Design and Analysis of Engine Block

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ABSTRACT:

A cylinder block is an integrated structure comprising the cylinder(s) of a reciprocating engine and often some or all of their associated surrounding structures The various main parts of an engine (such as cylinder(s), cylinder head(s), coolant passages, intake and exhaust passages, and crankcase) are conceptually distinct, and these concepts can all be instantiated as discrete pieces that are bolted together. The purpose of the engine block is to support the components of the engine. Additionally, the engine block transfers heat from friction to the atmosphere and engine coolant.

From carburetor or fuel injector (fuel and air mixture) is supplied to cylinders of the engine. The fuel and air mixture are injected at high pressure into cylinders of the engine. Due to this applied pressure on the cylinder, the cylinder undergoes some deformation and produce stresses in the cylinder. With respect to stresses, Weight is also important factor in automobile industries, due to heavy weight of engine block, power consumption is high.

In this paper, a research on static and dynamic behavior of a diesel engine block is carried out in Finite Element Method (FEM) software for composite HM Carbon/Epoxy. Stresses, Natural frequencies and Modal shapes are obtained by FEM calculation. Besides, based on the results, the stress positions on this block are identified to reduce the weight of engine. Analysis is carried on designed model for HM Carbon/Epoxy. NX-CAD software is used for 3d modeling of engine block and ansys software is used for analysis of engine block.

INTRODUCTION
1.1 IC ENGINE

An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel.

The internal combustion engine was conceived and developed in the late 1800s. It has had a significant impact on society, and is considered one of the most significant inventions of the last century. The internal combustion engine has been the foundation for the successful development of many commercial technologies. For example, consider how this type of engine has transformed the transportation industry, allowing the invention and improvement of automobiles, trucks, airplanes and trains.

Internal combustion engines can deliver power in the range from 0.01 kW to 20×10^3 kW, depending on their displacement. The complete in the market place with electric motors, gas turbines and steam engines. The major applications are in the vehicle (automobile and truck), railroad, marine, aircraft, home use and stationary areas. The vast majority of internal combustion engines are produced for vehicular applications, requiring a power output on the order of 10^2 kW.

Next to that internal combustion engines have become the dominant prime

mover technology in several areas. For example, in 1900 most automobiles were steam or electrically powered, but by 1900 most automobiles were powered by gasoline engines. As of year 2000, in the United States alone there are about 200 million motor vehicles powered by internal combustion engines. In 1900, steam engines were used to power ships and railroad locomotives; today two- and four-stoke diesel engines are used. The two stroke diesel engines are generally employed in marine propulsion. The four stroke diesel engines are generally employed in heavy duty vehicles such as buses, trucks, tractors, diesel locomotives and in earth moving machinery.

1.2 Principle parts of an I.C. Engine:-

The principle parts of an I.C. engine are

1. Cylinder block, cylinder head and cylinder liner,
2. Piston, piston rings and piston pin or gudgeon pin.
3. Connecting rod with small and big end bearing,
4. Crank, crankshaft and crank pin, and
5. Valve gear mechanism.

Cylinder block construction:

The cylinder-block assembly is the casting housing the cylinders, the crankshaft, and (depending on the design) the camshaft which controls the inlet and exhaust valves. Within the cylinders, combustion produces rapid and periodic rises in temperature and pressure. These will induce circumferential and longitudinal tensile stresses - that is, around the cylinder and in the direction of the cylinder axis.
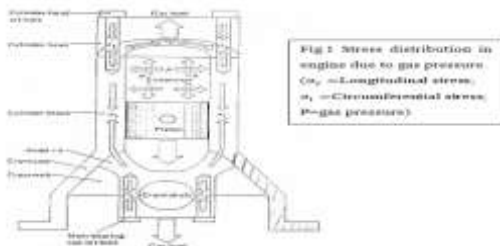

Fig.1 shows cylinder block construction

The reaction to the gas pressure is shown by the arrows tending to stretch longitudinally the set-bolts of the cylinder head and the main-bearing housing at the opposite ends of the cylinder block. Simultaneously the gas tries to expand outwards against the cylinder walls, so a plan section view of the cylinder walls would show a ring subjected to tensile circumferential stresses trying to expand the cylindrical sleeve.

1.3 TYPES OF CYLINDERS:
1) In-line cylinders:

The inline-four engine or straight-four engine is an internal combustion engine with all four cylinders mounted in a straight line, or plane along the crankcase. The single bank of cylinders may be oriented in either a vertical or an inclined plane with all the pistons driving a common crankshaft. Where it is inclined, it is sometimes called a slant-four. In a specification chart or when an abbreviation is used, an inline-four engine is listed either as I4 or L4.

Fig.2 shows Monobloc cylinder block and crankcase

The inline-four layout is in perfect primary balance and confers a degree of mechanical simplicity which makes it popular for economy cars. However, despite its simplicity, it suffers from a secondary imbalance which causes minor vibrations in smaller engines. These vibrations become worse as engine size and power increase, so the more powerful engines used in larger cars generally are more complex designs with more than four cylinders.

Today almost all manufacturers of four cylinder engines for automobiles produce the inline-four layout, with Subaru's flat-four being a notable exception, and so four cylinder is synonymous with and a more widely used term than inline-four. The inline-four is the most common engine configuration in modern cars, while the V6 is the second most popular. Usually found in four- and six-cylinder configurations, the straight engine, or inline engine is an internal combustion engine with all cylinders aligned in one row, with no offset.

A straight engine is considerably easier to build than an otherwise equivalent horizontally opposed or V-engine, because both the cylinder bank and crankshaft can be milled from a single metal casting, and it requires fewer cylinder heads and camshafts. In-line engines are also smaller in overall physical dimensions than designs such as the radial, and can be mounted in any direction. Straight configurations are simpler than their V-shaped counterparts.

An even-firing inline-four engine is in primary balance because the pistons are moving in pairs, and one pair of pistons is always moving up at the same time as the other pair is moving down. However, piston acceleration and deceleration are greater in the top half of the crankshaft rotation than in the bottom half, because the connecting rods are not infinitely long, resulting in a non sinusoidal motion. The reason for the piston's higher speed during the 180° rotation from mid-stroke through top-dead-centre, and back to mid-stroke, is that the minor contribution to the piston's up/down movement from the connecting rod's change of angle here has the same direction as the major contribution to the piston's up/down movement from the up/down movement of the crank pin. By contrast, during the 180° rotation from mid-stroke through bottom-dead-centre and back to mid-stroke, the minor contribution to the piston's up/down movement from the connecting rod's change of angle has the opposite direction of the major contribution to the piston's up/down movement from the up/down movement of the crank pin.

2) Horizontally opposed cylinders:

To enable the engine to be assembled and dismantled, horizontally opposed cylinders may have either a separate crankcase with banks of two or three cylinders bolted on opposite sides or two half integral cylinder-black-and-crankcase banks bolted together There may be a central camshaft to actuate the valve push-rods, or two camshafts - one for each bank -- may be more appropriate for high performance.

