MODELING & ANALYSIS OF ENGINE BLOCK

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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 and dynamic loading. The cylinder block has to withstand the stresses and deformations due to loads acting on it. The solid model of the block is generated in CATIA V5 R21. The model is imported to HYPERMESH 11 through IGES format. The quality mesh is prepared in HYPERMESH for converged solution and the solver set as ANSYS in which loads and boundary conditions are applied for analysis. By using different materials Aluminium, Grey cast iron, Steel, Titanium and Brass. The static analysis is performed to predict the deformations and stresses. The model analysis using lanczo's algorithm to predict the natural frequencies and corresponding mode shapes.

Keywords: CATIA V5 R21, HYPERMESH 11, ANSYS, Engine Block

1.0 INTRODUCTION

The finite element method (FEM) has now become a very important tool of engineering analysis. Whether a civil engineer designing bridges, dams or a mechanical engineers designing auto engines, rolling mills, machine tools or an aerospace engineer interested in the analysis of dynamics of an aero plane or temperature rise in the heat shield of a space shuttle or a metallurgist concerned about the influence of a rolling operation on the microstructure of a rolled product or an electrical engineer interested in analysis of the electromagnetic field in electrical machinery-all find the finite element method handy and useful.

Traditional methods of engineering analysis, while attempting to solve an engineering problem mathematically, always try for simplified formulation in order to overcome the various complexities involved in exact mathematical formulation.

The stress analysis in the fields of civil, mechanical and aerospace engineering, nuclear engineering is invariably complex and for many of the problems it is extremely difficult and tedious to obtain analytical solutions.

One of the most popular numerical methods used is the Finite Element (FEM) offered by the existing CAD/CAM/CAE.

ALTAIR HYPERMESH is widely used for meshing. It is almost used in all automobile-leading industries. For complex geometries it is best suited. The effective mesh generation is done. The main objective is to check all the element quality checking such as aspect ratio, war page angle, skew angle, and jacobian. So tetra mesh and mapped mesh of motorcycle engine block is done. Another objective is to find out the stresses, deformation and natural frequencies using structural and model analysis. The material properties and loading conditions for motorcycle engine block are taken into consideration.

This paper presents structural analyses performed on an in-line, four-cylinder and two-liter automotive diesel engine for vibration reduction purposes. Both finite element modeling and experimental structural analysis were performed on the existing design. After applying both of these methods to the same structure, the reliability of the structural model was established. The finite element model, which was constructed as simple as possible, could then be used for predicting the effect of design changes on the structural behavior of the block. A relatively simplified finite element model proved a very useful and accurate tool.

2.0 GEOMETRIC MODELING AND FINITE ELEMENT ANALYSIS

CatiaV5 R21 is an interactive Computer-Aided Design and Computer Aided Manufacturing system. The CAD functions automate the normal engineering, design and drafting capabilities found in today's manufacturing companies. The CAM functions provide NC programming for modern machine tools using the CatiaV5 R21 design model to describe the finished part. CatiaV5 R21 functions are divided into "applications" of common capabilities. These applications are supported by a prerequisite application called "CatiaV5 R21 Gateway".

CatiaV5R15 is fully three dimensional, double precision system that allows to accurately describing almost any geometric shape. By combining these shapes, one can design, analyze, and create drawings of products.

Creation of a 3-D model in CatiaV5 R21 can be performed using three workbenches i.e., sketcher, modeling and assembly.

2.1 CREATION OF SOLID BODIES

Solid bodies were created by sweeping sketch and non-sketch geometry to create associative features or Creating primitives for the basic building blocks, then adding more specific features (for example, holes and slots).

