

# DESIGN AND THERMAL ANALYSIS OF PISTON

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## ABSTRACT

This project mainly deals with the design and analysis of piston. Piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders among other similar mechanisms. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. Here the piston is designed and analysis has been studied.

Piston temperature has considerable influence on efficiency, emission, performance of the SI engine. Purpose of the investigation is measurement of piston transient temperature at several points on the piston, from cold start to steady condition and comparison with the results of finite element analysis. In this project the piston is modeled and assembled with the help of CATIA software and the component is meshed and analysis is done in ANSYS software and the thermal and static behavior is studied and the results are tabulated. The various stresses acting on the piston under various loading conditions has been studied. Coupled field analysis (i.e) structural + thermal is done on the piston to verify the strength. The analysis is done using two different materials Aluminum-boron and Aluminium-5045. Comparison is done for the two materials to verify the better material for our designed piston.

In the preset, thesis work has been taken up on the following aspects to cover the research gaps and to present the results based on the systematic studies :

- Temperature distribution and heat flow through the piston of an engine.
- FEA analysis of the piston to measure temperature at the points where it is not possible to find out practically and to observe the heat flow inside the piston.

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## **CHAPTER-1**

### **INTRODUCTION**

#### **1.1 I.C ENGINE**

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

The term *internal combustion engine* usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with variants, such as the Winkle rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described.

The internal combustion engine (or ICE) is quite different from external combustion engines, such as steam or Sterling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in some kind of boiler.

A large number of different designs for ICEs have been developed and built, with a variety of different strengths and weaknesses. Powered by an energy-dense fuel (which is

very frequently gasoline, a liquid derived from fossil fuels). While there have been and still are many stationary .

applications, the real strength of internal combustion engines is in mobile applications and they dominate as a power supply for cars, aircraft, and boats, from the smallest to the largest.

## **INTRODUCTION TO PISTON**

Automobile components are in great demand these days because of increased use of automobiles. The increased demand is due to improved performance and reduced cost of these components. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products . A piston is a component to reciprocating IC-engines. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. As an important part in an engine, piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head/crown cracks and so on. The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure. On the other hand piston over heating-seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall.

A *piston* is a cylindrical engine component that slides back and forth in the cylinder bore by forces produced during the combustion process. The piston acts as a movable end of the combustion chamber. The stationary end of the combustion chamber is the cylinder head. Pistons are commonly made of a cast aluminum alloy for excellent and lightweight thermal conductivity. *Thermal conductivity* is the ability of a material to conduct and transfer heat.

Aluminum expands when heated, and proper clearance must be provided to maintain free piston movement in the cylinder bore. Insufficient clearance can cause the piston to seize in the cylinder. Excessive clearance can cause a loss of compression and an increase in piston noise.

Piston features include the piston head, piston pin bore, piston pin, skirt, ring grooves, ring lands, and piston rings. The *piston head* is the top surface (closest to the cylinder head) of the piston which is subjected to tremendous forces and heat during normal engine operation.

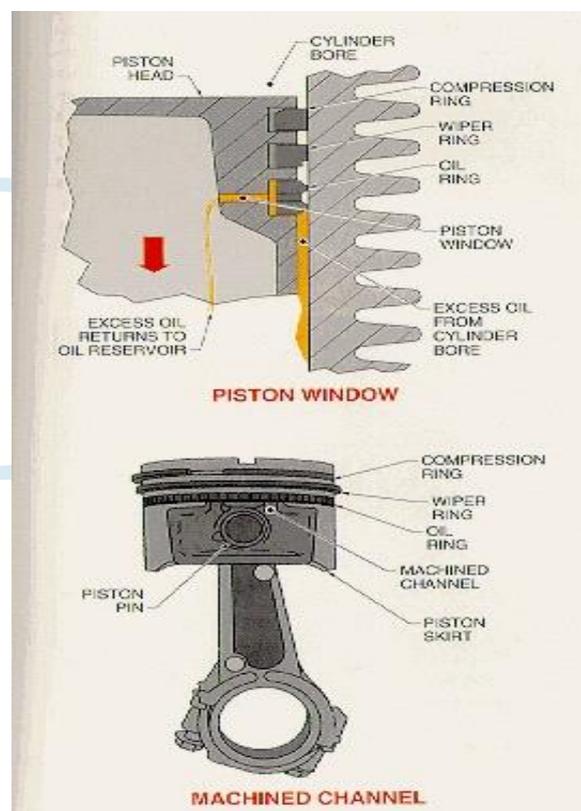
A *piston pin bore* is a through hole in the side of the piston perpendicular to piston travel that receives the piston pin. A *piston pin* is a hollow shaft that connects the small end of the connecting rod to the piston. The *skirt* of a piston is the portion of the piston closest to the crankshaft that helps align the piston as it moves in the cylinder bore. Some skirts have profiles cut into them to reduce piston mass and to provide clearance for the rotating crankshaft counterweights.

A *ring groove* is a recessed area located around the perimeter of the piston that is used to retain a piston ring. *Ring lands* are the two parallel surfaces of the ring groove which function as the sealing surface for the piston ring. A *piston ring* is an expandable split ring used to provide a seal between the piston and the cylinder wall. Piston rings are commonly made from cast iron. Cast iron retains the integrity of its original shape under heat, load, and other dynamic forces. Piston rings seal the combustion chamber, conduct heat from the piston to the cylinder wall, and return oil to the crankcase. Piston ring size and configuration vary depending on engine design and cylinder material.

Piston rings commonly used on small engines include the compression ring, wiper ring, and oil ring. A *compression ring* is the piston ring located in the ring groove closest to the piston head. The compression ring seals the combustion chamber from any leakage during the combustion process. When the air-fuel mixture is ignited, pressure from combustion gases is applied to the piston head, forcing the piston toward the crankshaft. The pressurized gases travel through the gap between the cylinder wall and the piston and into the piston ring groove. Combustion gas pressure forces the piston ring against the cylinder wall to form a seal. Pressure applied to the piston ring is approximately proportional to the combustion gas pressure.

A *wiper ring* is the piston ring with a tapered face located in the ring groove between the compression ring and the oil ring. The wiper ring is used to further seal the combustion chamber and to wipe the cylinder wall clean of excess oil. Combustion gases that pass by the compression ring are stopped by the wiper ring.

An *oil ring* is the piston ring located in the ring groove closest to the crankcase. The oil ring is used to wipe excess oil from the cylinder wall during piston movement. Excess oil is returned through ring openings to the oil reservoir in the engine block. Two-stroke cycle engines do not require oil rings because lubrication is supplied by mixing oil in the gasoline, and an oil reservoir is not required.



**Figure 4 - Piston Rings**

Piston rings seal the combustion chamber, transferring heat to the cylinder wall and controlling oil consumption. A piston ring seals the combustion chamber through inherent and applied pressure. Inherent pressure is the internal spring force that expands a piston ring based on the design and properties of the material used. Inherent pressure requires a

significant force needed to compress a piston ring to a smaller diameter. Inherent pressure is determined by the uncompressed or free piston ring gap. Free piston ring gap is the distance between the two ends of a piston ring in an uncompressed state. Typically, the greater the free piston ring gap, the more force the piston ring applies when compressed in the cylinder bore.

A piston ring must provide a predictable and positive radial fit between the cylinder wall and the running surface of the piston ring for an efficient seal. The radial fit is achieved by the inherent pressure of the piston ring. The piston ring must also maintain a seal on the piston ring lands.

In addition to inherent pressure, a piston ring seals the combustion chamber through applied pressure. Applied pressure is pressure applied from combustion gases to the piston ring, causing it to expand. Some piston rings have a chamfered edge opposite the running surface. This chamfered edge causes the piston ring to twist when not affected by combustion gas pressures.

Another piston ring design consideration is cylinder wall contact pressure. This pressure is usually dependent on the elasticity of the piston ring material, free piston ring gap, and exposure to combustion gases. All piston rings used by Briggs & Stratton engines are made of cast iron. Cast iron easily conforms to the cylinder wall. In addition, cast iron is easily coated with other materials to enhance its durability. Care must be exercised when handling piston rings, as cast iron is easily distorted. Piston rings commonly used on small engines include the compression ring, wiper ring, and oil ring.

### **Compression Ring**

The compression ring is the top or closest ring to combustion gases and is exposed to the greatest amount of chemical corrosion and the highest operating temperature. The compression ring transfers 70% of the combustion chamber heat from the piston to the cylinder wall. Most Briggs & Stratton engines use either taper-faced or barrel-faced compression rings. A taper faced compression ring is a piston ring that has approximately a  $1^\circ$  taper angle on the running surface. This taper provides a mild wiping action to prevent any excess oil from reaching the combustion chamber.