Fig.3 shows horizontal type of engine

3) Radial engine:

The radial engine is a reciprocating type internal combustion engine configuration in which the cylinders point outward from a central crankshaft like the spokes on a wheel. This configuration was very commonly used in large aircraft engines before most large aircraft started using turbine engines.

In a radial engine, the pistons are connected to the crankshaft with a master-and-articulating-rod assembly. One piston has a master rod with a direct attachment to the crankshaft. The remaining pistons pin their connecting rods` attachment to rings around the edge of the master rod. Four-stroke radials always have an odd number cylinders per row, so that a consistent every-other-piston firing order can be maintained, providing smooth operation.

This achieved by the engine talking two revolution of the crankshaft to complete the four stokes (intake, compression, power, exhaust), which means the firing order is 1,3,5,2,4 and back to cylinder 1 again. This means that there is always a two-piston gap between the piston on its
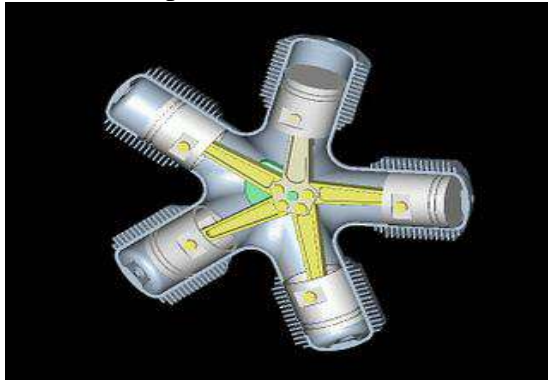

Fig.4 shows radial type of engine

power stroke and the next piston on fire (piston compression). If an even number of cylinders was uses, the firing order would be something similar to 1,3,5,2,4,6 which leaves a three-piston gap between firing piston on the first crank shaft revolution and only one-piston gap on the second. This leads to an uneven firing order within the engine, and is not ideal.

4) V-banked cylinders:

V engine or Vee engine is a common configuration for an internal combustion engine. The cylinders and pistons are aligned in two separate planes or "banks", is that they appear to be in a "V" when viewed along the axis of the crankshaft. The Vee configuration generally reduces the overall engine length, height and weight compared to the equivalent inline configuration.

Various cylinder bank angles of Vee are used in different engines depending on the number of the cylinders; there may be angles that work better than others for stability. Very narrow angles of V combine some of the advantages of the straight and V engine. The most common of V engines is V6. It is an engine with six cylinders mounted on the crankcase in two banks of three cylinders, usually set at either a right

angle or an accurate angle to each other, with all six pistons driving a common crankshaft. It is second common engine configuration in modern cars after the inline-four.

It is becoming more common as the space allowed in modern cars is reduced at the time as power requirements increase, and has largely replaced the inline-6, which is too long to fit in the many modern engine compartments. Although it is more complicated and not as smooth as the inline-6, the V6 is more rigid for a given weight, more compact and less prone to torsional vibrations in the crankshaft for a given displacement.

Fig.5 shows V banked type of engine

The most efficient cylinder bank angle for V6 is 60 degrees, minimizing size and vibration. While 60 degrees V6 are not as well balanced as inline-6 and flat-6 engines, modern techniques for designing and mounting engines have largely disguised their vibrations. Unlike most others angles, 60 degree V6 engines can be made acceptably smooth without the need for balance shafts.

The cylinder block ratio$(\frac{L_c}{D})$:-

The distance between the centre lines of adjacent cylinders in the cylinder block is determined by the ratio $\frac{L_c}{D}$.

Where L_c: is the distance between the centers of adjacent cylinders, D: cylinder diameter.

Engine type	$\frac{L_b}{D}$	
	Gasoline	Diesel
In-line with dry liners, double-span crankshaft main bearings	1.20-1.24	
In-line, single-span crankshaft main bearings	1.20-1.28	1.25-1.30
V-type with sliding friction main bearings	1.33	1.47-1.55
V-type with main roller bearings	1.30	1.30

1.4 Materials:

The cylinder block should be mad from materials which, when cast in a monobloc form, have adequate strength and rigidity in compression bending, torsion. This is essential so that the necessary support is provided against the gas loads and to the components which convert the reciprocating action of individual -cylinder's mechanisms into a single rotary action along the crankshaft length.

The desirable properties of a cylinder-block material are as follows:

➢ It should be relatively cheap,
➢ It should readily produce castings with good impressions,
➢ It should be easily machined,
➢ It should be rigid and strong enough in both bending and torsion,
➢ It should have good abrasion resistance,
➢ It should have good corrosion resistance,
➢ It should have low thermal expansion,
➢ It should have a high thermal conductivity,
➢ It should retain its strength at high operating temperatures,
➢ It should have a relatively low density.

Cast iron meets most of these requirements except that it has a low thermal conductivity and it is a comparatively heavy material because of these limitations with cast iron, there has been a trend for petrol engines to adopt light aluminum alloys as alternative cylinder-block materials. Cylinder liners may be incorporated in cast-iron blocks as an option, but they are essential with the relatively soft light aluminum alloys, which cannot be used directly for wear-resisting cylinders. To compensate for the lower strength of the aluminum alloys, the alloy blocks are cast with thicker sections and additional support ribs, which brings their relative weight to about half that of the equivalent cast iron blocks.

UNIGRAPHICS INTRODUCTION:

NX, also known as NX unigraphics or usually just u-g, is an advanced CAD/CAM/CAE software package developed by Siemens PLM software.

It is used, among other tasks, for:

• Design (parametric and direct solid/surface modelling)
• Engineering analysis (static, dynamic, electro-magnetic, thermal, using the finite element method, and fluid using the finite volume method).
• Manufacturing finished design by using included machining modules

First release of the new "next generation" version of unigraphics and i-deas, called NX. this will eventually bring the functionality and capabilities of both unigraphics and i-deas together into a single consolidated product.

Increasing complexity of products, development processes and design teams is challenging companies to find new tools and methods to deliver greater innovation and higher quality at lower cost. leading-edge technology from Siemens PLM software delivers greater power for today's design challenge. from innovative synchronous technology that unites parametric and history-free modeling, to NX active mockup for multi-cad assembly design, NX delivers breakthrough technology that sets new standards for speed, performance, and ease of use.

NX automates and simplifies design by leveraging the product and process knowledge that companies gain from experience and from industry best practices. it includes tools that designers can use to capture knowledge to automated repetitive tasks. the result is reduced cost and cycle time and improved quality.

Advantages of Solid Modeling:

Solid Modeling raises the level of expression so that designs can be defined in terms of engineering features, rather than lower-level CAD geometry. Features are parametrically defined for dimension-driven editing based on size and position.

Features:

➢ Powerful built-in engineering-oriented form features-slots, holes, pads, bosses, pockets-capture design intent and increase productivity

➢ Patterns of feature instances-rectangular and circular arrays-with displacement of individual features; all features in the pattern are associated with the master feature.

