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Static Analysis of V-12 Engine Cylinder Block Using FEM

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ABSTRACT

The Cylinder Block forms the basic framework of the engine. It houses the engine cylinders, which serve as bearings and guides for the pistons reciprocating in them. The analysis of the engine block is to be carried-out to predict its behavior under static loading. The cylinder block has to with stand the stresses and deformations due to loads acting on it. An attempt is made in this paper to perform static analysis on V-12 Engine cylinder block to obtain the variation of the stresses and the deformations at different pressures of 8 MPa, 10 MPa, 12 MPa and 15 MPa on the Engine Cylinder Block. Three dimensional model of the Engine Cylinder Block was created using CATIA V5 R22 software and the mesh is generated using TET Elements. The Analysis of the Engine Cylinder Block is carried-out using Compacted Graphite cast Iron (CGI GJV 450) and NASA 398 (hypereutectic Al-Si alloy) materials using ABAQUS 6.14 software. The mechanical boundary conditions were applied to the Engine Cylinder Block and different pressures are applied and static analysis are analyzed. The results are observed for selecting the best suitable material for the Engine Cylinder Block From the analysis results, it gives a clear idea that the stress distributions in both the cases are nearly same. So in deformation point of view, CGI GJV 450 has less deformation and hence CGI GJV 450 is considered as the best material for Engine Cylinder

Keywords : Engine Cylinder Block, CGI GJV 450, NASA 398, CATIA V5, ABAQUS/CAE, Static Analysis.

I. INTRODUCTION

The cylinder block is the main integrated structure of the IC Engine and is also called as Engine Block. All the engine parts are mounted on it. It provides housing for cylinders, pistons, and it also gives passages for the coolant, lubricating oils, exhaust, and intake gases to pass over the Engine. It constitutes about 3 to 5% of the total weight of the average vehicle. It is usually a casting and well ribbed to support and distribute loads applied by the expansion of the combustion gases. It is also provided with water jackets to cool the engine. Both the spark ignition cylinder block and compression ignition cylinder blocks are similar relatively heavier and stronger to withstand high compression ratios and internal pressure.

The cylinder block is bored for cylinders for the pistons to reciprocate. One end of the cylinder block is closed with cylinder head where as other end opens towards the crankcase. The cylinders are provided with liners which may be easily replaced whenever required. It is provided with water jackets for cooling the engine and drilled oil holes to supply lubricating oil to all other components of the engine block.

FUNCTIONS OF CYLINDER BLOCK

- Maintaining engine's stability, while withstanding a variety of temperatures and loads.
- Transferring oil to all parts of the engine and lubricating all the critical components.
- Providing cooling to the engine to maintain a constant optimal operating temperature.

II. MATERIALS FOR CYLINDER BLOCK

Cast iron and aluminum alloys are the most widely used materials to manufacture the cylinder block. Cast iron alloys are used because they contain good casted engine block gives a good surface finish and high machinability compared with cast iron alloys.
As the Technology increases the engineers has found new materials such as Compacted Graphite cast Iron (CGI GJV 450)and NASA 398.

Compacted Graphite cast Iron has a higher tensile strength and modulus of elasticity compared with Grey cast iron. It is due to the compact graphite found on the microstructure of CGI. Similar to Grey cast iron it has a good damping Transferring absorption and thermal conduction, but its low machinability has limited its wide usage. The typical CGI GJV 450 contains 3.6% to 3.8% C, 2.1% to 2.5% Si, 0.7% to 1% Cu and small amounts of sulphur and manganese.

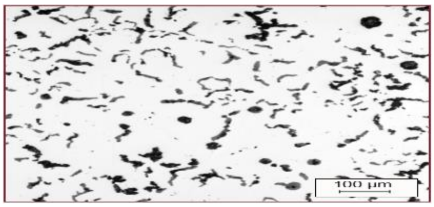


Fig.1.2: CGI GJV450 Microstructure

NASA 398, an ideal low cost Aluminium - Silicon alloy with 6% to 18% silicon content especially used for high temperature cast components like cylinder blocks, cylinder heads and pistons. The alloy possesses high hardness and wear resistant properties along with low thermal expansion and has excellent dimensional stability.