A barrel faced compression ring is a piston ring that has a curved running surface to provide consistent lubrication of the piston ring and cylinder wall. This also provides a wedge effect to optimize oil distribution throughout the full stroke of the piston. In addition, the curved running surface reduced the possibility of an oil film breakdown due to excess pressure at the ring edge or excessive piston tilt during operation.

### **Wiper Ring**

The wiper ring, sometimes called the scraper ring, Napier ring, or back-up compression ring, is the next ring away from the cylinder head on the piston. The wiper ring provides a consistent thickness of oil film to lubricate the running surface of the compression ring. Most wiper rings in Briggs & Stratton engines have a taper angle face. The tapered angle is positioned toward the oil reservoir and provides a wiping action as the piston moves toward the crankshaft.

The taper angle provides contact that routes excess oil on the cylinder wall to the oil ring for return to the oil reservoir. A wiper ring incorrectly installed with the tapered angle closest to the compression ring results in excessive oil consumption. This is caused by the wiper ring wiping excess oil toward the combustion chamber.

### **Oil Ring**

An oil ring includes two thin rails or running surfaces. Holes or slots cut into the radial center of the ring allow the flow of excess oil back to the oil reservoir. Oil rings are commonly one piece, incorporating all of these features. Some on-piece oil rings utilize a spring expander to apply additional radial pressure to the piston ring. This increases the unit (measured amount of force and running surface size) pressure applied at the cylinder wall.

The oil ring has the highest inherent pressure of the three rings on the piston. Some Briggs & Stratton engines use a tree-piece oil ring consisting of two rails and an expander. The oil rings are located on each side of the expander. The expander usually contains multiple slots or windows to return oil to the piston ring groove. The oil ring uses inherent piston ring pressure, expander pressure, and the high unit pressure provided by the small running surface of the thin rails.

The piston acts as the movable end of the combustion chamber and must withstand pressure fluctuations, thermal stress, and mechanical load. Piston material and design contribute to the overall durability and performance of an engine. Most pistons are made from die- or gravity-cast aluminum alloy. Cast aluminum alloy is lightweight and has good structural integrity and low manufacturing costs. The light weight of aluminum reduces the overall mass and force necessary to initiate and maintain acceleration of the piston. This allows the piston to utilize more of the force produced by combustion to power the application. Piston designs are based on benefits and compromises for optimum overall engine performance

### **THE MAIN BASIC PARTS ARE**

- **Piston head**
- **Piston ring**
- **Piston pin**
- **Piston skirt**



#### **piston Head**

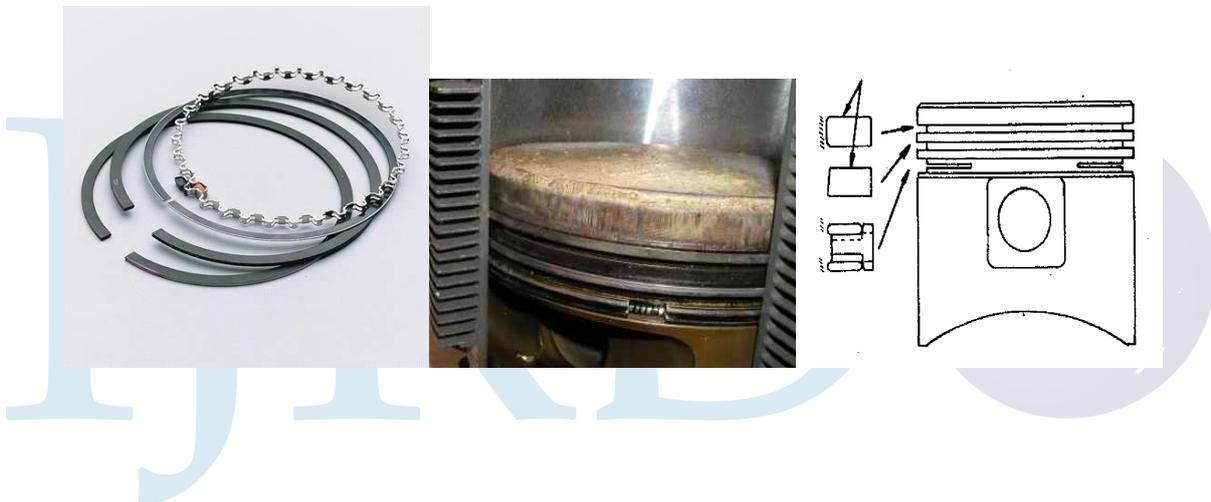
performance engines have flat head as shown. In some such pistons which come quite close to the valves, the head is provided valve relief. Pistons used in some high powered engines have a raised dome which is used to increase the compression ratio as well as to control combustion.

In some other engines the piston may be dished to form a desired shape of combustion chamber, jointly with cylinder head. In case of piston containing part of the combustion chamber, the top of the piston is called head or crown. Generally low cost low performance engines have a flat head. The top of the piston is called head or crown. Generally low cost low performance engines have a flat head. In its crown, compression ratio can be controlled very accurately but the disadvantage is that in this case much larger amount of heat has to be dissipated through the pistons and rings.

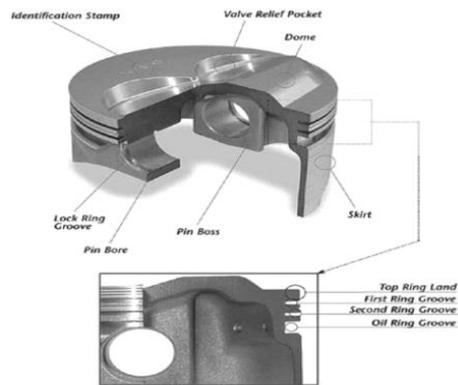
#### **Piston rings**

**Piston rings** are made to maintain the cylinder and combustion pressure of the automobile. They prevent any [oil](#) from seeping into the combustion chamber as well as sealing in the [air and fuel](#) to be able to compress them. There are typically three piston rings to every [piston](#), and each one of these rings does different things to help the engine operate.

Towards the top of the piston of a few grooves are cut to house the piston rings. The bands left between the grooves are known as lands. These lands support the rings against the gas pressure and guide them so that they may flux freely in the radial direction. The supporting webs transmit the force of explosion directly from the crown to the piston pin bosses thereby relieving the groove portion of the large load and thus by preventing the deformation of the ring grooves



The first ring is known as the **top ring**; also know as the **compression ring**. This ring helps the piston work, because during the [4combustion process](#) it doesn't allow it to lose any pressure. This ring maintains any pressure build up as the piston arrives at the top of the [4stroke](#). This is possible because the top ring acts as a barrier.



The **second ring** is also known as the **secondary compression ring**. This ring is a back up compression ring with a slightly tighter tolerance to help the top compression ring in sealing the combustion chamber.



The last ring is called the **oil ring**. These work with the piston in the engine to lubricate the cylinder, walls, pistons, rings, and wrist pins. This ring keeps the oil out of the combustion process. The oil rings also help the thermal control because it cools the piston by directing oil around it. The piston rings are located on the piston. The [piston](#) is located in the cylinder, and multiple cylinders are usually arranged side by side in a bank. This bank is known as the engine block.

### **Piston Skirt.**

The part of the piston below the rings is called skirt. Its function is to form a guide suitable for absorbing side thrust due to gas pressure. The side thrust is produced on account

of the inclination of the connecting rod with the cylinder axes. The skirt is provided with the bosses on the inside of the piston pin. It must be of sufficient length to resist tilting of the piston under load. It is kept quite close fitting in the cylinder but even then it is separated from the cylinder walls by means of lubricating oil film for smooth running. The combustion pressure from the piston crown is transmitted to the connecting rod through webs inside the piston. The bosses form a bearing surface for the rocking motion of the connecting rod. The thick-sectioned webs also form heat paths from the piston crown to the pin bosses and the skirt and thus have to be designed so as to avoid expansion problems.

aluminium alloy piston in actual practice is only about 50 percent in weight as compared to its cast iron counterpart. Further aluminium alloy is relatively soft as a result of which fine particles in the lubricating oil become embedded in it. Aluminium alloy piston with fine particles embedded in it causes a sort of grinding or abrasion of the cylinder walls thus shortening cylinder life. Another important drawback of using aluminium alloy pistons for cast iron cylinders is their unequal coefficient of expansion which causes engine slaps. Because if the cold clearance is kept just sufficient there is danger of seizure at operating temperatures and if cold clearance is kept large the engine knocks or slaps when cold. This difficulty has been overcome by different methods. Some of the functions are

1. Keeping the heat away from the lower part of the piston as far as possible. This is done by cutting horizontal slot in the piston on the thrust and non thrust sides just now the oil control ring. Thus the skirt does not become very hot and consequently it does not expand quite so much. In some designs the circumferential slots are made in the oil control ring groove and these slots end in inclined slots extending downwards. These elongated slots provide additional heat barriers and so reduce even more the amount of heat reaching the working faces of the skirt. Moreover the drooping end makes the skirt flexible in the upper region. Making a heat dam. It consists of a groove cut near the top of the piston. This reduces the path of heat travel from the piston crown to the skirt. The skirt therefore runs cooler and does not expand much.