Blending and Chamfering:

➢ zero radius
➢ Ability to chamfer any edge
➢ Cliff-edge blends for designs that cannot accommodate complete blend radius but still require blends

Advanced Modeling Operations:

➢ Profiles can be swept, extruded or revolved to form solids

➢ Extremely powerful hollow body command turns solids into thin-walled designs in seconds; inner wall topology will differ from the outer wall, if necessary

➢ Fixed and variable radius blends may overlap surrounding faces and extend to a Tapering for modeling manufactured near-net shape parts

➢ User-defined features for common design elements (Unigraphics NX/User-Defined Features is required to define them in advance

General Operation:
Start with a Sketch

Use the Sketcher to freehand a sketch, and dimension an "outline" of Curves. You can then sweep the sketch using Extruded Body or Revolved Body to create a solid or sheet body. You can later refine the sketch to precisely represent the object of interest by editing the dimensions and by creating relationships between geometric objects. Editing a dimension of the sketch not only modifies the geometry of the sketch, but also the body created from the sketch.

Creating and Editing Features:

Feature Modeling lets you create features such as holes, slots and grooves on a model. You can then directly edit the dimensions of the feature and locate the feature by dimensions. For example, a Hole is defined by its diameter and length. You can directly edit all of these parameters by entering new values. You can create solid bodies of any desired design that can later be defined as a form feature using User Defined Features. This lets you create your own custom library of form features.

Associativity:

Associatively is a term that is used to indicate geometric relationships between individual portions of a model. These relationships are established as the designer uses various functions for model creation. In an associative model, constraints and relationships are captured automatically as the model is developed. For example, in an associative model, a through hole is associated with the faces that the hole penetrates. If the model is later changed so that one or both of those faces moves, the hole updates automatically due to its association with the faces. See Introduction to Feature Modeling for additional details.

Positioning a Feature:

Within Modeling, you can position a feature relative to the geometry on your model using Positioning Methods, where you position dimensions. The feature is then associated with that geometry and will maintain those associations whenever you

edit the model. You can also edit the position of the feature by changing the values of the positioning dimensions.

Expressions:

The Expressions tool lets you incorporate your requirements and design restrictions by defining mathematical relationships between different parts of the design. For example, you can define the height of a boss as three times its diameter, so that when the diameter changes, the height changes also.

Boolean Operations:

Modeling provides the following Boolean Operations: Unite, Subtract, and Intersect. Unite combines bodies, for example, uniting two rectangular blocks to form a T-shaped solid body. Subtract removes one body from another, for example, removing a cylinder from a block to form a hole. Intersect creates a solid body from material shared by two solid bodies. These operations can also be used with free form features called sheets.

Undo:

You can return a design to a previous state any number of times using the Undo function. You do not have to take a great deal of time making sure each operation is absolutely correct, because a mistake can be easily undone. This freedom to easily change the model lets you cease worrying about getting it wrong, and frees you to explore more possibilities to get it right.

Additional Capabilities:

Other Unigraphics NX applications can operate directly on solid objects created within Modeling without any translation of the solid body. For example, you can perform drafting, engineering analysis, and NC machining functions by accessing the appropriate application. Using Modeling,

you can design a complete, unambiguous, three dimensional model to describe an object. You can extract a wide range of physical properties from the solid bodies, including mass properties. Shading and hidden line capabilities help you visualize complex assemblies. You can identify interferences automatically, eliminating the need to attempt to do so manually. Hidden edge views can later be generated and placed on drawings. Fully associative dimensioned drawings can be created from solid models using the appropriate options of the Drafting application. If the solid model is edited later, the drawing and dimensions are updated automatically.

Parent/Child Relationships:

If a feature depends on another object for its existence, it is a child or dependent of that object. The object, in turn, is a parent of its child feature. For example, if a HOLLOW (1) is created in a BLOCK (0), the block is the parent and the hollow is its child. A parent can have more than one child, and a child can have more than one parent. A feature that is a child can also be a parent of other features. To see all of the parent-child relationships between the features in your work part, open the Part Navigator.

Creating a Solid Model:

Modeling provides the design engineer with intuitive and comfortable modeling techniques such as sketching, feature based modeling, and dimension driven editing. An excellent way to begin a design concept is with a sketch. When you use a sketch, a rough idea of the part becomes represented and constrained, based on the fit and function requirements of your design. In this way, your design intent is captured. This ensures that when the design is passed down to the next level of engineering, the basic requirements are not lost when the design is edited.

The strategy you use to create and edit your model to form the desired object depends on the form and complexity of the object. You will likely use several different methods during a work session. The next several figures illustrate one example of the design process, starting with a sketch and ending with a finished model. First, you can create a sketch "outline" of curves. Then you can sweep or rotate these curves to create a complex portion of your design.

Introduction to Drafting:

The Drafting application is designed to allow you to create and maintain a variety of drawings made from models generated from within the Modeling application. Drawings created in the Drafting application are fully associative to the model. Any changes made to the model are automatically reflected in the drawing. This Associativity allows you to make as many model changes as you wish. Besides the powerful Associativity functionality, Drafting contains many other useful features including the following:

➢ An intuitive, easy to use, graphical user interface. This allows you to create drawings quickly and easily.

➢ A drawing board paradigm in which you work "on a drawing." This approach is similar to the way a drafter would work on a drawing board. This method greatly increases productivity.

➢ Support of new assembly architecture and concurrent engineering. This allows the drafter to make drawings at the same time as the designer works on the model.

➢ The capability to create fully associative cross-sectional views with automatic hidden line rendering and crosshatching.

➢ Automatic orthographic view alignment. This allows you to quickly place views on a drawing, without having to consider their alignment.

➢ Automatic hidden line rendering of drawing views.

➢ The ability to edit most drafting objects (e.g., dimensions, symbols, etc.) from the graphics window. This allows you to create drafting objects and make changes to them immediately.

➢ On-screen feedback during the drafting process to reduce rework and editing.

➢ User controls for drawing updates, which enhance user productivity.

Finally, you can add form features, such as chamfers, holes, slots, or even user defined features to complete the object.

Updating Models:

A model can be updated either automatically or manually. Automatic updates are performed only on those features affected by an appropriate change (an edit operation or the creation of certain types of features). If you wish, you can delay the automatic update for edit operations by using the Delayed Update option. You can manually trigger an update of the entire model. You might, for example, want to use a net null update to check whether an existing model will successfully update in a new version of Unigraphics NX before you put a lot of additional work into modifying the model. (A net null update mechanism forces a complete update of a model, without changing it.)

The manual methods include:

➢ The Unigraphics NX Open C and C++ Runtime function, UF_MODEL. Update all features, which logs all the features in the current work part to the Unigraphics NX update list, and then performs an update. See the Unigraphics NX Open C and C++ Runtime Reference Help for more information.

➢ The Playback option on the Edit Feature dialog, which recreates the model, starting at its first feature. You can step through the model as it is created one feature at a time, move forward or

backward to any feature, or trigger an update that continues until a failure occurs or the model is complete.