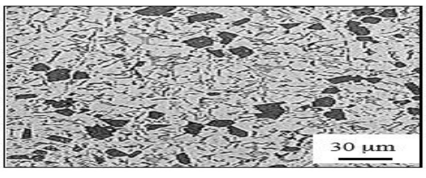


Fig.1.3: NASA 398 Microstructure

mechanical properties, low cost, and availability compared with other metals. But certain aluminum alloys contain most of the characteristics of cast iron but with low weight, and also aluminum alloy

III. DESIGN CONSIDERATIONS FOR THE CYLINDER BLOCK

In designing the cylinder block, the following points should be taken into consideration.

- High strength at elevated temperatures
- Ability to withstand the high pressure of combustion gases
- High wear and abrasion resistance
- High Thermal conductivity and better heat dissipation
- Good dampness
- Light in weight

IV. LITERATURE REVIEW

This Literature Review is to provide of past research by referring the such as journals or articles related to modeling, meshing, static and dynamic Analysis of the Engine Block by using the FEM/ABAQUS software's in order to understand the present research.Suresh R et al [6] has carried-out thermo-mechanical analysis of Engine Block of IC engine to find the temperature and stress distribution in transient analysis of hypereutectic Al-Si alloy (NASA 398) materials under different operating conditions of pressure and temperature. The paper consists of modeling of a three dimensional in line Engine Block with four cylinders using CATIA V5 R16, meshing was done using in HYPERMESH 10.0 analysis done by ABAQUS 6.10 . It is observed that the yield strength of the cylinder block material more than the maximum stress produced in the engine block. Vikram V Harsure et al [7] has done the model analysis on a motor cycle engine block under static and dynamic loading. The solid model of the block is generated using CATIA V5 R19,then meshing done by HYPERMESH 10 through IGES format. After quality meshing, for converged solution, ANSYS is used in which loads and boundary conditions are applied for analysis. The model analysis is performed using Lancoz's algorithm to predict first five natural frequencies and their corresponding mode shapes of five different materials, aluminium, grey cast iron, steel, titanium and brass. Finally, they concluded that aluminium block has less induced stress, which is 410.3526 MPa and the frequencies as 58Hz, 65Hz, 67Hz, 74Hz and 85Hz, and have chosen it as best material for that engine block. Nitin Kumar Srivastav et al [5] they were generated a 3-D model of piston using CATIA and imported it to ABAQUS after getting a quality mesh by using the finite element analysis. The analysis predicted that stress generated on the top surface of the piston, it was damaged and hence they decided to modify the design features for extended service. Y.Sathaiah et al [9] has carried -out their work on the dynamic analysis of Engine Block for selection of suitable material for cost and weight reduction. Using CREO, parametric pro-E, they designed a combustion chamber taking cast iron as the Engine Block material first and performed static, fatigue, thermal and dynamic analysis and evaluated the results. Then, they changed the cylinder block material with aluminium and ZAMAK material and performed the analysis with parameters of cost, weight of the cylinder block. Finally, they have concluded that ZAMAK material would considerably increase the life of the Engine Block and reduces cost by 9000/- up to 190 kgs.

OBJECTIVE OF THE PAPER: *An attempt made in this paper to find the* static load analysis of the Engine Cylinder Block made of different materials of compacted graphite cast iron, NASA 398 under different pressures. The model is created by using CATIAV5 and analysis is done by using ABAQUS software to find which material suited the best for Engine cylinder block.