1. Use of vertical slots; vertical or t slots on the non linear side of the piston were earlier used quite commonly. These slots allow the piston skirt to expand without increase of diameter. However the mechanical strength is decreased on account of slot. Moreover with the slot the skirt tends to collapse inwards without elastic

recovery. As a result the diameter is reduced permanently which increases the piston slap, instead of decreasing it. For these reasons fully split skirts in which the slot goes only about halfway up with blunting holes at the ends to avoid stress concentration have been used in pistons of some light duty engines. Heavy duty pistons never use any such slots.

1. Taper pistons: the pistons are sometimes turned taper the crown side being smaller in diameter than the skirt end. As higher temperatures occur towards the crown than the side expands more than the skirt due to which the piston diameter becomes uniform under running conditions.
1. Cam ground pistons; the pistons are cam ground such that they have elliptical section instead of the usual circular one. The minor diameter of the ellipse lies in the direction of the piston pin axis. Such pistons after expanding at operating temperatures become circular automatically the more expansion along minor axis being caused by the metal of piston bosses there. Generally tapered and ovality are combined in the same piston. The amount of ovality is kept maximum at the piston pin boss level and is reduced gradually towards the bottom of the skirt.

In this case pistons are cam ground with the major diameter perpendicular to the piston pin axis. At higher temperatures during running the bimetallic action of the inserts causes them to bend outward thus causing the piston to expand along the piston pin whereas in the direction perpendicular to piston pin there is corresponding contraction of the piston due to metallic action.

Another such arrangement which provides even better expansion control enabling smaller skirt to cylinder wall clearances to be employed. In this steel inserts are employed on the thrust and non thrust sides of the piston skirt. There is clearance between the inserts on the inside and the upper piston region interrupts the heat flow to the upper piston region interrupts the heat flow to the skirt and keeps its temperature and expansion lower. Moreover these steel inserts having lower coefficient of expansion than the aluminium alloy. Besides these inserts strengthen the skirt still maintaining the flexibility between the upper part of the piston and the piston pin bosses.

Another method which is sometimes used to eliminate slapping tendency of pistons is to offset them from the cylinder center line towards the major line. The piston pin hole is not symmetrically placed as usual but is slightly offset.

As the piston approaches top dead center during compression stroke the offset causes it to tilt slightly so that its top skirt surface on the minor thrust side is placed against the cylinder wall. Simultaneously the bottom surface of the piston skirt on the major thrust side is also placed against the cylinder wall. When the top dead centre is passed the inclination of the connecting rod forces the piston against the major thrust surface. However the since lower surface of the skirt is already in contact with the cylinder wall because of the offset as explained above the piston skirt very smoothly wipes into the full wall contact thus avoiding piston slap. If the piston located towards the minor thrust side a higher mechanical advantage is obtained. Moreover fewer pistons to cylinder friction are caused. However it will not decrease the piston slap. Therefore in racing car engines the pistons are offset towards minor thrust side since noise and life are not as important as performance in such engines.

Apart from the special construction of pistons mentioned above solely for the purpose of avoiding piston slap there is exist other piston types too having their own advantages. Some of these are given below:

1. Piston with inserted ring carrier.
2. Cast steel pistons.
3. Anodized pistons
4. Tinned pistons
5. Oil cooled pistons
6. Two piece pistons
7. Squeeze pistons
8. Econoguide pistons
9. Piston with inserted ring carrier.
10. Cast steel pistons.
11. Anodized pistons
12. Tinned pistons
13. Oil cooled pistons
14. Two piece pistons
15. Squeeze pistons

## 16. Econoguide pistons

The fuels have high sulphur content from sulphur dioxide or sulphur trioxide on combustion which with water also formed along side form sulphurous and sulphuric acids respectively these having corrosive action on the piston rings particularly because these acids are formed on cylinder walls with which the rings come into contact. To avoid this special ring inserts made from austenitic iron or cast iron have been used. Which resist the corrosive action of the acids produced. As the coefficient of thermal expansion of the austenitic iron and aluminum alloy are nearly the same, the ring insert does not work groove being machined into it's as usual.

For more heavy ratings the carrier is provided for the second grooves also. The bonding process produces a true metallurgical union of the two metals ensuring a perfect bond. Heat flow is uninterrupted. The pistons cast from alloy steel containing silicon and copper, with cadmium plating have been found to be highly wear and heat resistant. The very hard aluminium coating protects the piston against scoring. The tin layer gradually wears off during subsequent running of the piston.

Pistons are among most mechanical and thermal loaded components of internal combustion engines. They have to meet very high demands regarding dimensional stability, strength and durability. It is hard to meet these requirements using classical materials and technologies. Nowadays, the most often used are aluminum alloys founded in metal moulds with cast iron or steel inserts.

One of solutions providing required functional parameters of the pistons can be application of composite materials. Composites, comparing to presently used materials, have very advantageous features, like lower coefficient of thermal expansion and higher values of strength parameters.

The paper presents some results of simulation research of pistons locally in the area of piston crown. The aim of research was to analyze the influence of local piston crown on thermal deformations and determine suitable constructional proportions of pre forms used in production of composite pistons for direct injection diesel engine, operated under severe conditions.

## **Properties of aluminium**

After iron, aluminium is now the second most widely used metal in the world. This is because aluminium has a unique combination of attractive properties. Low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium's most important properties. Aluminium is also very easy to recycle.

### **Weight**

Aluminium is light with a density one third that of steel, 2.700 kg/m<sup>3</sup>.

### **Strength**

Aluminium alloys commonly have tensile strengths of between 70 and 700 MPa. The range for alloys used in extrusion is 150 – 300 MPa. Unlike most steel grades, aluminium does not become brittle at low temperatures. Instead, its strength increases. At high temperatures, aluminium's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account.

### **Linear expansion**

Compared with other metals, aluminium has a relatively large coefficient of linear expansion. This has to be taken into account in some designs.

### **Corrosion resistance**

Aluminium reacts with the oxygen in the air to form an extremely thin layer of oxide. Though it is only some hundredths of a (my)m thick (1 (my)m is one thousandth of a millimetre), this layer is dense and provides excellent corrosion protection. The layer is self-repairing if damaged.

Anodising increases the thickness of the oxide layer and thus improves the strength of the natural corrosion protection. Where aluminium is used outdoors, thicknesses of between 15 and 25  $\mu\text{m}$  (depending on wear and risk of corrosion) are common.

Aluminium is extremely durable in neutral and slightly acid environments. In environments characterised by high acidity or high basicity, corrosion is rapid.

Further details are given in Corrosion Resistance.

### **Conductivity**

Aluminium is an excellent conductor of heat and electricity. An aluminium conductor weighs approximately half as much as a copper conductor having the same conductivity.

### **Zero toxicity**

After oxygen and silicon, aluminium is the most common element in the Earth's crust. Aluminium compounds also occur naturally in our food.