The Edit during Update dialog, which appears when you choose Playback, also includes options for analyzing and editing features of the model as it is recreated (especially useful for fixing problems that caused update failures).Methods that users have tried in the past that has led to some problems or is tricky to use:

➢ One method uses the Edit Feature dialog to change the value of a parameter in each root feature of a part, and then change it back before leaving the Edit Feature dialog. This method produces a genuine net null update if used correctly, but you should ensure that you changed a parameter in every root feature (and that you returned all the parameters to their original values) before you trigger the update.

➢ Another method, attempting to suppress all of the features in a part and then unsuppressed them, can cause updates that are not net null and that will fail. The failures occur because not all features are suppressible; they are left in the model when you try to suppress all features. As the update advances, when it reaches the point where most features were suppressed, it will try to update the features that remain (this is like updating a modified version of the model). Some of the "modifications" may cause the remaining features to fail. For these reasons, we highly recommend that you do not attempt to update models by suppressing all or unsurprising all features. Use the other options described here, instead.

Assemblies concepts:
Components:

Assembly part files point to geometry and features in the subordinate parts rather than creating duplicate copies of those objects at each level in the assembly. This technique not only minimizes the size of assembly parts files, but also provides high levels of Associativity. For example, modifying the geometry of one component causes all assemblies that use that component in the session to automatically reflect that change. Some properties, such as translucency and partial shading (on the Edit Object Display dialog), can be changed directly on a selected component. Other properties are changed on selected solids or geometry within a component. Within an assembly, a particular part may be used in many places. Each usage is referred to as a component and the file containing the actual geometry for the component is called the component part.

Top-down or Bottom-up Modeling:

You are not limited to any one particular approach to building the assembly. You can create individual models in isolation, and then later add them to assemblies (bottom-up), or you can create them directly at the assembly level (top-down). For example, you can initially work in a top-down fashion, and then switch back and forth between bottom-up and top-down modeling.

Design in Context:

When the displayed part is an assembly, it is possible to change the work part to any of the components within that assembly (except for unloaded parts and parts of different units). Geometry features, and components can then be added to or edited within the work part. Geometry outside of the work part can be referenced in many modeling operations. For example, control points on geometry outside of the work part can be used to position a feature within the work part. When an object is designed in context, it is added to the reference set used to represent the work part.

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Associativity Maintained:

Geometric changes made at any level within an assembly result in the update of associated data at all other levels of affected assemblies. An edit to an individual piece part causes all assembly drawings that use that part to be updated appropriately. Conversely, an edit made to a component in the context of an assembly results in the update of drawings and other associated objects (such as tool paths) within the component part. See the next two figures for examples of top-down and bottom-up updates.

Mating Conditions:

Mating conditions let you position components in an assembly. This mating is accomplished by specifying constraint relationships between two components in the assembly. For example, you can specify that a cylindrical face on one component is to be coaxial with a conical face on another component. You can use combinations of different constraints to completely specify a component's position in the assembly. The system considers one of the components as fixed in a constant location, then calculates a position for the other component which satisfies the specified constraints. The relationship between the two components is associative. If you move the fixed component's location, the component that is mated to it also moves when you update. For example, if you mate a bolt to a hole, if the hole is moved, the bolt moves with it.

Using Reference Sets to Reduce the Graphic Display:

Large, complex assemblies can be simplified graphically by filtering the amount of data that is used to represent a given component or subassembly by using reference sets. Reference sets can be used to drastically reduce (or even totally eliminate) the graphical representation of portions of the assembly without modifying the actual assembly structure or underlying geometric

models. Each component can use a different reference set, thus allowing different representations of the same part within a single assembly. The figure below shows an example of a bushing component used twice in an assembly, each displayed with a different reference set. When you open an assembly, it is automatically updated to reflect the latest versions of all components it uses. Load Options lets you control the extent to which changes made by other users affect your assemblies. Drawings of assemblies are created in much the same way as piece part drawings. You can attach dimensions, ID symbols and other drafting objects to component geometry. A parts list is a table summarizing the quantities and attributes of components used in the current assembly. You can add a parts list to the assembly drawing along with associated callout symbols, all of which are updated as the assembly structure is modified. See the following figure.

Machining of Assemblies:

Assembly parts may be machined using the Manufacturing applications. An assembly can be created containing all of the setup, such as fixtures, necessary to machine a particular part. This approach has several advantages over traditional methods:

➢ It avoids having to merge the fixture geometry into the part to be machined.
➢ It lets the NC programmer generate fully associative tool paths for models for which the programmer may not have write access privilege.

It enables multiple NC programmers to develop NC data in separate files simultaneously.

1.7 HISTORY OF FINITE ELEMENT METHOD

The Basic concept in FEM is that the body or structure may be divided into

smaller elements of finite dimensions called "Finite Elements". The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called "Nodes" or "Nodal Points". Simple functions are chosen to approximate the displacements over each finite element. Such assumed functions are called "shape functions". This will represent the displacement within the element in terms of the displacement at the nodes of the element.

The Finite Element Method is a mathematical tool for solving ordinary and partial differential equations. Because it is a numerical tool, it has the ability to solve the complex problems that can be represented in differential equations form. The applications of FEM are limitless as regards the solution of practical design problems.

Due to high cost of computing power of years gone by, FEM has a history of being used to solve complex and cost critical problems. Classical methods alone usually cannot provide adequate information to determine the safe working limits of a major civil engineering construction or an automobile or an aircraft. In the recent years, FEM has been universally used to solve structural engineering problems. The departments, which are heavily relied on this technology, are the automotive and aerospace industry. Due to the need to meet the extreme demands for faster, stronger, efficient and lightweight automobiles and aircraft, manufacturers have to rely on this technique to stay competitive.

FEA has been used routinely in high volume production and manufacturing industries for many years, as to get a product design wrong would be detrimental. For example, if a large manufacturer had to recall one model alone due to a hand brake design fault, they would end up having to replace up to few millions of hand brakes. This will cause a heavier loss to the company.

The finite element method is a very important tool for those involved in engineering design; it is now used routinely to solve problems in the following areas.