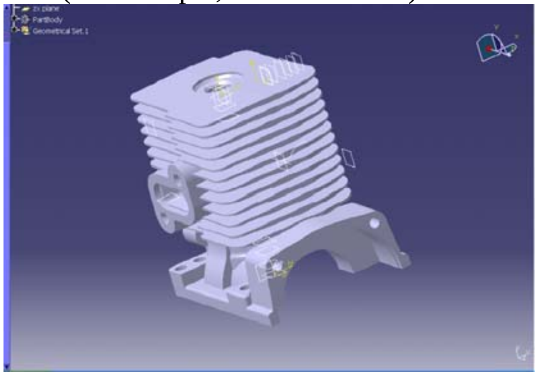


Fig: 2.1 Top portion of motorcycle engine block

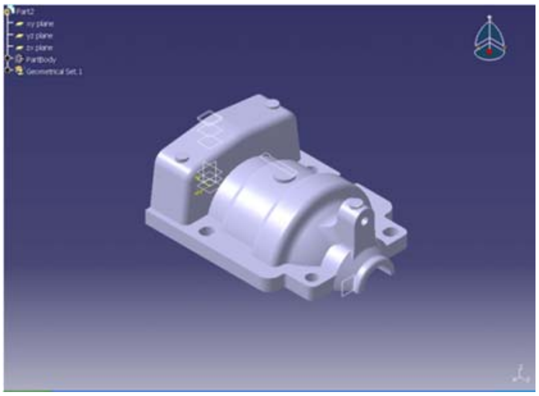


Fig: 2.2 Bottom portion of motorcycle engine block

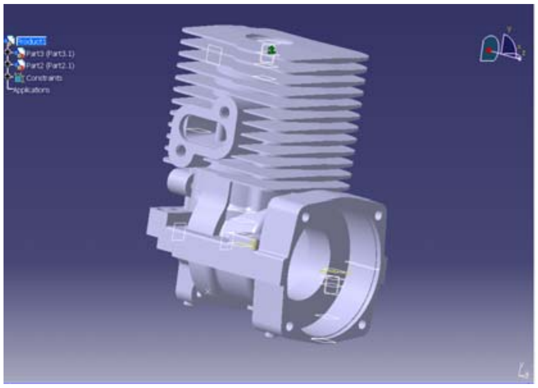


Fig: 2.3 Assembly of motorcycle engine block

2.2 SELECTING A SOLVER

The following table provides general guidelines you may find useful in selecting which solver to use for a given problem.

Table 2.1 Different Solvers

Solver	Typical Applications	Model Size	Memory Requirement	Disk Requirement
Frontal solver (Direct Elimination solver)	When robustness is required i.e., non-linear analysis or when memory is limited	Under 50,000 DOF'S	Low	High
Sparse Direct solver	When robustness and	10,000 – 5,00,000 DOF'S	Medium	High

(Direct Elimination solver)	solution speed are required i.e., for non-linear analysis	more for shells		

2.3 SOLID 92 INPUT SUMMARY

Element Name	Solid 92
Nodes	I, J, K, L, M, N, O, P, Q, R
Degrees of Freedom	UX, UY, UZ
Material Properties	EX, EY, EZ, PRXY, PRYZ, PRXZ, ALPX, ALPY, ALPZ, DENS
Special Features	Plasticity, Creep, Stress stiffing,and large strain Large deflection

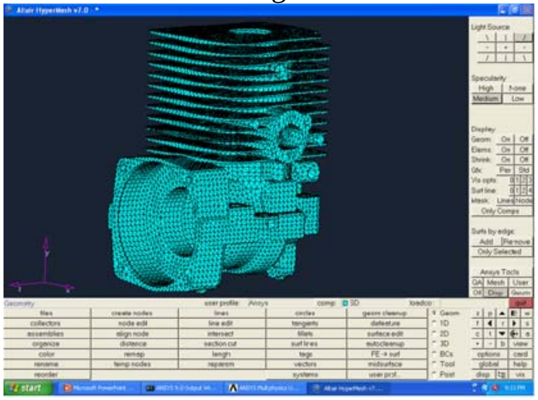


Fig 2.4 Meshed model of motorcycle engine block

The numbers of elements in the model are 73,866. The element is 10-node tetra hedraleral; hence each element will have 10 nodes. The jacobian for the meshed model is 0.7, the aspect ratio is 5 and the skew angle is 60.

3.0 STRUCTURAL ANALYSIS OF A MOTORCYCLE ENGINE BLOCK

Element Type 1: solid 92 10 node tetra heral element

Table 3.1: Material properties

Material	Density (kg/mm^3)	Young's Modulus (N/mm^2)	Poisson's Ratio	Yield Strength (MPa)
Aluminium	2700 e^{-9}	0.675 e^5	0.34	300
Grey Cast Iron	7000 e^{-9}	0.75 e^5	0.27	--
Steel	7850 e^{-9}	2 e^5	0.3	650
Titanium	4500 e^{-9}	1.1 e^5	0.33	1050
Brass	8500 e^{-9}	1 e^5	0.34	300

The engine specifications of various company motorcycles are in the following table 3.1.