## **1.5 MATERIALS AND CONSTRUCTIONAL FEATURES**

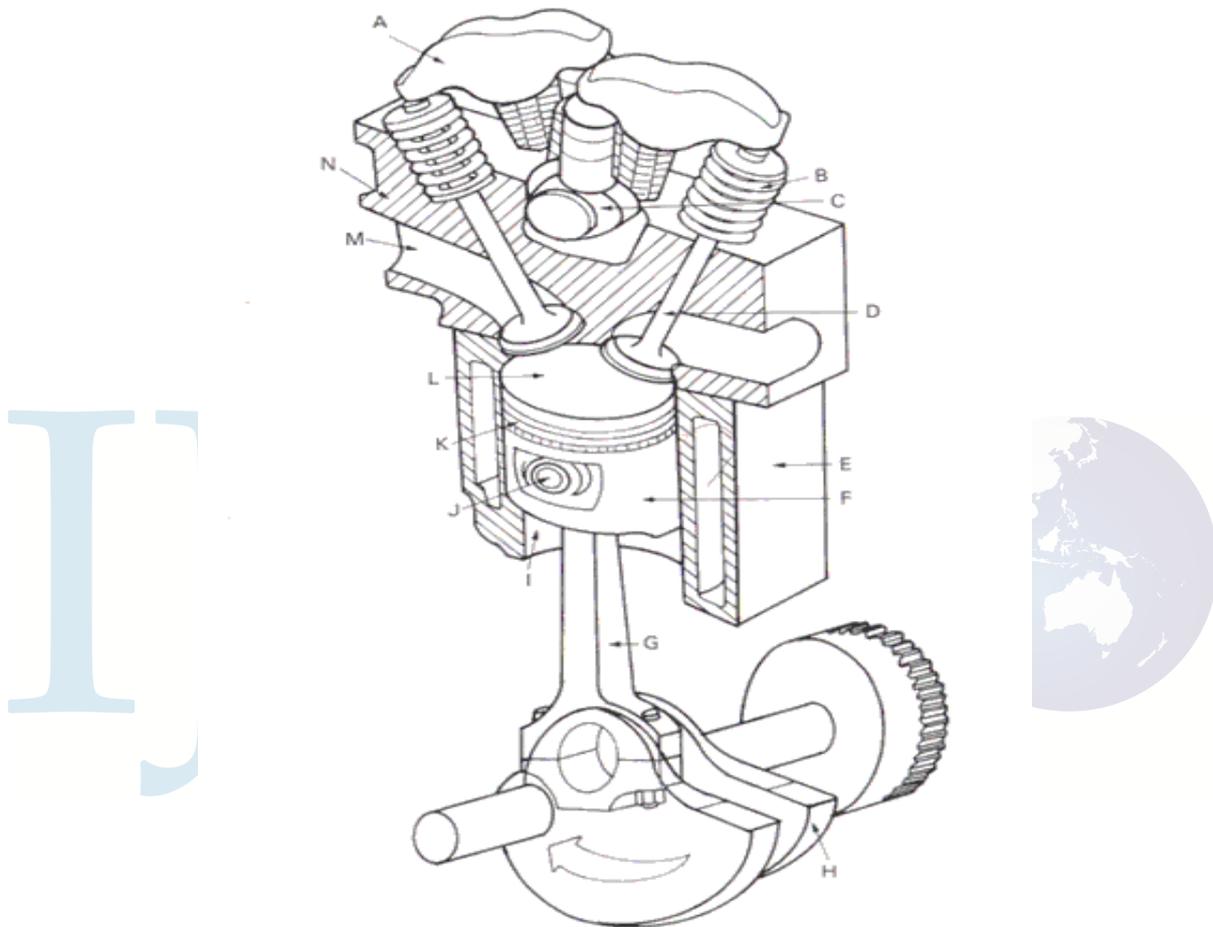
The distance between the axis of the piston pin and the top of the piston crown is called compression height and determines the compression ratio for a given engine. Thus the same engine a piston with lesser compression height would give lesser compression ratio and vice versa.

The material used for pistons at one time was cast iron which has good wearing qualities. As the technology developed Aluminium alloy containing silicon replaced cast iron as piston material, because of two distinct advantages. Firstly it is as much as three times lighter than the cast iron which makes it is desirable from inertia point of view.

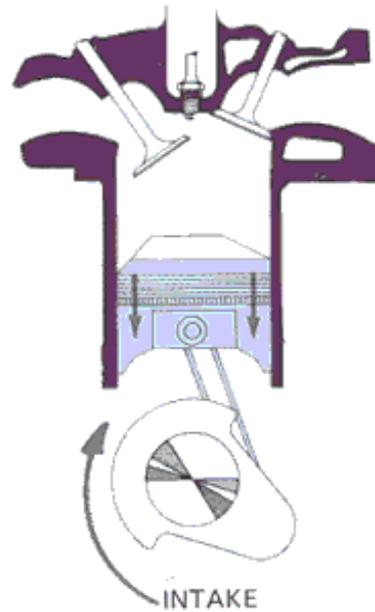
Secondly it possesses a higher thermal conductivity which causes it to run cool. But the aluminium alloy has its own advantages. It is not as a stronger as cast iron and hence thicker sections have to be used. As a result of which the weight of piston is increased. It is seen that an

### **ROLE OF PISTON IN AN IC ENGINE**

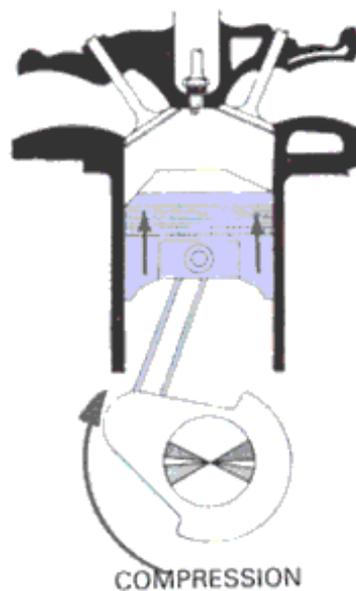
A four-stroke engine is the most common type used in automobiles. The four strokes are intake, compression, power, and exhaust. Each stroke requires approximately 180 degrees of crankshaft (or flywheel) rotation, so the complete cycle would take 720 degrees. Each stroke plays a very important role in the combustion process, and each has a different pressure surrounding it.



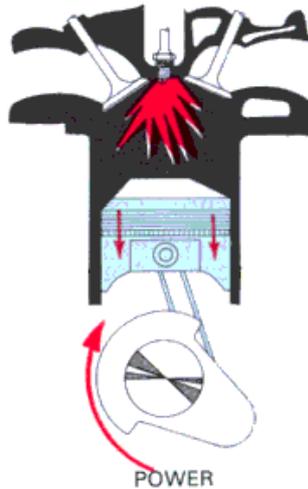
A – Rocker Arm	H – Cam Shaft
B – Valve Springs	I – Cylinder Clearance
C – Rocker Arm Pin	J – Connecting Rod Pin
D – Inlet Valves	K – Piston Rings
E – Cylinder Head	L – Piston Head
F – Piston Skirt	M – Exhaust Valves
G – Connecting Rod	N – Cross-Section



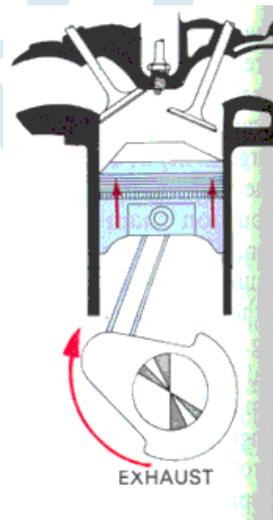
In the intake cycle, as the picture shows, the piston is moving downward while one of the valves is open. This creates a vacuum, and an air-fuel mixture is sucked into the chamber. This would be cause for very little pressure on the piston, so  $P$  is small.



Moving on to compression, we can see that both valves are closed, and the piston is moving upward. This creates a much larger amount of pressure on the piston, so we would have a different representation of  $P$  in our equation for this stroke.



The next stroke is the big one: power. This is where the compressed air-fuel mixture is ignited with a spark, causing a tremendous jump in pressure as the fuel burns. The pressure seems to "spike", so the most cause for concern occurs here. (This is also the area in which the dangers of engine knock or pre-detonation can occur, causing an even larger spike.)



Finally, we have the exhaust stroke. In this stroke, the exhaust valve is open, once again creating a chamber of low pressure. So, as the piston moves back upwards, it forces all the air out of the chamber. The pressure in this region is therefore considered very low.

## **1.6 FUNCTIONS**

The functions which a piston is called to perform in an IC engine are;

1. To transmit the force of explosion to the crankshaft.

2. To form a seal so that the high pressure gases in the combustion chamber do not escape into the crankcase.
3. To serve as a guide and a bearing for small end of the connecting rod. Apart from its capability to perform the above functions efficiently the pistons must have some other desirable characteristics.
4. The design should be such that the seizure does not occur.
5. It should offer sufficient resistance to corrosion due to some other products of combustion.
6. It should have the shortest possible length so as to decrease overall engine size.
7. It should be lighter in weight so that inertia forces created by its reciprocating motion are minimum.
8. It must have a long life.

### **1.7 The engine specifications**

- Data for design calculations:
  - Bore and Stroke :81×87.3 mm
  - Displacement : 1,799 cc
  - Rod Length : 142 mm
  - Rod/Stroke : 1.62 Compression : 10.5:1
  - Power : (128 hp/98kw) at 6000 rpm Torque: 110 Nm @ 6200 rpm
  - Compression pressure :15.5 bar
  - Combustion pressure :35.6 bar

## **Chapter - 2**

### **INTRODUCTION TO CAD & CATIA-V5**

- INTRODUCTION
- TECHNOLOGY OF CAD
- PRODUCT DEVELOPMENT THROUGH CAD PROCESS
- CAD TOOLS
- GEOMETRIC MODELING



## **2.1 CAD**

Computer Aided Design (CAD) is a technique in which man and machine are blended in to problem solving team, intimately coupling the best characteristics of each. The result of this combination works better than either man or machine would work alone , and by using a multi discipline approach, it offers the advantages of integrated team work.

