Modal Analysis of V-12 Engine Cylinder Block Using Abaqus Software for Different Materials

B. Jayachandraiah

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 Engine Cylinder Block is to be carried-out to predict its behavior under Modal Analysis. The Engine Cylinder Block has to with stand the frequencies and deformations due to Modal loads acting upon it. An attempt is made in this paper to perform Modal Analysis on V-12 Engine Cylinder Block for different materials to obtain the variation of the frequency and the maximum deformations. Three-dimensional model of the V-12 Engine Cylinder Block is created using CATIA V5 R22 software and the mesh is generated by using tetragonal (TET) elements. The analysis of the Engine cylinder Block is carried-out by using different materials of Compacted Graphite Cast Iron (CGI GJV 450), Grey Cast Iron, AMC-SC1 and NASA 398 (Hypereutectic Al-Si Alloy) of ABAQUS 6.14 software for the application of Finite Element Analysis. The mechanical boundary conditions are applied to the Engine Cylinder Block. The Results are the obtained frequency of NASA 398 is very high of about 6124.9 cycles/time and that of Grey Cast Iron is very low i.e., 4428.7 cycles/time. Also the frequencies of AMC-SC1 and CGI are 5313.7 and 5391.3 cycles/time respectively under Modal Analysis. Based on the results the life of the Engine Cylinder Block is recommended the NASA 398 is more compared to other materials followed by CGI GJV450, AMC-SC1 and Grey Cast Iron. The maximum deformation produced for Grey Cast Iron and CGI GJV450 are same about 1.004 mm which is quiet nearer to the deformations produced as in the case of AMC-SC1 ad NASA 398 about 1.005 mm. So, in deformation point of view, the Modal behavior of all the materials is nearly same. Hence NASA 398 is better material for the Engine Cylinder Block.***

Index Terms**: *ABAQUS/CAE, AMC-SC1, Cylinder Block, CGI GJV 450, CATIA V5, Modal Analysis, NASA 398***

I. INTRODUCTION

The Engine Cylinder Block is the main integrated structure of the IC Engine and is also called as Engine Block [6]. 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 [7].

Revised Manuscript Received on December 22, 2018.

Dr. B. Jayachandraiah, Professor of Mechanical Engineering, Srikalahastheeswara Institute of Technology, Srikalahasti, Chittoor Dist, A.P. India.

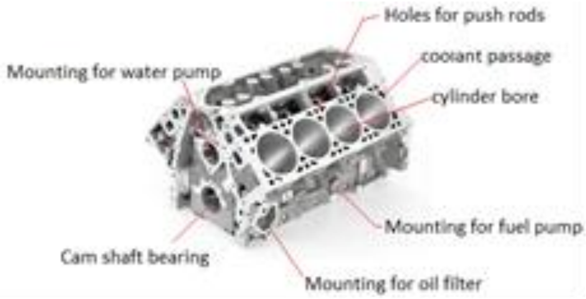

Fig.1: Basic Components of Cylinder block

II. FUNCTIONS & MATERIALS OF CYLINDER BLOCK

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

Cast Iron and Aluminium Alloys are the most widely used materials to manufacture the cylinder block. Cast iron alloys are used because they contain good mechanical properties, low cost, and availability compared with other metals. But certain aluminium alloys contain most of the characteristics of cast iron but with low weight, and also aluminium alloy 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. All paragraphs must be justified alignment. With justified alignment, both sides of the paragraph are straight.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

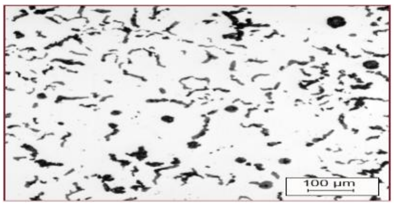

Fig. 2 CGI GJV450 Microstructure

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.