Table 3.2: Engine specifications of different companies

Two – Wheeler company names	Power (Bhp)	Torque (N-mm)	Pressure (MPa)	Yield Strength (MPa)
LML	8	10,000	10	300
KINETIC	11.6	12,000	12.5	--
HONDA	8.2	10,630	11.2	650
BAJAJ	7.48	11,000	10.8	1050

3.1 MODEL ANALYSIS OF OTORCYCLE ENGINE BLOCK:

We can use the model analysis to determine the vibration characteristics-natural frequencies and mode shapes of a structure or a machine component while it is being designed. It can be also a starting point for another dynamic analysis such as a transient dynamic analysis, a harmonic analysis, and a spectrum analysis.

4.0 RESULTS AND DISCUSSIONS

4.1 Static analysis results

The static analysis of engine block is performed on the model imported to ansys from hypermesh as shown in fig 4.1using five different materials

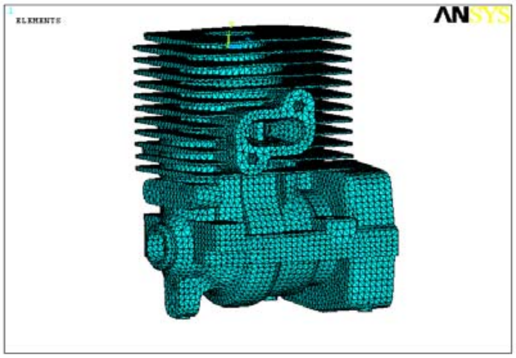


Fig 4.1 Finite element model imported to ansys from hypermesh

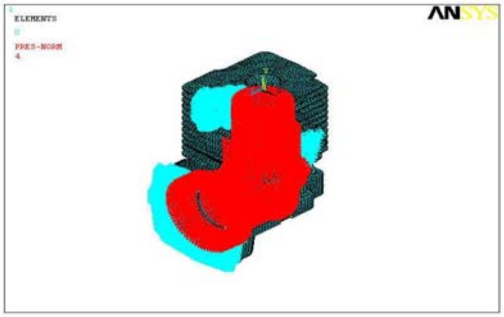


Fig 4.2 Boundary conditions applied for the engine block

Fig 4.2 shows the boundary conditions applied on the motorcycle engine block. The area shown in light blue colour indicates the area where the block is constrained. The red colour area indicates the area where the pressure is applied. The value of pressure applied is 4.5MPa.

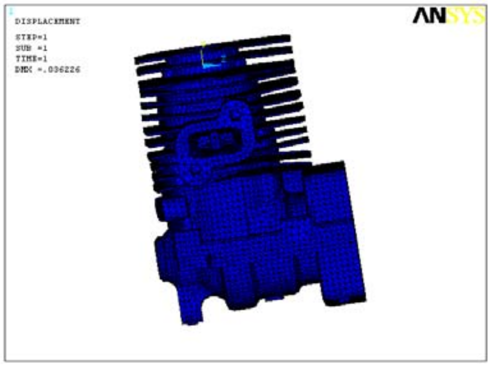


Fig 4.3 Deformation after analysis of engine block using aluminum

Fig 4.3 shows the deformation of the aluminium engine block. Pressure of 4.5MPa is applied on the block. The displacement is taken in z-direction the value of deformation after applying the pressure is 0.036226 mm.

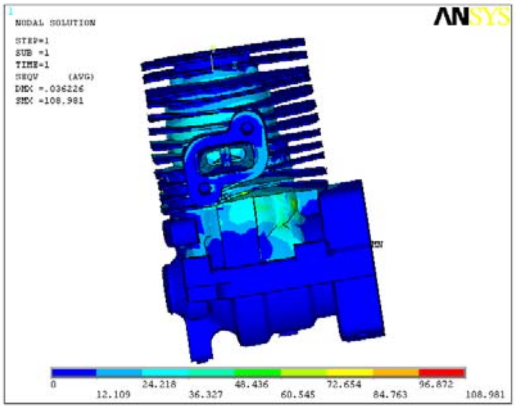


Fig 4.4 Vonmises stress after analysis of engine block using aluminium

Fig 4.4 shows the stresses in the aluminium engine block. The minimum stress is near the bottom portion of the engine block. The stress induced near the fins is 24.218MPa. The stress induced near the outer surface of the cylinder is 60.545MPa. The maximum stress induced is 108.981MPa.