- Structural analysis
- Thermal analysis
- Vibrations and Dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mold flow simulations

Nowadays, even the most simple of products rely on the finite element method for design evaluation. This is because contemporary design problems usually cannot be solved as accurately & cheaply using any other method that is currently available. Physical testing was the norm in the years gone by, but now it is simply too expensive and time consuming also.
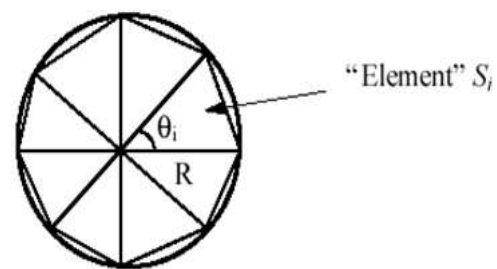
"Element" S_i

Basic Concepts: The Finite Element Method is based on the idea of building a complicated object with simple blocks, or, dividing a complicated object into small and manageable pieces. Application of this simple idea can be found everywhere in everyday life as well as engineering. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

Area of one Triangle: $S_i = \frac{1}{2} * R2 * \sin \theta I$

Area of the Circle: SN = ½ * R2 * N * Sin (2 ∏ / N) → ∏ R2 as N → ∞
 Where N = total number of triangles (elements)

If one needs to evaluate the area of the circle without using the conventional formula, one of the approaches could be to divide the above area into a number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

LITERATURE REVIEW

1) Structure Analysis and Improvement of Diesel Engine Block by Weineng Zhang, Xiaohui Cao, In this project, The finite element analytical model of a diesel engine is established to analyze the stress, the flatness, the roundness and the rate of light leakage of the diesel engine block .The analysis result shows that the optimized scheme improves the body's stress concentration and deformation obviously: the tensile stress between the upper cylinder sleeve shoulders spigot and the counter bore of cylinder head bolt decreases by 15% compares to the original diesel engine block. The maximum stress decreases obviously and the stress concentration region moves down slightly by changing the "T" type stiffener above the head of the block into rectangular stiffener; the flatness of the end surface of cylinder liner spigot decreases by 11.3%; the circularity and the rate of light leakage of each cross section on cylinder liner decreases obviously.

2) Design a four-cylinder Internal Combustion Engine by Radoslav Plamenov Georgiev and Dr. Pedro Villanueva Roldan Dk, The aim of this Thesis is to introduce to the interesting world of internal combustion engines and to describe what actually Internal Combustion Engine is. What are its main components and structure? How the engine indeed operates. Also to design a real engine, having into account all necessary calculations concerning with kinematics, dynamics and strength calculation of basic details. Another purpose of the project is to define the proper materials for each part. Next to that I will make 2D and 3D drawings on UNIGRAPHICS and animation of working Internal Combustion Engine.

3) Finite element analysis of the dynamic behavior of an engine block and comparison with experimental modal test results by Walter ott, Hans-Jurgen Kaiser, Jurgen Meyer,Ford-Werke AG,Koln, In this project, the combustion engine is the main source of noise and vibration in modern vehicles. Today the finite element method (FEM) is the main important CAE tool to assist the engineer in the early stage of the development of an engine structure. The generation of the model is the most time consuming part of the FEM analysis. For reliable predications a good compromise must be found between modeling effort and necessary accuracy of results. In this paper, two shell-solid element models and two solid element models of a typical 4-cylinder in-line engine block are compared. The natural modes for these four models were calculated up to 2kHz with MSC/NASTRAN SOL3 AND SOL63 respectively. The analytical results have been compared with modal test data. The assessment of the calculated eigenvectors was based on computer animation of the mode shapes and the evaluation of the MAC(modal assurance criteria) values. The shell-solid models show a good agreement with the measured frequencies, whereas the solid models produce too high frequencies especially for the torsion modes.

PROBLEM DEFINIION & SOLUTION METHODOLOGY

In this paper, a research on static and dynamic behavior of a diesel engine block is carried out in Finite Element Method (FEM) for grey cast iron. Stresses obtained by FEM calculation. Based on the results, the stress positions on this block are identified to reduce the weight of engine. Analysis is carried on model for Carbon/Epoxy.

In this study NX-CAD software is used for 3Dmodeling of Engine block, ANSYS software shall be used for the finite element analysis of an Engine block.

The methodology followed in my project is as follows:

➤ Create a 3D model of the Engine block by using NX-CAD software.
➤ Perform static analysis on Engine block using ANSYS software and obtain the deflections and von mises stresses values produced in the Engine block.
➤ Modal analysis of engine block done for estimating natural frequencies(free vibrations).
➤ Harmonic analysis of engine block done for estimating natural forced vibrations.

3D MODELLING OF ENGINE BLOCK

The 3D model of the Engine block is created using UNIGRAPHICS NX software from the 2d drawings. UNIGRAPHICS NX is the world's leading 3D product development solution. This software enables designers and engineers to bring better products to the market faster. It takes care of the entire product definition to serviceability. NX delivers measurable value to manufacturing companies of all sizes and in all industries.

For this Engine block design, 2D Drawing inputs are taken from previous standard journal only. The Engine block model is single body consists of cylinders, cooling jackets, studs,etc.

The CAD model of the engine block is shown below:

2D drawing:
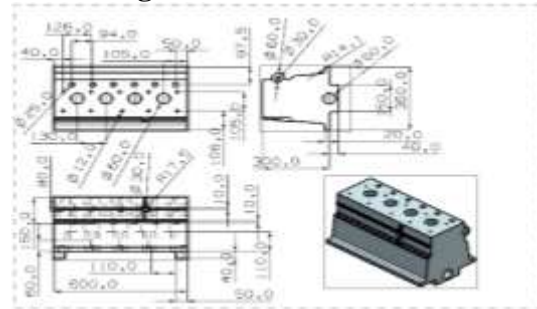
Fig.6 shows the drafting of engine block

3D model is generated from 2D input using Unigraphics software.

➤ The total length of engine block =600mm
➤ The height of engine block =300mm
➤ The width of engine block =350mm
➤ The core diameter of cylinder=60mm
➤ Thickness of cylinder =8mm
➤ Diameter of the studs =12mm
➤ The distance between the adjacent cylinders = 130mm
➤ Length of the cylinder =120mm

3D modeling:
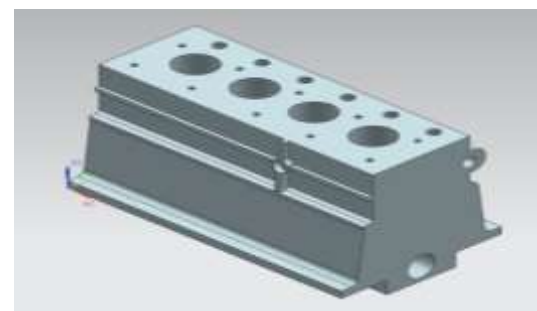
Fig.7 shows CAD model of the inlet manifold

3D MODEL OF ENGINE BLOCK:
Front view of Engine block:
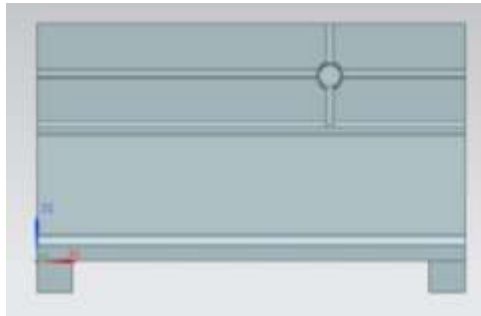
Fig.8 Shows the Front view of Engine block
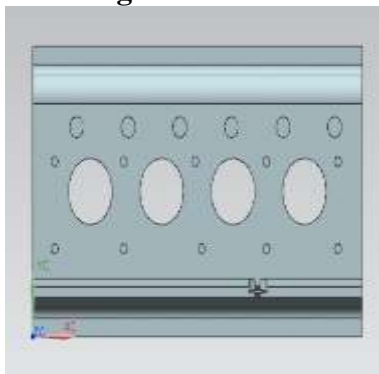
Top view of Engine block:

Fig.9 Shows the Top view of Engine block

Right view of Engine block:

Fig.10 Shows the Right view of Engine block

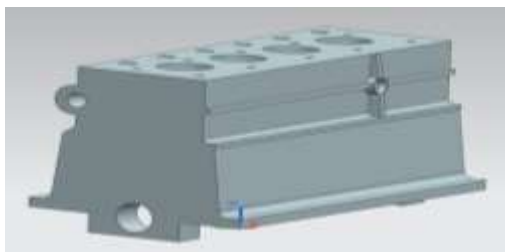**Isometric view of Engine block:**

Fig.11 Shows the Isometric view of Engine block

FINITE ELEMENT ANALYSIS OF ENGINE BLOCK

STRUCTURAL ANALYSIS OF ENGINE BLOCK

Finite Element Modeling (FEM) and Finite Element Analysis (FEA) are two most popular mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is perhaps the most popular numerical technique for solving engineering problems. The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems and designs where closed form solutions are governing equilibrium equations are not available. In addition it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

FINITE ELEMENT METHOD

The FEM is numerical analysis technique for obtaining approximate solutions to wide variety of engineering problems. The method originated in the aerospace industry as a tool to study stresses in complicated airframe structures. It grew out of what was called the matrix analysis method used in aircraft design. The method has gained popularity among both researchers and practitioners and after so many developments codes are developed for wide variety of problems.

METHODS OF PERFORMING STRUCTURAL ANALYSIS

To perform an accurate analysis a structural engineer must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural

analysis may examine dynamic response, stability and non-linear behavior.

There are three approaches to the analysis: the mechanics of materials approach (also known as strength of materials), the elasticity theory approach (which is actually a special case of the more general field of continuum mechanics), and the finite element approach. The first two make use of analytical formulations which apply mostly to simple linear elastic models, lead to closed-form solutions, and can often be solved by hand. The finite element approach is actually a numerical method for solving differential equations generated by theories of mechanics such as elasticity theory and strength of materials. However, the finite-element method depends heavily on the processing power of computers and is more applicable to structures of arbitrary size and complexity.

STRENGTH OF MATERIALS APPRAOCH (CLASSICAL METHODS)

The simplest of the three methods here discussed, the mechanics of materials method is available for simple structural members subject to specific loadings such as axially loaded bars, prismatic beams in a state of pure bending, and circular shafts subject to torsion. The solutions can under certain conditions be superimposed using the superposition principle to analyze a member undergoing combined loading. Solutions for special cases exist for common structures such as thin-walled pressure vessels. The solutions are based on linear isotropic infinitesimal elasticity and Euler-Bernoulli beam theory.

FINITE ELEMENT METHOD APPRAOCH

Finite element method models a structure as an assembly of elements or components with various forms of connection between them. Thus, a continuous system such as a plate or shell is modeled as a discrete system with a finite number of elements interconnected at finite number of nodes.

The behavior of individual elements is characterized by the element's stiffness or flexibility relation, which altogether leads to the system's stiffness or flexibility relation. To establish the element's stiffness or flexibility relation, we can use the mechanics of materials approach for simple one-dimensional bar elements, and the elasticity approach for more complex two- and three-dimensional elements. The analytical and computational development is best effected throughout by means of matrix algebra.

STRUCTURAL ANALYSIS

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses.

Objective: Perform Finite element analysis of an engine block under pressure conditions. Characteristics of stress distribution and high stress locations are determined from the analysis. NX-CAD software is used for 3D modeling of the engine block model and ANSYS software is used to perform the structural analysis of the engine block.

STATIC ANALYSIS OF ENGINE BLOCK

A static analysis can however include steady inertia loads and time varying loads that can be approximated as static equivalent loads. The 3d model of the engine block is created in NX-CAD and converted into parasolid. The parasolid file

is imported into ANSYS and finite element analysis is carried out using ANSYS software.
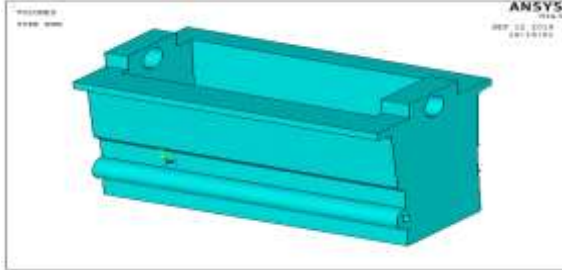

Fig.12 shows the geometric model of the Engine block

MATERIAL PROPERTIES:

➤ **Carbon/Graphite fibers:** its advantages include high specific strength and modulus, low coefficient of thermal expansion, and high fatigue strength. Graphite, when used alone has low impact resistance. Its drawbacks include high cost, low impact resistance, and high electrical conductivity.

S. No	Property	Units	HM Carbon/Epoxy
1.	E_{11}	GPa	190.0
2.	E_{22}	GPa	7.7
3.	G_{12}	GPa	4.2
4.	v_{12}	-	0.3
5.	$S^t_1 = S^c_1$	MPa	870.0
6.	$S^t_2 = S^C_2$	MPa	94.0
7.	S_{12}	MPa	30.0
8.	ρ	Kg/m^3	1600.0

Table. Properties of HM Carbon/Epoxy

SOLID187 Element Description

SOLID187 has a quadratic displacement behavior and is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element also has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

Fig.13 shows the meshed model of Engine block

BOUNDARY CONDITIONS:

➤ Stud locations at the bottom of engine block are constrained in all Dof.
➤ Pressure load of 0.7MPa is applied on inner surface of cylinder.
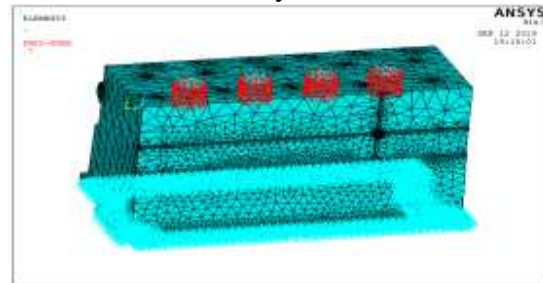
Fig.14 shows the applied boundary conditions and pressure of Engine block

RESULTS

DEFLECTION:

The Max. Deformation observed 0.0004mm on Engine block in X-dir.
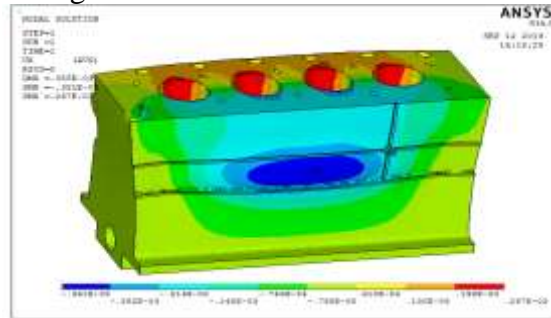
Fig.15 shows the deformation of Engine block in X-dir

The Max. Deformation observed 0.0003mm on Engine block in Y-dir.