The advances in Computer Science and Technology resulted in the emergence of very powerful hardware and software tool. It offers scope for use in the entire design process resulting in improvement in the quality of design. The emergency of CAD as a field of

specialization will help the engineer to acquire the knowledge and skills needed in the use of these tools in an efficient and effective way on the design process.

Computer Aided Design is an interactive process, where the exchange of information between the designer and the computer is made as simple and effective as possible. Computer aided design encompasses a wide variety of computer based methodologies and tools for a spectrum of engineering activities planning, analysis, detailing, drafting, construction, manufacturing, monitoring, management, process control and maintenance. CAD is more concerned with the use of computer-based tools to support the entire life cycle of engineering system.



**CATIA-V5** is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that CATIA-V5 is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Catia-v5 is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Catia-v5 provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

#### **Advantages of CATIA-V5:**

- It is much faster and more accurate.
- Once a design is completed. 2D and 3D views are readily obtainable.
- The ability to changes in late design process is possible.

- It provides a very accurate representation of model specifying all other dimensions hidden geometry etc.
- It is user friendly both solid and surface modeling can be done.
- It provides a greater flexibility for change. For example if we like to change the dimensions of our model, all the related dimensions in design assembly, manufacturing etc. will automatically change.
- It provides clear 3D models, which are easy to visualize and understand.
- CATIA provides easy assembly of the individual parts or models created it also decreases the time required for the assembly to a large extent.

## **2.2 Technology of CAD**

CAD technology makes use of drawings of parts and assemblies on computer files which can be further analyzed and optimized. The functional, ergonomic and aesthetic features of the product can be evaluated on the computers. This has been made possible through the use of the design workstations or CAD terminals and graphics and analytic software, which help the designer to interactively model and analyze object or component.

CAD can be put to a variety of uses, some of which are listed below.

- Create conceptual product model/models.
- Editing or refining the model to improve aesthetic, ergonomics and performance,
- Display the product in several colors to select color combination most appealing to customers,
- Rotate and views the object from various sided and direction.
- Create and display all inner details of the assembly.
- Check for interference or clearance between mating parts in static and /or dynamic situations.
- Analyze stress, static deflection and dynamic behavior for different mechanical and thermal loading configurations and carry out quickly any necessary design modifications to rectify deficiencies in design.

- Study the product from various aspects such as material requirements, costs, value engineering manufacturing processes, standardization, simplification, weight reduction, service life, lubricants, servicing and maintenance aspects etc.
- Prepare detailed component drawings giving full details of dimensions, tolerances, surface finish requirements, functional specification etc.
- Prepare assembly drawing depicting the orientation of components,
- Assembly procedures and requirements and incorporation , as required , such
- Details as hydraulic or electric connections.
- Prepare exploded view of the assemblies. These views could be so oriented as to provide better visibility and improved comprehension of the design. Plot to print the picture/drawing stored in a computer file or the computer screen on different media.
- Store the database of the object. Part of the drawing in a magnetic disc or tape for the retrieval at the later date for the use in some other design.

### **Modification of existing design**

The above description reveals that **CAD** technologies give the design engineer a powerful tool for graphical tasks . Modern **CAD** systems are based on interactive computer graphics communicates data and commands to the computer through the several input devices, to create an image or model on the computer screen by entering command to call and active the required software subroutines stored in the computer. In a 2-dimensional drafting system the images are constructed out of basic geometric elements or entities like points, lines, arcs, circles etc. These images can then be modified. Rotated, scaled or transformed in several ways depending upon the designer's requirement.

### **2.3 PRODUCT DEVELOPMENT THROUGH CAD PROCESS:**

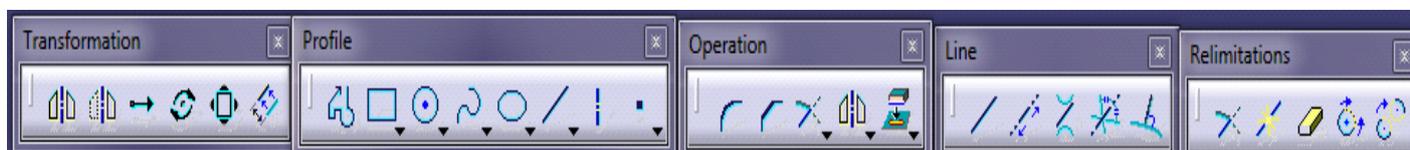
The product begins with a need that is identified based on costumer and market's demands . The product goes through two main processes from the idea conceptualization to the finished product the design process and the manufacturing process.

Product development through CAD product. Synthesis and analysis are the main sub processes that constitute the design process. Synthesis is crucial to design an analysis.

The philosophy, functionality and uniqueness of the product are all determined during the synthesis. The major financial commitment to turn the conceived product idea into reality is also made. Most of the information generated during the synthesis and process is qualitative and consequently is hard to capture in a computer system expert and knowledge-based systems have made a great deal of progress in this regard and the interested conceptual design of the prospective product. Typically, this design takes the form of a sketch or surrounding constraints. It is also employed during brainstorming discussions among various design terms and the presentation purpose.

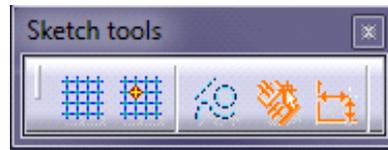
## **2.4 CAD TOOLS:**

CAD tools can be defined as the intersection of three sets: geometric modeling, computer graphics, and the design tool such as definition. As can be perceived from this, the abstracted concepts of geometric modeling and the computer graphics must be applied innovatively to serve the design process. Based on implementation in a design environment, CAD tools can be defined as the design tools being augmented by computer hardware and software through its various passes to achieve the design goal efficiently and competitively. Designers will always require tools that provide them with fast and reliable solutions to design geometric tools, such as developing analysis and optimization routines on the other extreme. In between these two extremes, typical tools currently available include tolerance analysis, mass property calculations, and finite element modeling and analysis to name a few.



## **2.5 GEOMETRIC MODELING:**

A geometric modeling should be an unambiguous representation of its corresponding object. The model should be unique and complete to all engineering functions from documentation to engineering analysis to manufacturing .



### **SOLID MODELING:**

A solid model of an object is a completed representation of the object. This model is capable of complex geometry data representation that is the art completely defined, solid modeling techniques based on information ally complete, valid and unambiguous of object solid modelers store more information (geometry and topology) than wire frame modelers of surface (geometry only). Both wire frame and surface modelers are incapable of handling special address ability as well as verifying that the model is well framed or not. Solid models can be quickly created without having to define individual locations as with wire frames. Solid modeling produces accurate designs, provides complete three-dimensional improves the quality of the design, improves and has potential for functional automation and integration.

### **BOUNDARY REPRESENTATION:**

Boundary representation is one of the most popular and widely used schemes to create solid of physical objects. Boundary representation of object in term of its surface boundaries like vertices, edges and faces . B-reps model is based on the topological notation that a physical object is bounded by a set of faces . These faces region (or) subsets of closed and oriental surface .Each face is bounded by edges and each edge has 2 vertices. Thus topologically a boundary model of any object is comprised of faces , edge and vertices of an objects linked together in such a way as to ensure the topological consistency of the model. The database of bounded model contains both is topology and geometry performing Euler operations creates topology and performing Euclidean calculations creates geometry.

Euler's operations are used to create, manipulate and edit the faces; edges and vertices of a boundary model as the set of Boolean operations to create, manipulate and edit primitives of CSG models. Euler's operations ensure the integrity (closeness, no dangling edges (or) faces) of the models. Effects of Boolean operation on a CSG models or simply an addition of the CSG tree. However B-Rep systems require an explicit representation of the boundary of the solid they must evaluate the new boundary that is 6<sup>th</sup> result of the operation.

