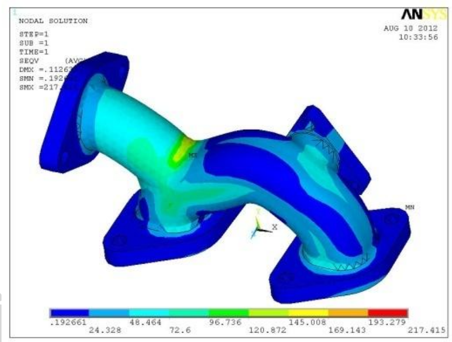

Fig.10: Vonmises Stress

5.2 Thermal analysis:

Thermal analysis of exhaust manifold made up with Cast iron with vermicular graphite GJV SiMo 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 exhaust manifold shown in Fig. 17

Table 3: Thermal Analysis of Cast iron with vermicular graphite GJV SiMo

Name	Results as per Analysis	Allowable stresses and deflection	Reference figure
Displacement in X-direction, mm	0.1053	2.0	11
Displacement in Y-direction, mm	0.1013	2.0	12
Displacement in Z-direction, mm	0.0417	2.0	13
Stress in X-direction, MPa	412.452	528	14
Stress in Y-direction, MPa	463.588	528	15
Stress in Z-direction, MPa	412.452	528	16
Vonmises stress, MPa	463.253	528	17

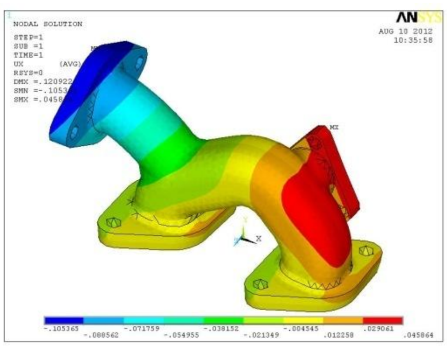

Fig. 11: Displacement in X- direction

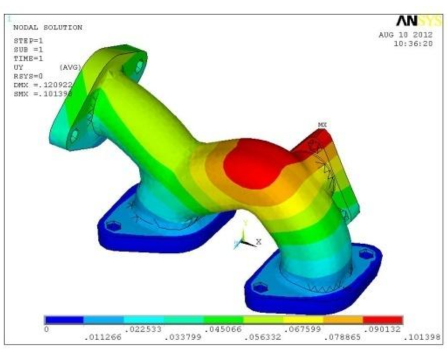

Fig. 12: Displacement in Y- direction

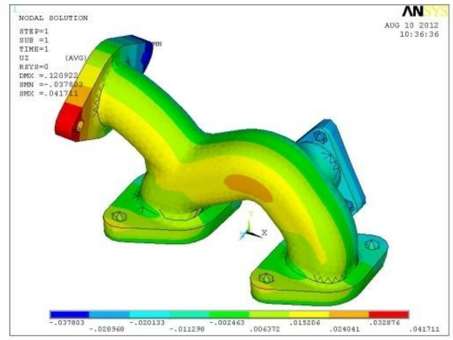

Fig. 13: Displacement in Z- direction

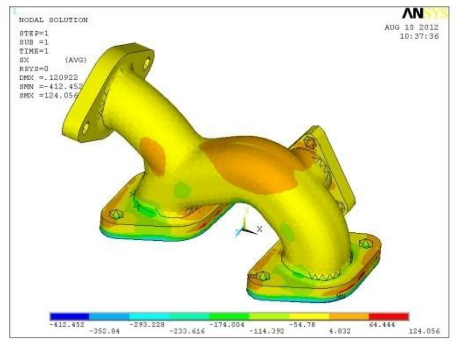

Fig. 14: Stress in X direction

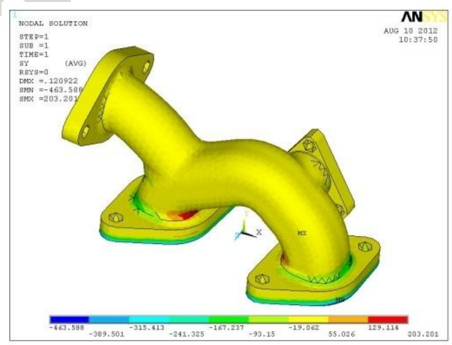

Fig. 15: Stress in Y direction

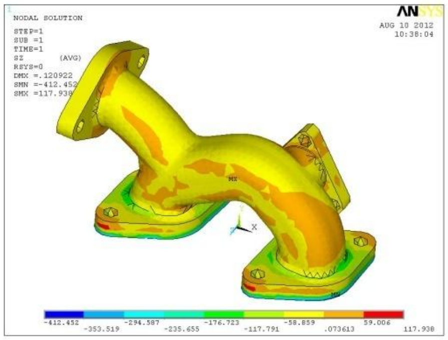

Fig.16: Stress in Z direction

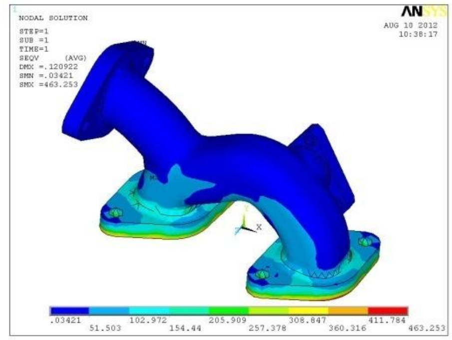

Fig.17: Vonmises Stress

5.3 Combined load Analysis

Combination of internal pressure and uniform temperature is applied to find stresses. Displacements in X, Y and Z directions are shown in Fig.18, Fig.19 and Fig.20 respectively.Fig.20 shows stress in X direction. Stress in Y direction is shown in Fig. 22. Fig. 23 shows stress in Z direction. The Vonmises stress of the exhaust manifold shown in Fig. 24