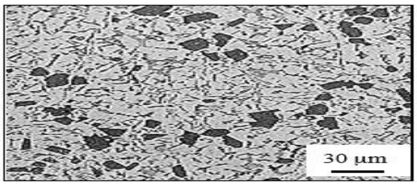

Fig. 3 NASA 398 Microstructure

Grey cast iron is the first and most material used for manufacturing of engine blocks. Though the aluminium alloy also contains many similarities with low weight, it is still used in the manufacturing of diesel engine blocks because their internal stresses are higher. Grey cast iron contains 2.5-4% of carbon, 1-3% of silicon, 0.2-1% manganese, 0.02-0.25% of sulphur, and 0.02 -1% of phosphorus and remaining iron.

Fig.4 Grey cast iron Microstructure

Australian Magnesium Corporation presented their discovery of sand-cast AMC-SC1 magnesium alloy [Anonymous, "Magnesium alloy resists high temperature in engine blocks," Advanced Materials and Processes, August 2003, vol. 161, issue 8, p. 13.]. This grade of magnesium alloy contains two rare earth elements, lanthanum and cerium, and was heat-treated with T6. This stabilizes the strength of the alloy at high engine operating temperatures, which is a necessary requirement for a cylinder block material [5]. The cylinder block is made of AMC-SC1 and is said to have decreased the weight of a comparably-built gray cast iron and aluminium alloy block by 57% and 24%.

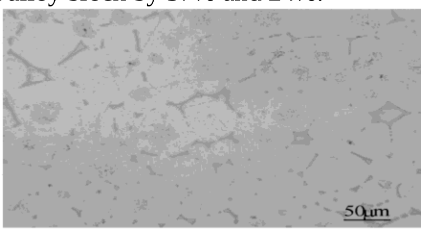

Fig.5 AMC-SC1 Microstructure

III. DESIGN CONSIDERATIONS

In designing the Engine 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 modal Analysis of the Engine Block by using the FEM/ABAQUS software's in order to understand the present Research. Suresh R et al [1] 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 [2] has done the model analysis on a motor cycle engine block under static and modal 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 [3] have 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 [4] has carried-out their work on the modal 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 Modal 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.

V. MAJOR OBJECTIVE & DATA COLLECTION

An attempt made in this paper to find the Modal Analysis of the Engine Cylinder Block is made of different materials of Grey Cast Iron, AMC-SC1, Compacted Graphite Cast Iron (CGI GJV450), NASA 398. The model is created by using CATIA V5 R22 and analysis is done by using ABAQUS software to evaluate best material suited for Engine Cylinder Block.

Table.1: Geometrical Entities of 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.2: Material Properties

Material / Property	CGI GJV 450	NASA 398	AMC-SC1	Grey Cast Iron
Density (ton/mm^3)	7.10E-09	2.76E-09	1.79E-09	7.20E-09
Elastic Modulus (MPa)	180000	88600	44000	126000
Poisson’s Ratio	0.27	0.35	0.281	0.211
Yield Strength (MPa)	640	235	130	276

VI. MODELING & MESHING

The modeling is done by CATIA V5 R22 software [8] 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 behaviour of the engine block.

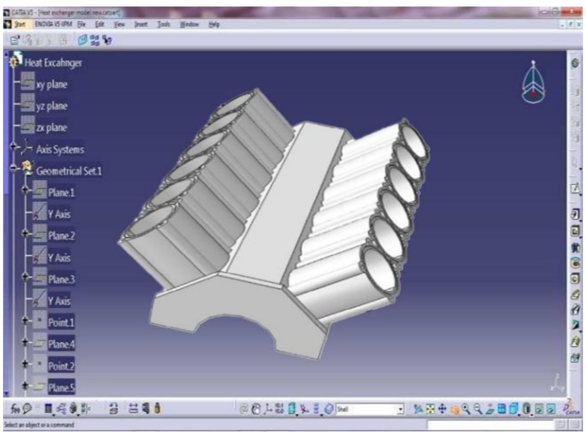

Fig. 6: 3-D Model of the V-12 engine cylinder block

The finite element mesh is generated for the Engine 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.