# IJRDO

## Chapter – 3

### CATIA

There are different modules in **CATIA** using which different tasks can be performed. The main window and modules of **CATIA** shown in figure:

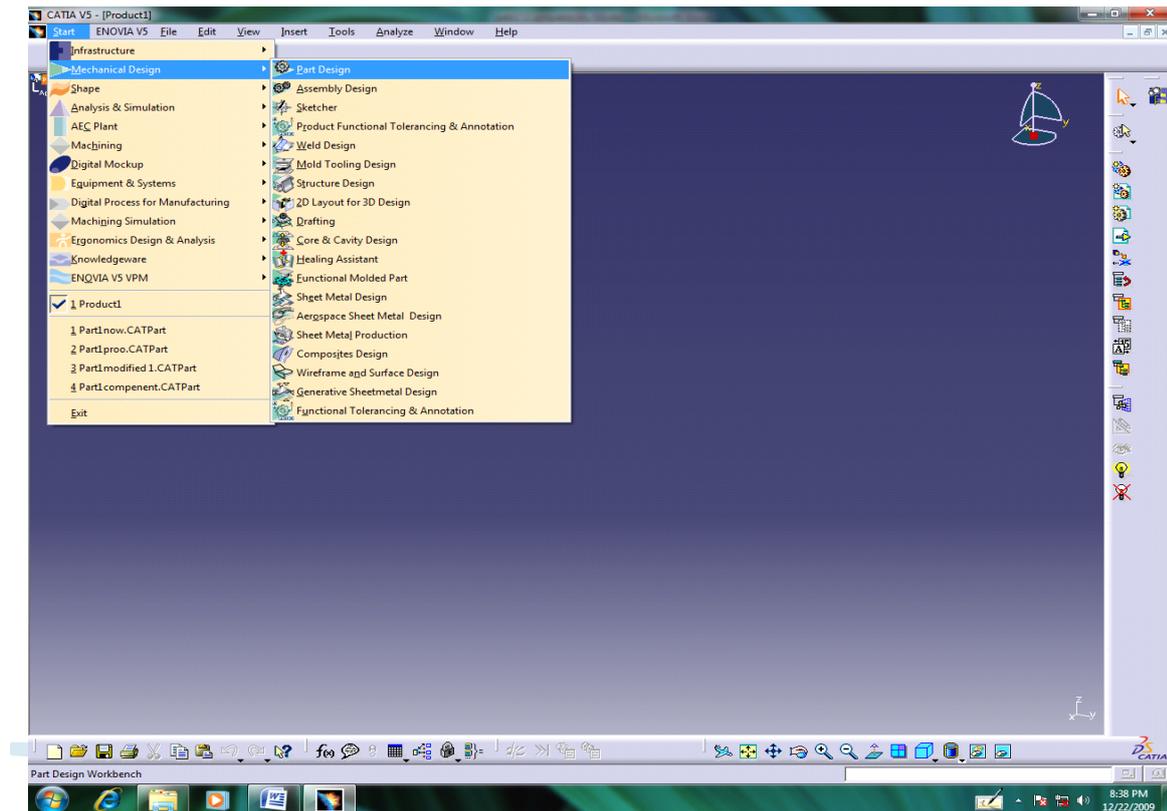


Fig. No.4. catia-v5 Interface

### The main modules are:

Part Design

Assembly

Drafting

Wireframe and Surface Design

Core & Cavity Design

### 3.1 PART DESIGN

The **Version 5 Part Design** application makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to

iterative detailed design. **Version 5 Part Design** application will enable you to accommodate design requirements for parts of various complexities, from simple to advanced.

This application, which combines the power of feature-based design with the flexibility of a Boolean approach, offers a highly productive and intuitive design environment with multiple design methodologies, such as post-design and local 3D parameterization.

Select **Start -> Mechanical Design -> Part Design** from the menu bar.

## SKETCHER

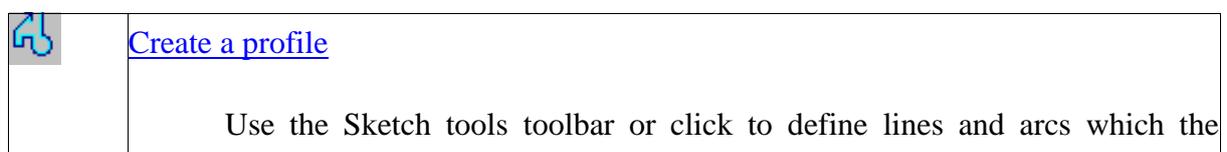
Sketcher application makes it possible for designers to sketch precise and rapid 2D profiles

Select the Sketcher icon  and click the desired reference plane either in the geometry area or in the specification tree, or select a planar surface. This creates a "non-positioned" sketch (i.e. a sketch for which you do not specify the origin and orientation of the absolute axis, which are not associative with the 3D geometry). The sketch absolute axis may "slide" on the reference plane when the part is updated.



Select one plane of the local axis. h and v are aligned to the main axes of this selected plane. Associativity is kept between both the plane and the sketch.

## Sketching Simple Profiles



	profile may be made of.
	<p><a href="#">Create a rectangle</a></p> <p>Use the Sketch tools toolbar or click the rectangle extremity points one after the other.</p>
	<p><a href="#">Create a circle</a></p> <p>Use the Sketch tools toolbar or click to define the circle center and then one point on the circle.</p>
	<p><a href="#">Create a three point circle</a></p> <p>Use the Sketch tools toolbar or click to define the circle start point, second point and end point one after the other.</p>
	<p><a href="#">Create a circle using coordinates</a></p> <p>Use the Circle Definition dialog box to define the circle center point and radius.</p>
	<p><a href="#">Create a tri-tangent circle</a></p> <p>Click three elements one after the other to create a circle made of three tangent constraints.</p>
	<p><a href="#">Create an arc</a></p> <p>Use the Sketch tools toolbar or click to define the arc center and then the arc start point and end point.</p>
	<p><a href="#">Create a three point arc</a></p> <p>Use the Sketch tools toolbar or click to define the arc start point, second point and end point one after the other.</p>
	<p><a href="#">Create a three point arc (using limits)</a></p> <p>Use the Sketch tools toolbar or click to define the arc start point, end point</p>

	and second point one after the other.
	<p><a href="#">Create a spline</a></p> <p>Click the points through which the spline will go.</p>
	<p><a href="#">Connect elements</a></p> <p>Click the points through which the spline will go.</p>
	<p><a href="#">Create an ellipse</a></p> <p>Use the Sketch tools toolbar or click to define the ellipse center, major semi-axis and minor semi-axis endpoints one after the other.</p>
	<p><a href="#">Create a parabola</a></p> <p>Click the focus, apex and then the parabola two extremity points.</p>
	<p><a href="#">Create a hyperbola</a></p> <p>Click the focus, center and apex, and then the hyperbola two extremity points.</p>
	<p><a href="#">Create a conic</a></p> <p>Click the desired points and eccentricity for creating an ellipse, a circle, a parabola or a hyperbola, using tangents, if needed.</p>
	<p><a href="#">Create a line</a></p> <p>Use the Sketch tools toolbar or click the line first and second points.</p>
	<p><a href="#">Create an infinite line</a></p> <p>Use the Sketch tools toolbar or click the infinite line first and second points.</p>
	<p><a href="#">Create a bi-tangent line</a></p>

	Click two elements one after the other to create a line that is tangent to these two elements.
	<a href="#">Create a bisecting line</a> Click two lines.
	<a href="#">Create a symmetrical extension</a> Use the Sketch tools toolbar or click the center point and then the extremity point of a line that is a symmetrical extension to an existing one.
	<a href="#">Create a point</a> Use the Sketch tools toolbar or click the point horizontal and vertical coordinates.
	<a href="#">Create a point using coordinates</a> Enter in the Point Definition dialog box cartesian or polar coordinates.
	<a href="#">Create an equidistant point</a> Enter in the Equidistant Point Definition dialog box the number and spacing of the points to be equidistantly created on a line or a curve-type element.
	<a href="#">Create a point using intersection</a> Create one or more points by intersecting curve type elements via selection.
	<a href="#">Create a point using projection</a> Create one or more points by projecting points onto curve type elements.