Table 4: Thermal Analysis of Exhaust Manifold

Name	Results as per Analysis	Allowable stresses and deflection	Reference figure
Displacement in X-direction, mm	0.066	2.0	18
Displacement in Y-direction, mm	0.134	2.0	19
Displacement in Z-direction, mm	0.049	2.0	20
Stress in X-direction, MPa	432.73	528	21
Stress in Y-direction, MPa	513.236	528	22
Stress in Z-direction, MPa	432.73	528	23
Vonmises stress, MPa	480.786	528	24

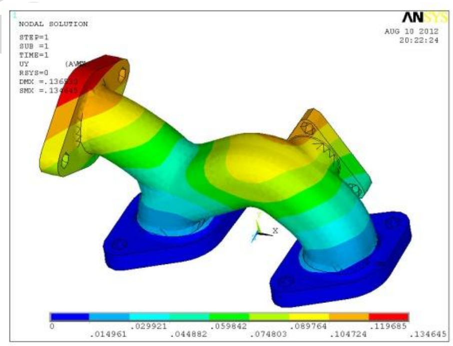

Fig. 19: Displacement in Y- direction

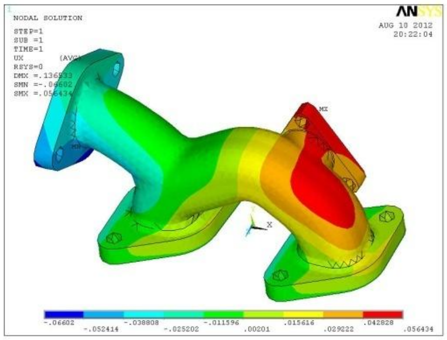

Fig. 18: Displacement in X- direction

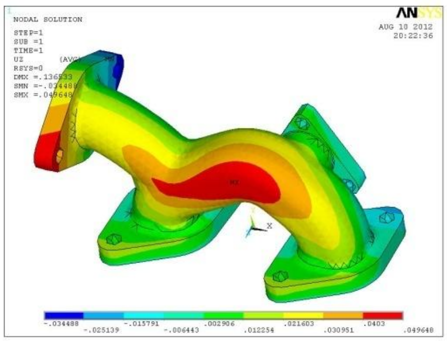

Fig. 20: Displacement in Z- direction

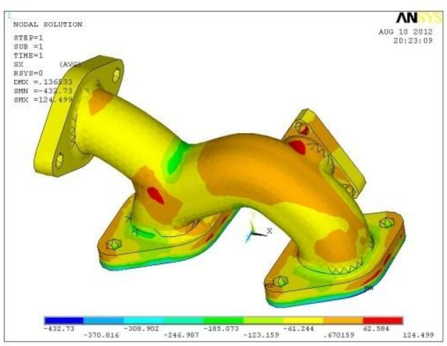

Fig. 21: Stress in X direction

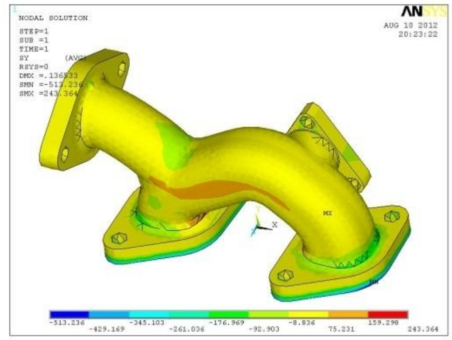

Fig. 22: Stress in Y direction

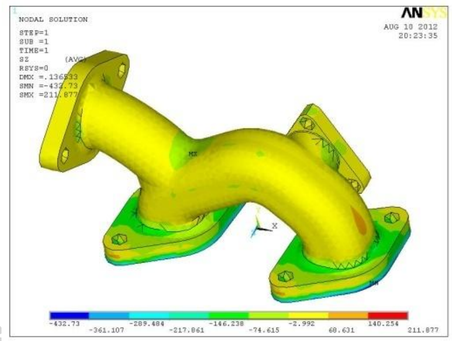

Fig. 24: Stress in Z direction

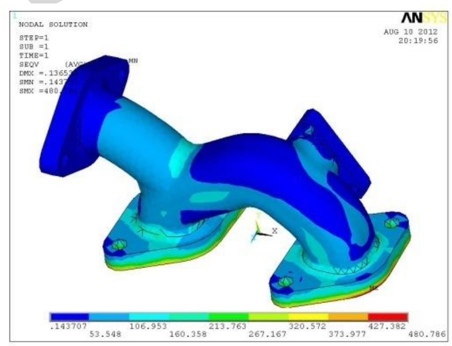

Fig. 23: Vonmises stress

6. CONCLUSION:

The following conclusions are drawn from the present work.

1. The maximum deflection induced 0.0833 mm under 14 MPa loads which is within the allowable limits i.e. < 2mm.

2. The maximum stress induced is 219.028 MPa which is less than allowable limits of 528 MPa. Hence the factor of safety is 2.41.

3. The maximum deflection induced 0.1053 mm under uniform temperature of 80^0C load which is within the allowable limits i.e. < 2mm.

4. The maximum stress induced is 463.588 MPa which is less than allowable limits of 528 MPa. Hence the factor of safety is 1.138.

5. The maximum deflection induced 1.658 mm under combined loading of 14 MPa and uniform temperature of 80^0C load which is within the allowable limits i.e. < 2mm.

6. The maximum stress induced is 513.236 MPa which is less than allowable limits of 528 MPa. Hence the factor of safety is 1.028.

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