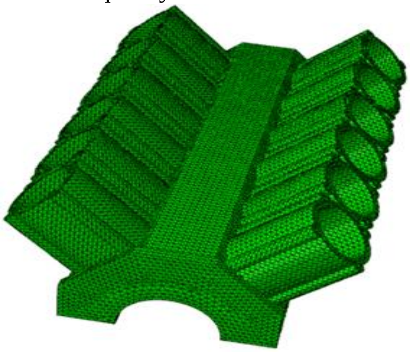

Fig.7: 3-D Meshed model of the cylinder block

VII. FINITE ELEMENT METHOD ANALYSIS

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.

A. Applying Boundary Conditions

The above Figures show the boundary conditions and loading considered for the model analysis.

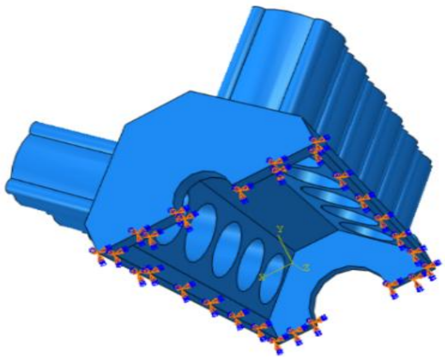

Fig.8: Boundary conditions applied on the 3-D cylinder block

B. Procedure For Modal Analysis

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

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

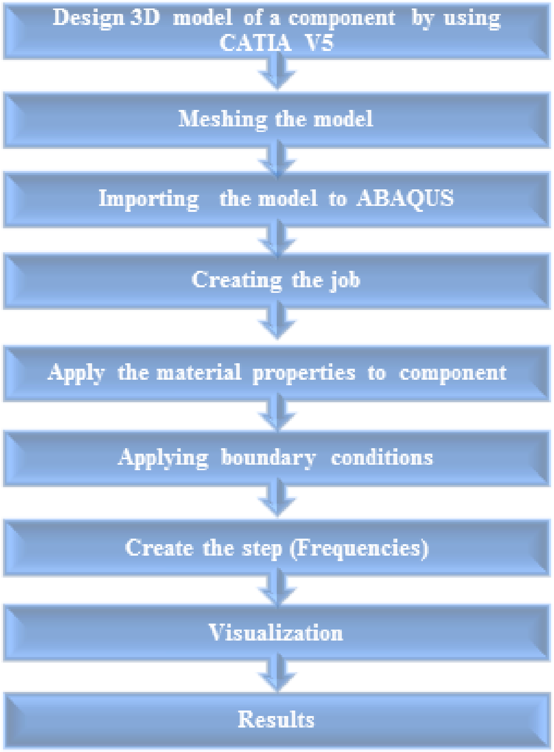

Fig. 9 Flow chart for Modal Analysis

VIII. RESULTS & DISCUSSION

From the finite element analysis using ABAQUS, various Maximum Deformations and Frequency values are obtained corresponding to different gas pressures [9].

A. Applying Boundary Conditions

In Modal analysis, using Grey Cast Iron, the maximum displacement produced is 1.004 mm which is very low but it has a low frequency of 4428.7 cycles/time.

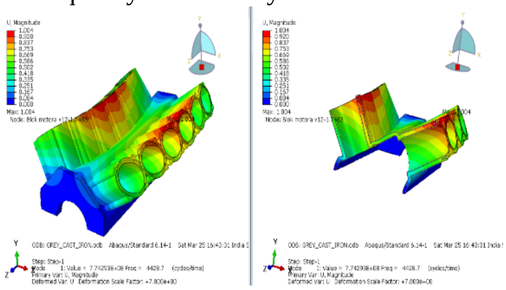

Fig. 10 Modal response contours for Grey Cast Iron

B. AMC-SC1

In Modal analysis, using AMC-SC1, the maximum displacement produced is 1.005 mm which is low and it has a frequency of about 5313.7 cycles/time which is greater than Grey Cast Iron.