V. DATA COLLECTION

TABLE 3.1: Geometricalentitiesof the cylinder block

S.NO	DESCRIPTION	VALUE	UNITS
1.	V-angle of the block	88	degree
2.	Capacity (displacement)	7263	cc
3.	Bore	85	mm
4.	Stroke length	160	mm
5.	Number of cylinders	12	-
6.	Compression ratio	16:1	-
7.	Maximum output	180	KW
8.	Engine speed	4000	rpm
9.	Maximum Torque	550	N-m
10.	Dry weight	185	Kg

TABLE 3.2: Material Properties

Material / Property	CGI GJV 450	NASA 398
Density (ton/mm^3)	7.10E-09	2.76E-09
Elastic Modulus (MPa)	160000	88600
Poisson's Ratio	0.27	0.35
Yield Strength (MPa)	470	235

Modelling and Meshing: The modeling was done by CATIA V5 software for the development of the V-12 Engine Block and then it is imported to HYPERMESH where meshing of the object was done. Finally it is exported to ABAQUS FEA software, where loads are applied to find the static behavior of the engine block.

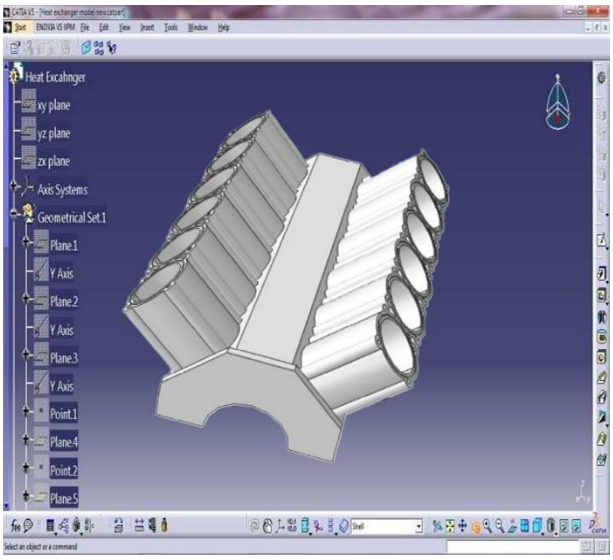


Fig.4.1: 3-D Model of the V-12 engine cylinder block

The finite element mesh is generated for the cylinder block by using tetragonal (TET) elements using the free meshing technique of the ABAQUS software. The meshed component contains 1,69,717 elements and 2,53,789 nodes and is tested for the quality of mesh.

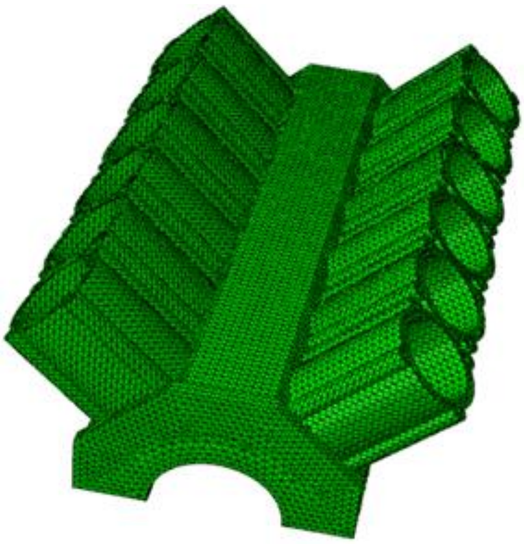


Fig.4.2: 3-D Meshed model of the cylinder block

VI. ANALYSIS USING FINITE ELEMENT METHOD

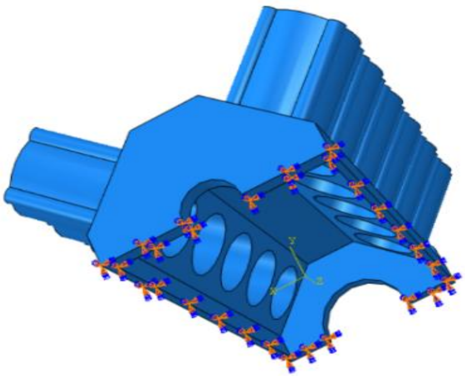
Finite Element Method is one of the most popular mechanical engineering applications offered by the CAD/CAM systems by involving computerized technique and breaking the geometry into finite elements, framing a series of equations to each solving the equations simultaneously. To evaluate the behaviour of entire system and used when geometry, loading and material properties are complicated and exact analytical solution is difficult to obtain.