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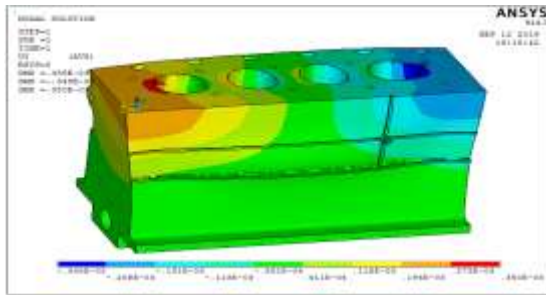
Fig.16 shows the deformation of Engine block in Y-dir

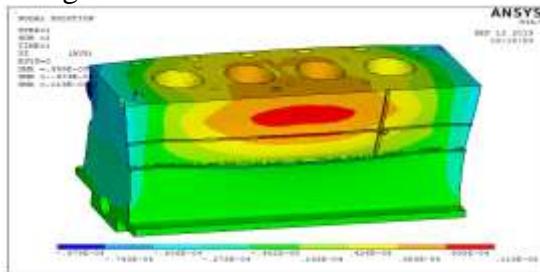The Max. Deformation observed 0.0002mm on Engine block in Z-dir.

Fig.17 shows the deformation of Engine block in Z-dir

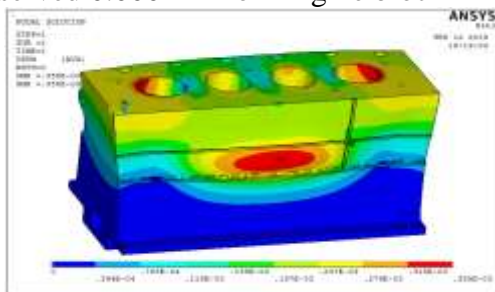The Max.Displacement vector sum observed 0.0004mm on Engine block

Fig.18 shows the Max. Displacement of Engine block

STRESS

The Max. Von Mises Stress observed 5.35MPa on Engine block
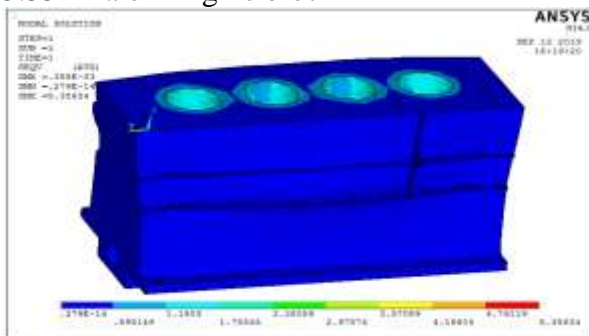
Fig.22 shows the Von Mises stress of Engine block

Table.1 shows the max.Deflection and Max.Stress

DEFLECTION (mm)				
UX	UY	UZ	USUM	Von mises
0.0004	0.0003	0.0002	0.0004	5.36MPa

From the above analysis:

➤ The Max Deflection and the Max Avg. Von Mises Stress observed on the Engine block for applied pressure is 0.00038mm and 5.36MPa with respectively. And the Yield strength of the material metal Carbon/Epoxy is 800MPa.

➤ Hence according to the Maximum Yield Stress Theory, the Von Mises stress is less than the yield strength of the material. The design of Engine block is safe for the above operating load

MODAL ANALYSIS OF ENGINE BLOCK

Modal Analysis

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a Seismic analysis.

The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. They are also required if you want to do a spectrum analysis or a mode superposition harmonic or transient analysis.
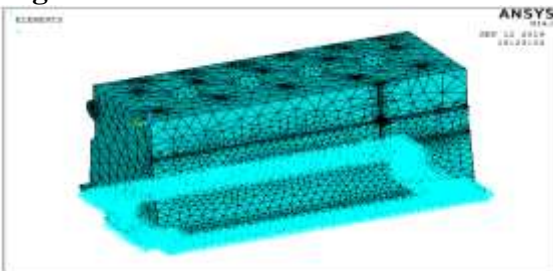
Imported engine block model
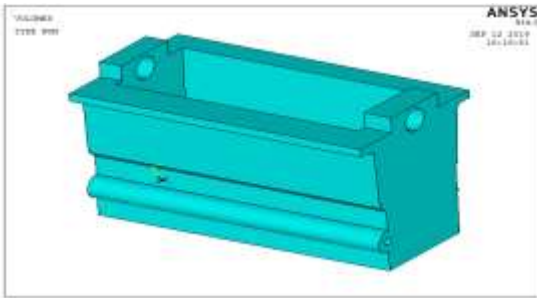
Mesh model


**Applied fixed condition at bottom of engine block**

Results

Modes are inherent properties of a structure, and are determined by the material properties (mass, damping, and stiffness), – and boundary conditions of the structure. Each mode is defined by a natural (modal or resonant) frequency, modal damping, and a mode shape (i.e. the so-called "modal parameters"). If either the material

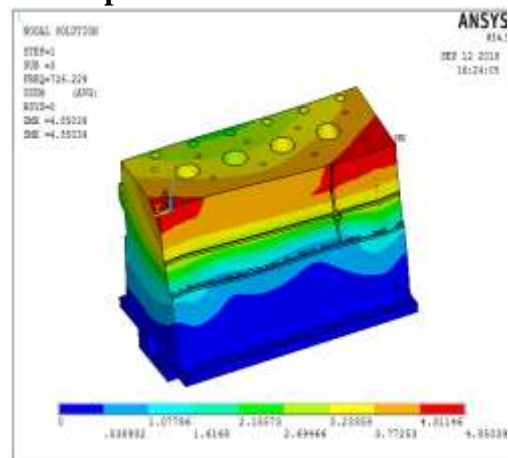properties or the boundary conditions of a structure change, its modes will change.

Mode shape-1
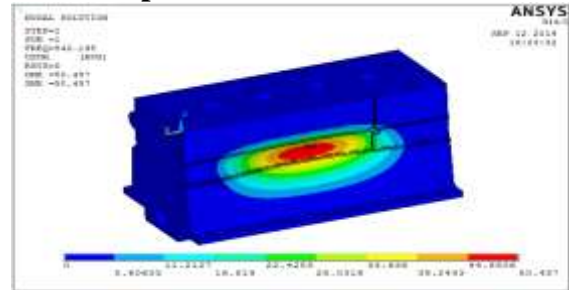
Mode shape-2
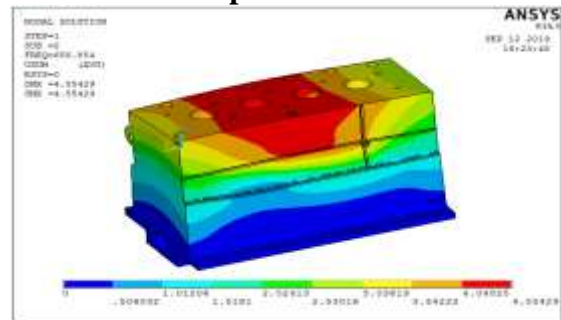
Mode shape-3

HARMONIC ANALYSIS OF ENGINE BLOCK

A *harmonic analysis* is used to determine the response of the structure under a steady-state sinusoidal (harmonic) loading at a given frequency.