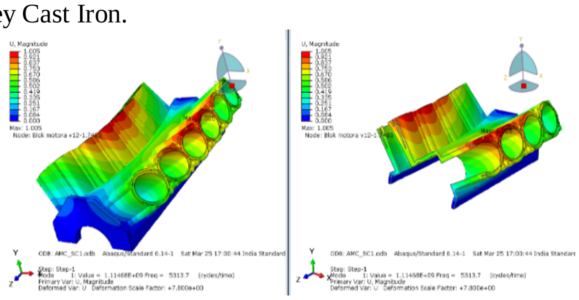

Fig. 11 Modal response contours for AMC-SC1

C. Compacted Graphite Cast Iron (CGI GJV450)

In Modal analysis, using Compacted Graphite Cast Iron, the maximum displacement produced is 1.004 mm which is very low and it has a frequency of about 5391.3 cycles/time which is greater than Grey Cast Iron and AMC-SC1.

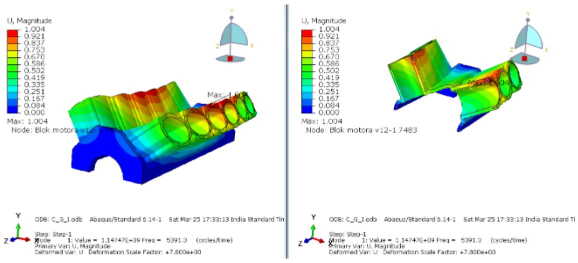

Fig. 12 Modal response contours for CGI GJV450

D. NASA 398

In Modal analysis, using NASA 398, the maximum displacement produced is 1.005 mm which is low and it has a frequency of about 6124.9 cycles/time which is far greater than Grey Cast Iron, CGI and AMC-SC1

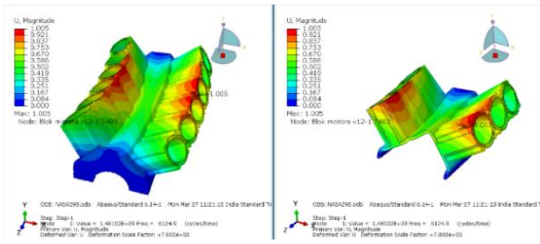

Fig. 13 Modal response of NASA 398

E. Modal Frequency Graph

Under the Modal Analysis, the frequency of NASA 398 is very high of about 6124.9 cycles/time and that of Grey Cast Iron is very low i.e., 4428.7 cycles/time. Also the frequencies of AMC-SC1 and CGI are 5313.7 and 5391.3 cycles/time respectively. The frequency indicates the average life of the engine cylinder block and the frequency of NASA 398 is very higher than the Grey Cast Iron, Compacted Graphite Cast Iron and AMC-S1 materials. This indicates that the number of working cycles of NASA 398 material is as high as the values obtained for other materials.

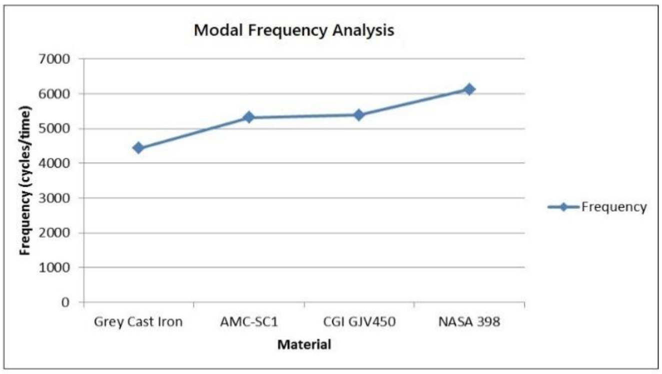

Fig. 14 Graph of Modal Frequencies for different materials

F. Modal Deformation Graph

Under the Modal Analysis, the maximum deformation produced for Grey Cast Iron and CGI are same about 1.004 mm which is quiet nearer to the deformations produced as in the case of AMC-SC1 ad NASA 398 about 1.005 mm. So, in deformation point of view, the Modal behaviour of all the materials is nearly same.