The procedure for analysis consists of four basic steps. They are as follows.

1) Modelling and meshing
2) Applying boundary conditions and loads
3) Obtaining solutions/results
4) Reviewing the results.

1) Applying boundary conditions and loads

Figures 4.3 & 4.4 shows the boundary conditions and loading considered for the analysis. Uniform



pressures of 8 MPa, 10 MPa, 12 MPa and 15 MPa are applied on the cylinder block.

Fig.4.3: Boundary conditions applied on the 3-D cylinder block

Applying pressures

Different pressures are applied on the cylinder walls to study the static as well and the dynamic behaviour of the cylinder block.

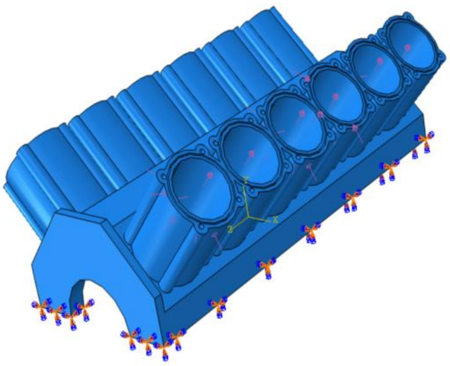


Fig.4.4: Pressures applied on the cylinder block

PROCEDURE FOR STATIC ANALYSIS

To perform static analysis, the following procedure is to be adopted.

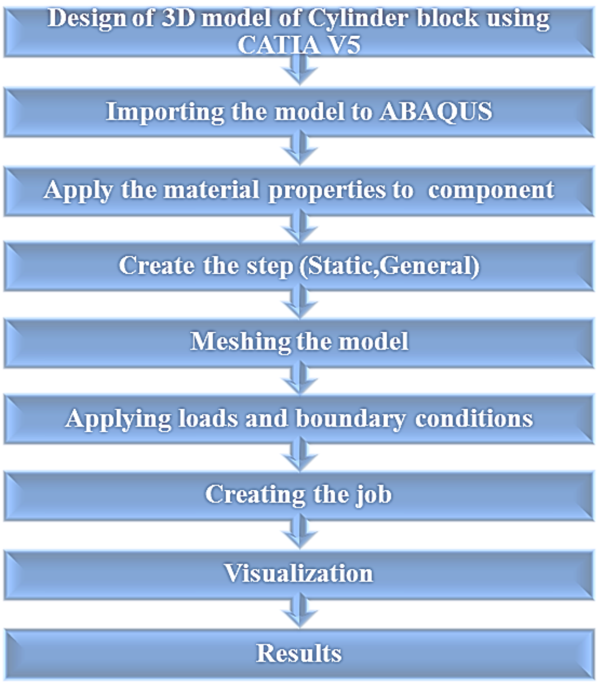


Fig. 4.5: Flow chart for Static Analysis

VII. RESULTS AND DISCUSSIONS

From the finite element analysis using ABAQUS, various Von Mises stress and deformation values are obtained corresponding to different gas pressures.

1) Von Mises stresses

The Von Mises stresses induced in the engine cylinder block under different loading conditions are given in table 5.1.

TABLE 5.1: Von Mises stress induced in the Cylinder block under different loading conditions (in MPa)

Material / Pressure (MPa)	CGI GJV 450	NASA 398
8	113.568	114.283
10	141.747	142.865
12	169.844	171.450
15	211.833	214.335

The induced stresses in NASA 398 are more than those induced in CGI GJV 450 at all the conditions, in a little amount. The stress distribution contours under different loading conditions are given below.