### **Sketching Pre-Defined Profiles**

	<a href="#">Create oriented rectangles:</a> Use the Sketch tools toolbar or click to define a first side for the rectangle
---	---

	and then a point corresponding to the rectangle length.
	<p><a href="#">Create parallelograms:</a></p> <p>Use the Sketch tools toolbar or click to define a first side for the parallelogram and then a point corresponding to the parallelogram length.</p>
	<p><a href="#">Create elongated hole:</a></p> <p>Use the Sketch tools toolbar or click to define the center to center axis and then a point corresponding to the elongated hole length and angle.</p>
	<p><a href="#">Create cylindrical elongated hole:</a></p> <p>Use the Sketch tools toolbar or click to define the center to center circular axis and then a point corresponding to the cylindrical elongated hole length and angle.</p>
	<p><a href="#">Create keyhole profiles:</a></p> <p>Use the Sketch tools toolbar or click to define the center to center axis and then both points corresponding to both radii.</p>
	<p><a href="#">Create hexagons:</a></p> <p>Use the Sketch tools toolbar or click to define the hexagon center and dimension.</p>

### **Performing Operations on Profiles**

	<p><a href="#">Create corners</a></p> <p>Create a rounded corner (arc tangent to two curves) between two lines using trimming operation.</p>
	<p><a href="#">Create chamfers</a></p> <p>Create a chamfer between two lines using trimming</p>

	operation.
	<a href="#">Trim elements</a> Trim two lines (either one element or all the elements)
	<a href="#">Trim multiple elements</a> Trim a few elements using a curve type element.
	<a href="#">Break and trim</a> Quickly delete elements intersected by other Sketcher elements using breaking and trimming operation.
	<a href="#">Close elements</a> Close circles, ellipses or splines using relimiting operation.
	<a href="#">Complement an arc (circle or ellipse)</a> Create a complementary arc.
	<a href="#">Break elements</a> Break a line using a point on the line and then a point that does not belong to the line.
	<a href="#">Create symmetrical elements</a> Repeat existing Sketcher elements using a line, a construction line or an axis.
	<a href="#">Translate elements</a> Perform a translation on 2D elements by defining the duplicate mode and then selecting the element to be duplicated. Multi-selection is not available.
	<a href="#">Rotate elements</a> Rotate elements by defining the duplicate mode and

	then selecting the element to be duplicated.	
	<p><a href="#">Scale Elements</a></p> <p>Scale an entire profile. In other words, you are going to resize a profile to the dimension you specify.</p>	
	<p><a href="#">Offset Elements</a></p> <p>Duplicate a line, arc or circle type element.</p>	
	<p><a href="#">Project 3D elements onto the sketch plane</a></p> <p>Project edges (elements you select in the Part Design workbench) onto the sketch plane.</p>	
	<p><a href="#">Creating Silhouette Edges</a></p> <p>Create silhouette edges to be used in sketches as geometry or reference elements.</p>	
	<p><a href="#">Intersect 3D elements with the sketch plane</a></p> <p>Intersect a face and the sketch plane.</p>	
	<p><a href="#">Create quick dimensional/geometrical constraints</a></p> <p>Set constraints on elements or between two or three elements. The constraints are in priority dimensional. Use the contextual menu to get other types of constraints and to position this constraint as desired.</p>	
	<p><a href="#">Define constraint measure direction</a></p> <p>Define the measure direction as you create a dimensional constraint.</p>	

	<a href="#">Modify constraint definition</a>	
	Double-click a constraint a modify the definition using the Constraint Definition dialog box.	
	<a href="#">Create constraints using a dialog box</a>	
	Set various geometrical constraints between one or more elements using a dialog box and if needed, multi-selection.	

## **OPTIONS USED TO CREATE SOLIDS**

**Pad** - Pad is a method of defining three-dimensional geometry by projecting a two-dimensional section at a specified distance normal to the sketching plane.

**Pocket** - Pocket is a method of extruding a profile or a surface and removing the material resulting from the extrusion

**Shaft** - The Shaft tool creates a feature by revolving a sketched section around a centerline.

**Fillet** - A fillet is a curved face of a constant or variable radius that is tangent to, and that joins, two surfaces. Together, these three surfaces form either an inside corner or an outside corner.

**Chamfer** - Chamfering consists in removing or adding a flat section from a selected edge to create a beveled surface between the two original faces common to that edge.

**Draft** - Drafts are defined on molded parts to make them easier to remove from molds.

**Thickness** – Adds or removes to the faces.

**Translation** – Moving a body.

**Mirror** - Mirroring a body or a list of features consists in duplicating these elements using a symmetry by selecting a face or plane as reference.

**Pattern** - To duplicate the whole geometry of one or more features and to position this geometry on a part.

## **REFERENCE ELEMENTS:**

Reference elements are used as references for constructing the model. They are not geometry features, but they aid in geometry construction by acting as references for sketching a feature, orienting the model, assemblies, components, and so on. Because of their versatility references are frequently used.

- **Reference plane**
- **Reference line**
- **Reference points**

### **REFERENCE PLANES::**

Datum planes are used as reference to construct feature. Datum planes are considered feature, but they are not considered model geometry. Datum planes can be created and used as a sketch plane where no suitable exists.

Reference plane options used are: Thru plane, Offset plane, Offset coordinate system, Blend section, Thru axis, Thru Point/Vertex, Normal to axis, Tangent to cylinder, Angle to the plane etc.

### **REFERENCE LINES:**

Reference lines are used to create surfaces and other features, or as a sweep trajectories. User sketch reference line in the same manner as any other features. Sketched curves can consist of one or more sketched segment and of one or more open or closed loop.

Reference lines option used are: Sketch, Intersection surface, Thru point, Form file, Composite, Projected, Formed, Split, Offset from surface, from curve, from curve, from boundary, Offset curve, Form equation etc.

**REFERENCE POINTS:** points are used to specify point loads for mesh generation, attach datum targets and notes in drawings, and create coordinate systems and pipe feature trajectories. User can also place axis, planes, holes and shafts at a point.

Point options used are: On surface, Offset surface, Curve coordinate surface, on vertex, Offset coordinate system, Three surface, at center, on curve, on surface, Offset point etc.

First Solid of the Model

## **3.2 GENERATIVE DRAFTING**

Generative Drafting is a new generation product that provides users with powerful functionalities to generate drawings from 3D parts and assembly definitions.

The *Generative Drafting* has been designed to show you how to generate drawings of varying levels of complexity, as well as apply dimensions, annotations and dress-up elements to these drawing.

Start – Mechanical Design – Drafting

## **Views**

**Front View** - A front view is a projection view obtained by drawing perpendiculars from all points on the edges of the part to the plane of projection. The plane of projection upon which the front view is projected is called the frontal plane.

**Projection View** – Projection views are views conceived to be drawn or projected onto planes known as projection planes. A transparent plane or pane of glass representing a projection plane is located parallel to the front surfaces of the part.

**Isometric View** – The **Isometric View** command enables to create a 2D view with any orientation, this orientation being the same as the one in the 3D viewer. Among other results, and depending on how the 3D viewer is oriented when created the view, can obtain a regular X-Y-Z isometric view.

## **Dimensioning**

**Generate Dimensions** - To generate dimensions in one shot from the constraints of a 3D part. Only the following constraints can be generated: distance, length, angle, radius and diameter.

**Dimensions** - To create and modify dimensions. These dimensions will be associative to the elements created from a part or an assembly. When created, these elements are associated with a view.

**Generate Balloons** – To generate balloons automatically to the components of an assembly which are previously generated in assembly.

**Text** - To create a text, with possible line wrapping.

### **3.3 WIREFRAME & SURFACE DESIGN**

The Wireframe and Surface DESIGN allows you to create wireframe construction elements during preliminary design and enrich existing 3D mechanical part design with wireframe and basic surface features. As a complement to Part Design, this product meets the requirements of solids-based hybrid modeling.

#### **INTRODUCTION TO SURFACES:**

A surface is a geometric feature with no defined thickness. The wall of surface feature does not have a defined thickness. Surface tools are used to create geometric shapes with complex contours and relations. A quilt is a combination of one or more surface features.

To enter into Surface Design workbench

**Start – Mechanical Design – Wireframe and Surface Design**

#### **SURFACE OPTIONS IN WIRE FRAME and SURFACES:**

In surface modeling most of the options available are similar to options found under the solid options menu. Wireframe and Surface creation options are Point Repetition, Polyline, Circle, Spline, Helix, Extrude, Revolve, Cylinder, Sphere, Sweep, Multi-section surface, Offset.

The wireframe options are used to create lines, circles and splines in 3D itself. Helix command is used to create helical 3d curves.

#### **SURFACE OPERATIONS:**

The surface operations are: Join, Healing, Disassemble, Split, Trim, Boundary, Extract, and Extrapolate.

Join – To join surfaces or curves

Healing – To join surfaces with some gap.

Disassemble - To unjoin single surfaces.

Split – To cut a curve by using a point, curve, surface and plane. To cut a surface by using a curve or a surface or a plane.

Trim – To cut two surfaces.

### **3.4 ASSEMBLY**

CATIA's assembly module allows parts to be grouped into assemblies or subassemblies to model a complete part. Assembly Design allows the design of assemblies with an intuitive and flexible user interface.

- **Start Mechanical design Assembly design**

### **TYPES OF ASSEMBLIES**

#### **BOTTOM UP ASSEMBLY**

Parts of the assembly are created in respective part files and assembled in assembly file. Used for components having lesser parts.