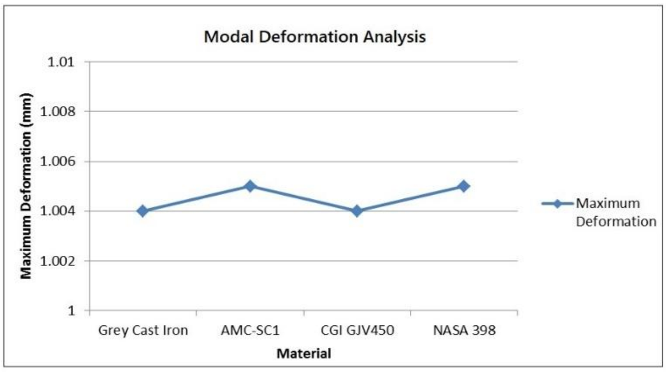

Fig. 15 Graph of Maximum Deformation for different materials

Table.3 Modal Analysis Results of The V-12 Engine Block

S.No.	Material	Frequency (cycles/time)	Maximum Deformation (mm)
1.	GREY CAST IRON	4428.7	1.004
2.	AMC-SC1	5313.7	1.005
3.	COMPACTED GRAPHITE CAST IRON (CGI GJV450)	5391.3	1.004
4.	NASA 398	6124.9	1.005

IX. CONCLUSION & FUTURE WORK

The following conclusions are made based on the results obtained from analysis. Under Modal loading conditions, the frequency of NASA 398 is very high of about 6124.9 cycles/time and that of Grey Cast Iron is very low i.e., 4428.7 cycles/time. Also the frequencies of AMC-SC1 and CGI are 5313.7 and 5391.3 cycles/time respectively. Hence the life of the cylinder block made of NASA 398 is more compared to other materials followed by CGI GJV450, AMC-SC1 and Grey Cast Iron. The maximum deformation produced for Grey Cast Iron and CGI are same about 1.004 mm which is quiet nearer to the deformations produced as in the case of AMC-SC1 ad NASA 398 about 1.005 mm. So, in deformation point of view, the Modal behaviour of all the materials is nearly same.

There are many issues regarding Technology that is already in practical use, such as shortening structure-modeling 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, aluminum 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 behavior of the Engine Block.

REFERENCES

1. Suresh R, Anil Kumar BN, Shyam Sunder N, Shridhar Deshpande – "Thermo-mechanical analysis of engine block of IC engine", International Journal for Technological Research in Engineering Volume 2, Issue 11, July 2015, ISSN:2347-4718.
2. Vikramakumar,VHarsure – "Modal analysis on motor cycle engine block" (IJSRD), Volume 4, ISSUE 09, 2016 ISSN(online):2321-0613.
3. Nitin Kumar Srivastav, Ram PoojanSahani, Amit Kumar, Girjesh Yadav, RajooSahani, Prashant Kumar Mishra – "Finite Element Analysis of Piston Head by ABAQUS" (IJSER), Volume 6, ISSUE 5, May-2015
4. Y. Sathaiah, Gandhi Perumallapalli, D. Sreeramprasad – Modal analysis of Engine Block for Selection of suitable material for Cost & Weight Reduction " Volume 2, ISSUE 3 June 30, 2015.
5. K Anushka & Dr. B Jayachandraiah – "Thermal Analysis of Four stroke diesel IC engine piston by using ABAQUS Software" SKIT, Srikalahasti, Chittoor Dist, A.P, India 2014.
6. A text book of Internal Combustion Engines by V Ganesan, 3rd edition, Tata Mc Graw Hill Publications.
7. A text book of Internal Combustion Engines by R.K. Rajput, 9/e, Lakshmi Publications.
8. Getting Started with CATIA V5 manual by Dassualt Systems.
9. Getting Started with Abaqus: Interactive Edition by Dassualt Systems