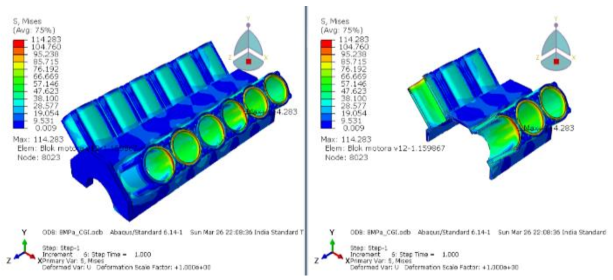


Fig.5.1: Stress Distribution Contours for CGI GJV 450 at 8 MPa

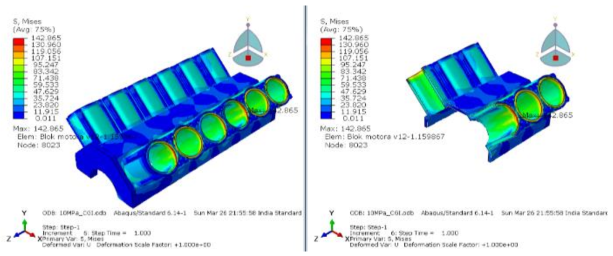


Fig.5.2: Stress Distribution Contours for CGI GJV 450 at 10 MPa

Fig.5.3: Stress Distribution Contours for CGI GJV 450 at 12 MPa

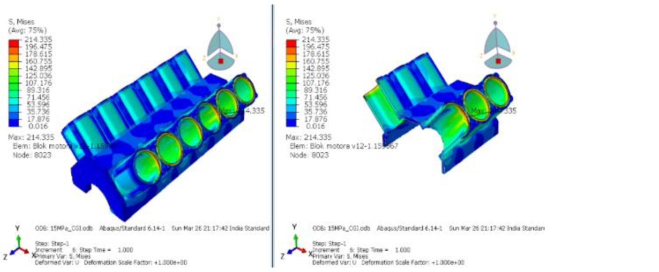


Fig.5.4: Stress Distribution Contours for CGI GJV 450 at 15 MPa

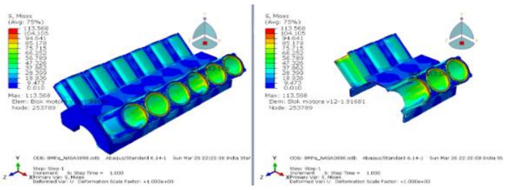
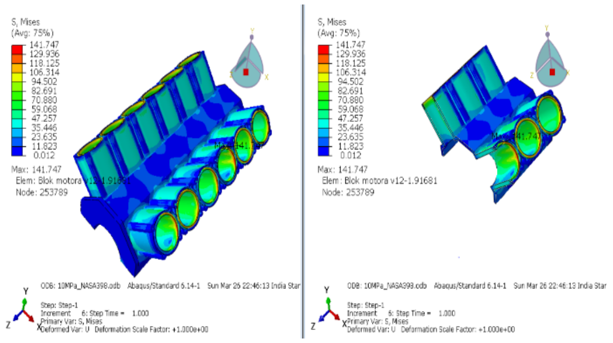
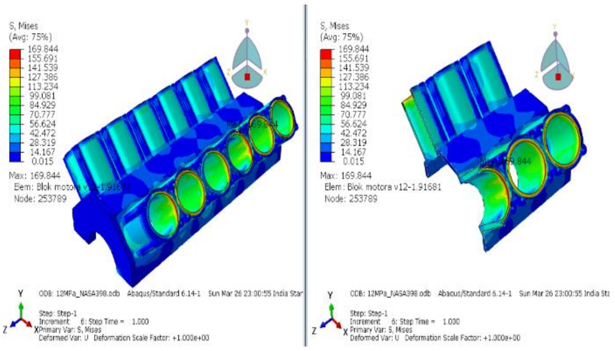