A harmonic, or frequency-response, analysis considers loading at one frequency only. Loads may be out-of-phase with one another, but the excitation is at a known frequency. This procedure is not used for an arbitrary transient load.

– One should *always* run a free vibration analysis prior to a harmonic analysis to obtain an understanding of the dynamic characteristics of the model.
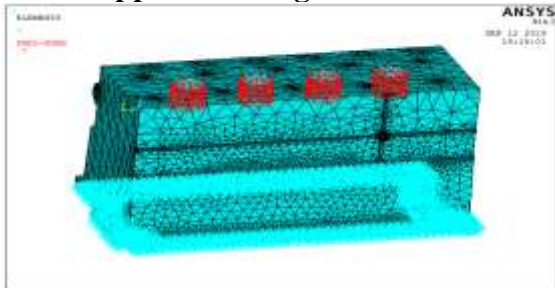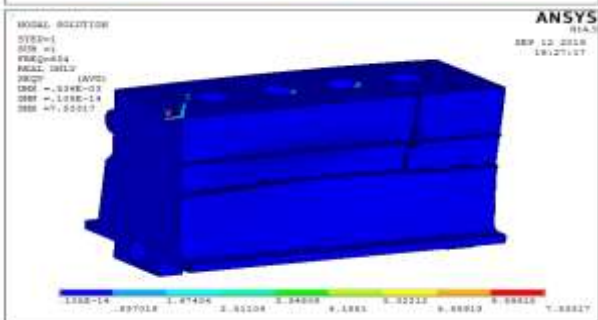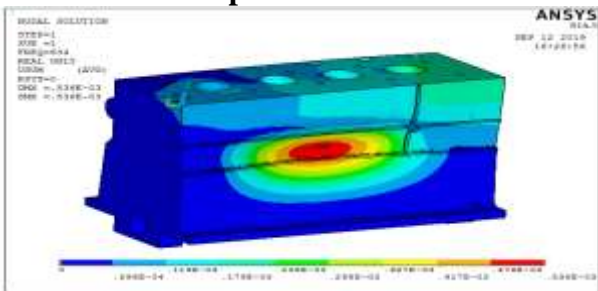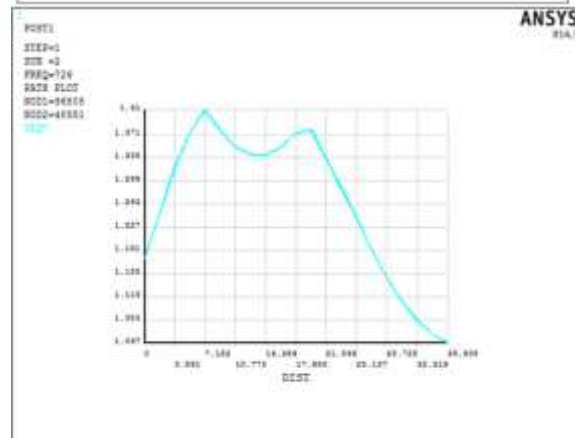
Imported model in Ansys
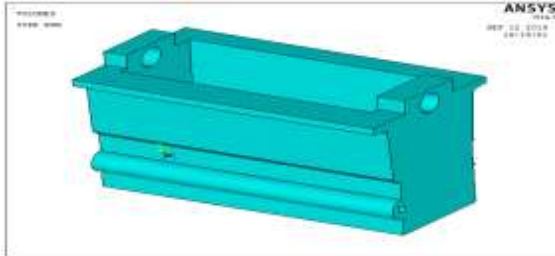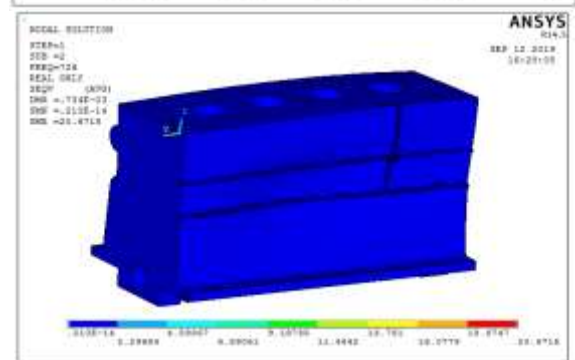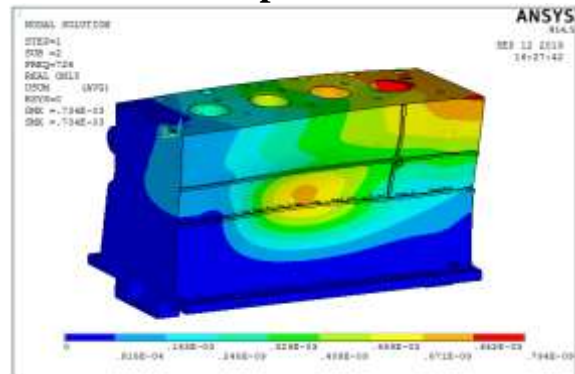

Mesh model
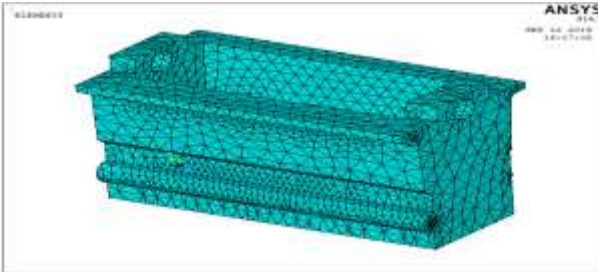
Applied loading condition

Mode shape-1

Mode shape-2

Frequency response

RESULTS AND CONCLUSION

RESULTS OF ENGINE BLOCK:

Engine block is subjected to structural analysis. The following observations are observed from structural analysis.

There is a case to study the Engine block for structural behavior:

➢ Static analysis
➢ MODAL Analysis
➢ Harmonic analysis

From the static analysis:

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➢ The Max Deflection and the Max Avg. Von Mises Stress observed on the Engine block for applied pressure is 0.00038mm and 5.36MPa with respectively. And the Yield strength of the material metal Carbon/Epoxy is 800MPa.

➢ Hence according to the Maximum Yield Stress Theory, the Von Mises stress is less than the yield strength of the material. The design of Engine block is safe for the above operating loads.

CONCLUSION

In the present project an engine block has been designed and analyzed for structural behaviors.

From the structural analysis results it is concluded that the Engine block has stresses and deflections within the design limits of the material used. The deflections and stresses obtained in the harmonic analysis are also under the design limits of the material.

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