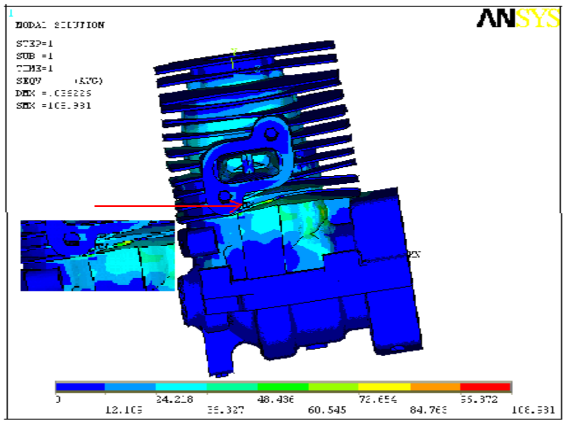


Fig 4.5 The weakest point of the aluminium engine block

Fig 4.5 shows the point indicated by the arrow, which is the weakest point of the aluminium engine block since the stress induced is maximum at this point, which is 108.981 MPa.

Table 4.1 Deformations, stresses and factor of safety obtained for engine block using different materials

Material	Deformation (mm)	Vonmises Stress (MPa)	Factor of Safety	Yield Strength (MPa)
Aluminium	0.036226	108.981	2.75	300
Grey cast iron	0.079445	447.69	1.8	--
Steel	0.046982	422.723	1.53	650
Titanium	0.085615	413.546	2.54	1050
Brass	0.093964	410.356	0.73	

Table 4.1 shows the deformations and stresses obtained for five different materials. The deformation value for aluminium engine block is 0.036226mm,the maximum stress is 108.981MPa and the factor of safety is 2.75,the deformation value for grey cast iron engine block is 0.079445 and the maximum stress value is 447.69MPa since grey cast iron does not have yield strength we cannot determine the factor of

safety, the deformation value for steel engine block is 0.046982mm,the maximum stress value is 413.546MPa and the factor of safety is 1.53,the deformation for titanium engine block is 0.085625mm,the maximum stress value is 413.546MPa and the factor of safety is 2.54,the deformation value for brass engine block is 0.093964mm and the factor of safety is 0.73.After comparing all the materials, aluminium is chosen as the suitable material since it has the least stress induced whose value is less than the yield strength value . The factor of safety for aluminium block is 2.74, which is within the allowable limit.

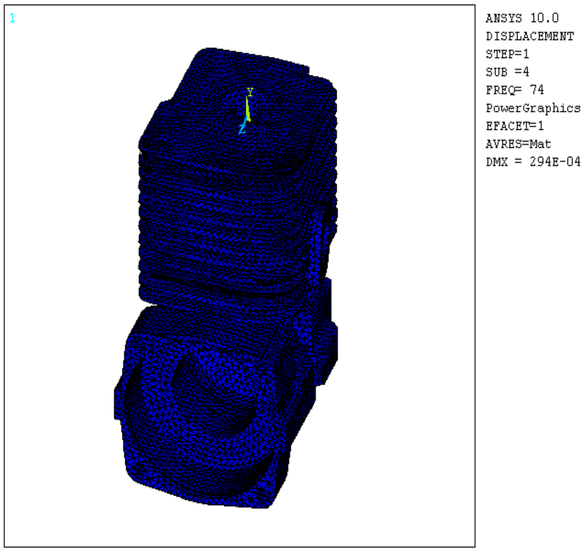
4.2 Model analysis

Model analysis has been performed for the engine block using five different materials, and first five mode frequencies are shown in the table 4.2.