Fig.5.5: Stress Distribution Contours for NASA 398



at 8 MPa

Fig.5.6: Stress Distribution Contours for NASA 398



at 10 MPa

Fig.5.7: Stress Distribution Contours for NASA 398 at 12 MPa

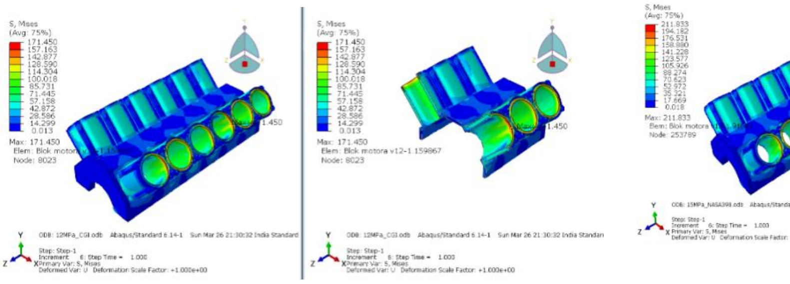


Fig.5.8: Stress Distribution Contours for NASA 398 at 15 MPa

2) Maximum Displacement

The maximum displacements produced in the engine cylinder block under different loading conditions are given in table 5.2.

TABLE 5.2: Maximum displacement produced in the cylinderblock under various loading conditions (in mm)

	CGI GJV 450	**NASA 398**
8	0.008	0.017
10	0.010	0.021
12	0.012	0.025
15	0.015	0.031

The maximum displacements produced in NASA 398 is more than those produced in CGI GJV 450 at all the conditions. The maximum displacement contours under different loading conditions are given below.