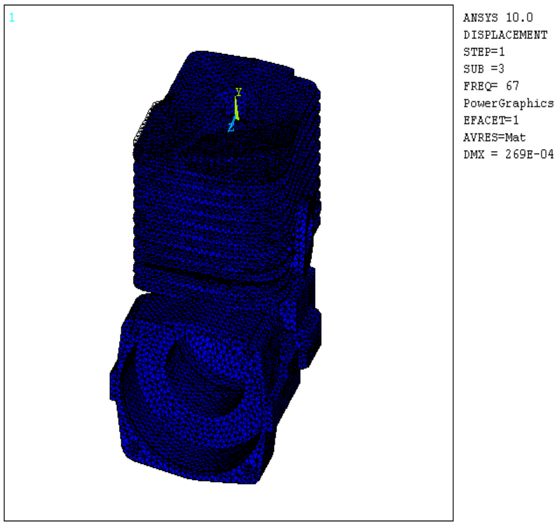
Table4.2 Natural frequencies of engine block for different materials

Material	Mode of Vibration, Hz				
	1	2	3	4	5
Aluminum	58	65	67	74	85
Grey cast iron	50	54	55	62	75
Steel	49	56	58	64	74
Titanium	52	58	60	66	76
Brass	39	44	45	50	58

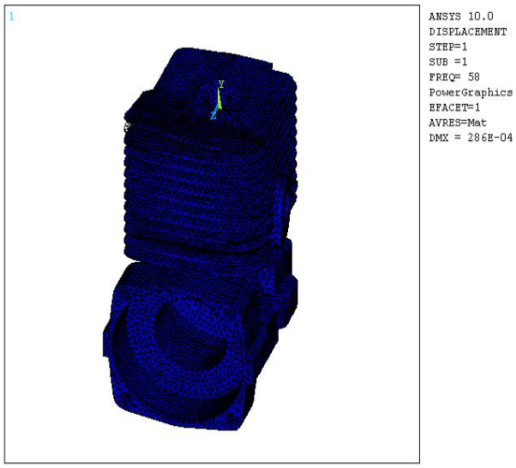
The five natural frequencies of different materials are shown in the above table. The frequencies for aluminium engine block are obtained between 58Hz to 85Hz,the frequencies for grey cast iron engine block are obtained between 50Hz to 75Hz,the frequencies for steel engine block are obtained between 59Hz to 74Hz, the frequencies for titanium engine block are obtained between 52Hz to 76Hz and the frequencies for brass engine block are obtained between 39Hz to 58Hz.



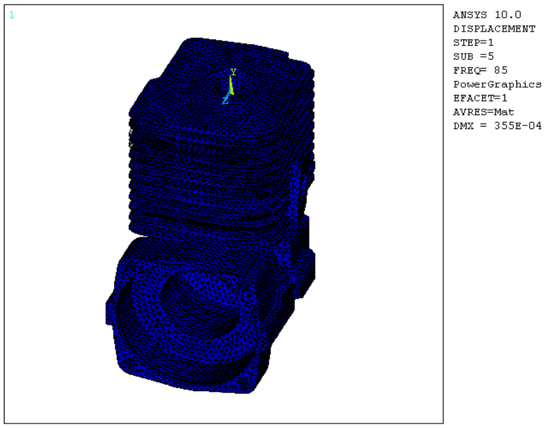
Mode 1



Mode 2



Mode 3



Mode 4

Fig 4.6 Mode shapes for aluminium engine block

5.0 CONCLUSIONS

The following conclusions are drawn from the present work

1. The deformations of engine block are obtained for different materials out of which aluminium has the least deformation, which is 0.036226mm.Based on these values for the static analysis; the design of motorcycle engine block is safe based on the rigidity criteria. The vonmises stresses are obtained for different materials out of which the stress induced in aluminium block is less, which is 108.981MPa. Based on the design criteria this value is less than the yield strength value and factor of safety is less, hence the design is safe based on strength criteria.
2. The model analysis using lancoz's algorithm is performed to predict five natural frequencies and their corresponding mode shapes of five different materials out of which aluminium has the highest excitation.

3. The frequencies for the aluminium engine block are 58Hz, 65Hz, 67Hz, 74Hz and 85Hz.
4. Harmonic analysis is performed on aluminium engine block and the maximum excitation occurs at 70Hz and the amplitude is observed to be 0.04mm, which is not significant hence, the engine block is dynamically stable.From the results of harmonic analysis, damping effect is more in composite blower which controls the vibration levels.

6.0 SCOPE OF THE WORK

1. Future engine block development will be more complex and technology will progress to yet a higher level, the role of FEA will become more important.
2. There are also many issues regarding technology that is already in practical use, such as shortening structure-modeling lead-time, further increasing the accuracy and reliability of computations, and simplification of analytical tasks.
3. Other materials, which will be lighter than aluminum and which can overcome its disadvantages, can also be developed.

7.0 REFERENCES

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