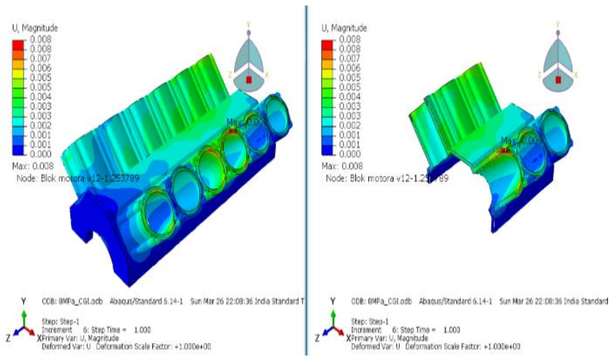


Fig.5.9: Maximum Displacement Contours for CGI GJV 450 at 8 MPa

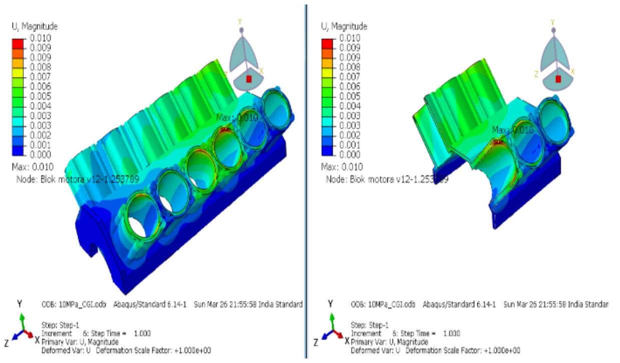


Fig.5.10: Maximum Displacement Contours for CGI GJV 450 at 10 MPa

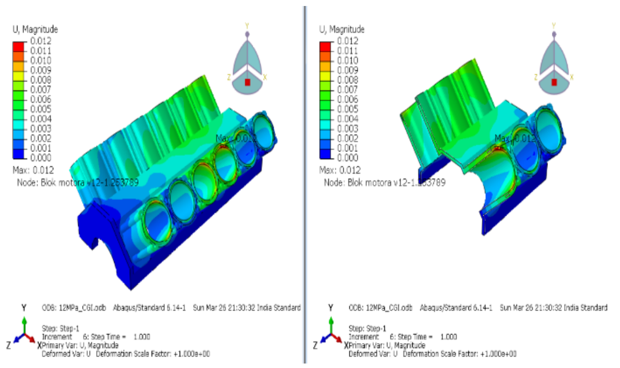


Fig.5.11: Maximum Displacement Contours for CGI GJV 450 at 12 MPa

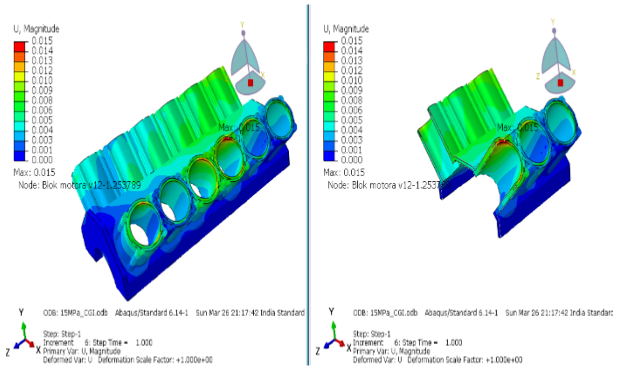


Fig.5.12: Maximum Displacement Contours for CGI GJV 450 at 15 MPa

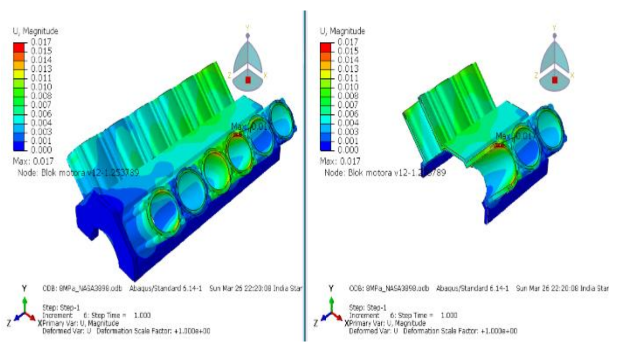


Fig.5.13: Maximum Displacement Contours for NASA 398 at 8 MPa

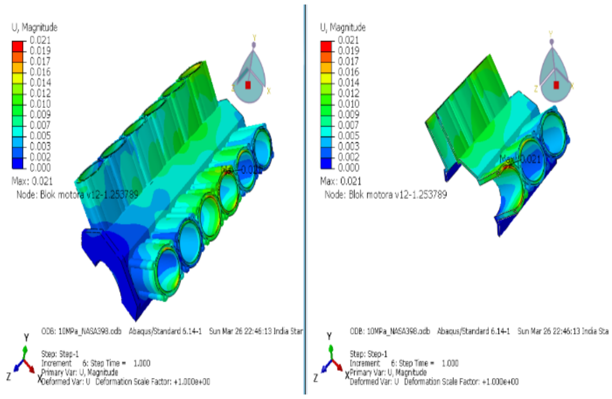


Fig.5.14: Maximum Displacement Contours for NASA 398 at 10 MPa

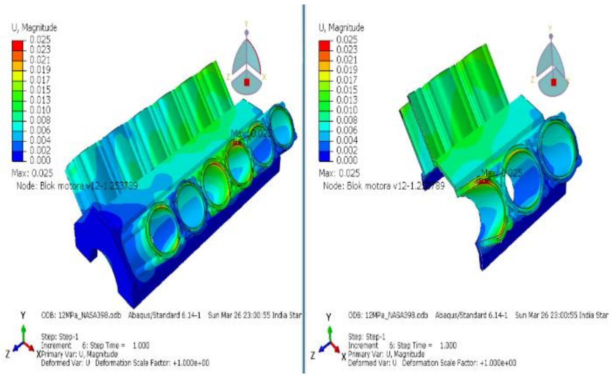


Fig.5.15: Maximum Displacement Contours for NASA 398 at 12 MPa

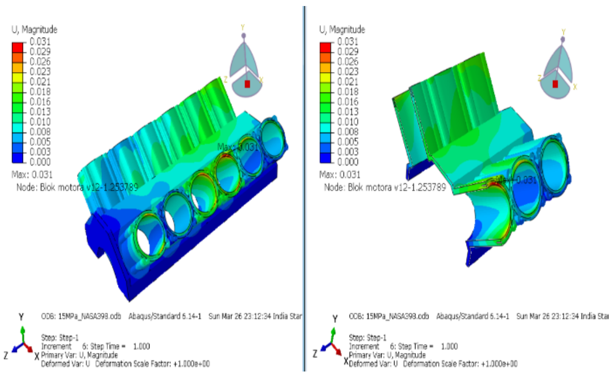
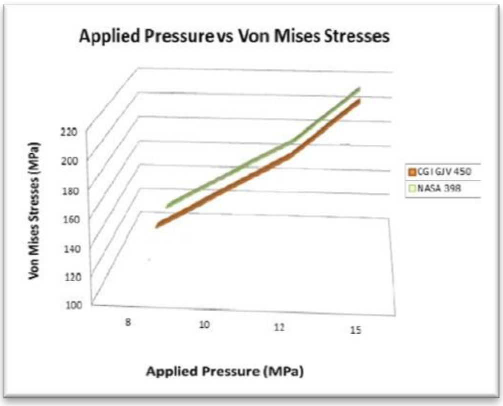


Fig.5.16: Maximum Displacement Contours for NASA 398 at 15 MPa

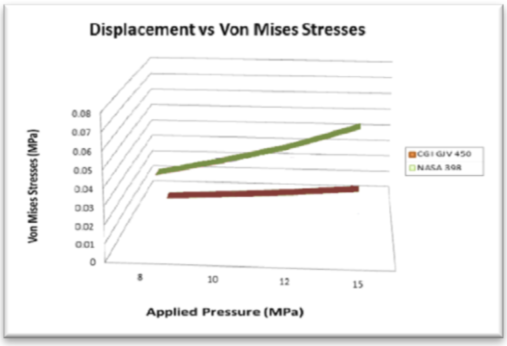
The above results show that the stress distribution at different loading conditions vary slightly but the deformation produced varies greatly. So, it is taken as the basic criteria for selection of suitable material for cylinder block.

GRAPH PLOTS

From the ABAQUS Static analysis results, graphs are plotted for stress distribution and displacements produced for different materials at different pressures.



Graph 1: Applied pressure vs Von Mises Stress



Graph 2: Displacement vs Von Mises Stress

From graph 1, stress distribution in both the materials vary by a small amount. Graph 2 shows a clear difference between the deformations produced in both the materials.

VIII. CONCLUSION

1. The above results give us a clear idea that the stresses induced in both the cases are nearly same.
2. So, it is difficult to decide the best material for the cylinder block based on the stresses induced, as they are nearly the same.
3. Displacements produced is noticeably high to decide the best choice of material selection for the cylinder block.
4. The maximum displacement produced in CGI GJV 450 is less than that of NASA 398 at all the loading conditions.
5. CGI GJV 450 shows better results in both stress induced and deformation produced.
6. Hence CGI GJV 450 can be selected as the most suitable material for the cylinder block under given static conditions.

IX. FUTURE SCOPE

There are many issues regarding technology that is already in practical use, such as shortening structure-modelling lead-time, further need for increasing the accuracy and reliability of computations, and simplification of analytical tasks.

- Other materials, which will be lighter than cast iron, aluminium and magnesium alloys, which can overcome their disadvantages, can also be developed.
- By using FEA, simulation on thermal related issues can be done and the performance of the engine block can be improved. Also dynamic and vibrational analysis can be carried out to predict the behaviour of the engine block.
- It is also possible to nullify the computational fluid dynamic problems in the engine block. Analysis can be simulated on composite elements or components.

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