#### **TOP DOWN ASSEMBLY**

Parts are created in the assembly file itself. Used for components having more parts.

#### **Assembly Procedure**

To assemble the already created components, select Product name in specification tree – right click – select Components – select Existing components

OR

To create parts in the assembly itself, select Product name in specification tree – right click – select Components – select New part or select New Component or New Product to create a sub assembly.

Apply constraints to the components to assemble.

### **CONSTRAINT TYPES**

Coincidence, Contact, Offset, Angle, Fix, Fix Together, Quick Constraint

### **3.5 Bill of Material [BOM]**

The Bill of Materials (BOM) provides a listing of all parts and parameters in the current assembly.

BOM is a table to display the number and name of the components belonging to the active component as well as the properties of these components.

**Generate Numbering** – Generates numbers to all parts.

**Manipulation** - A freehand translation or rotation of a component with the mouse by specifying directions.

### **ASSEMBLING A COMPONENT INTO A PATTERN:**

Assemble it to the leader of an existing component or feature pattern; then pattern using **Reuse pattern**. A pattern must exist in order to use this option.

**CATALOG:** In catalog standard we can get standard nuts, bolts, keys, pins, screw, washers, by selecting the required standard size and pitch by clicking ok we can get to assembly and we can use it.

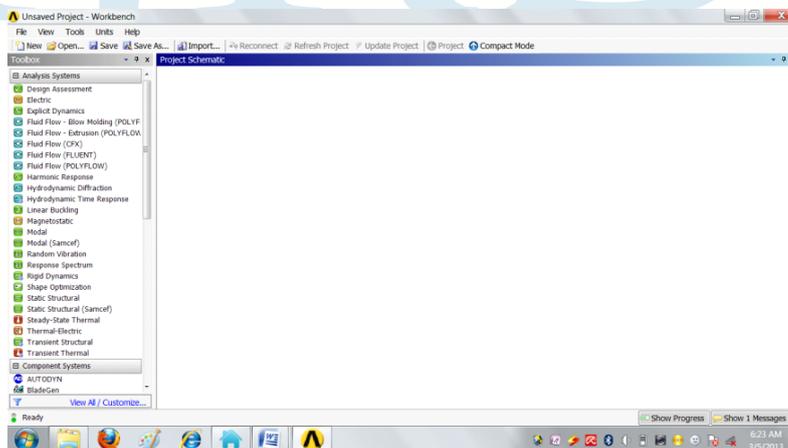
## Chapter - 4

### ANSYS WORKBENCH

#### 4.1 Procedure of Analyzing of Piston :

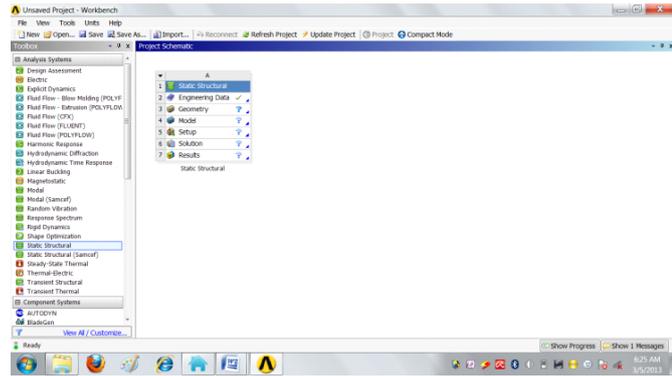
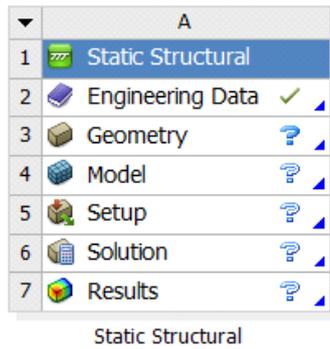
Step 1: GO TO START PROGRAMMES SELECT THE ANSYS WORKBENCH 12.0

THEN BELOW DIALOG BOX WILL APPEAR i.e



In the left hand said below the window select the analysis systems

For static analysis select the static structural (two times click)

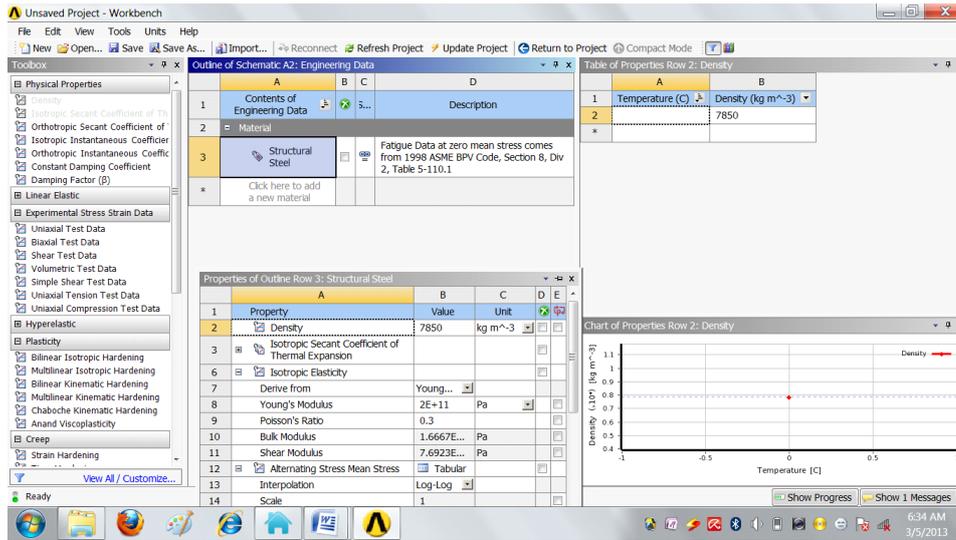


Then the above window will appear

1. STATIC STRUCTURAL
2. ENGINEERING DATA
3. GEOMETRY
4. MODEL
5. SETUP
6. SOLUTIONS
7. RESULTANTS

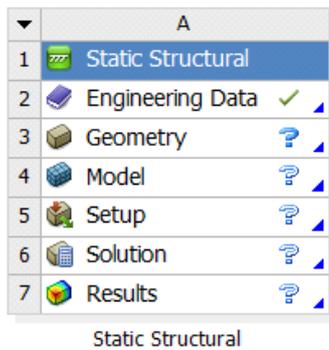
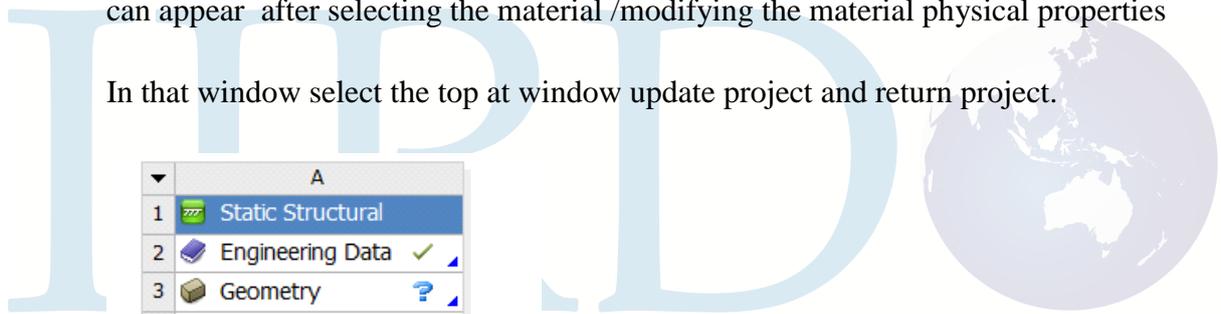
**Step 2.** The first step indicates the type of analysis .....

The second step is indicates the engineering the data means material properties adding from the library



For modification select the engineering data and click two times the above window can appear after selecting the material /modifying the material physical properties

In that window select the top at window update project and return project.

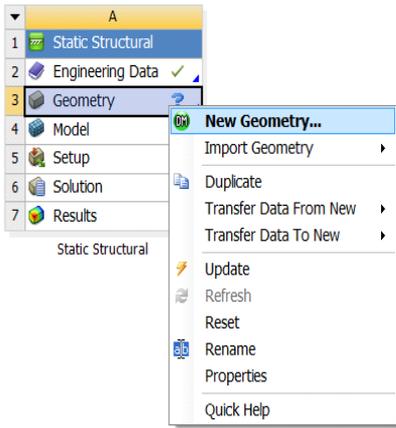


It generates first window

**Step 3 :** The right said of the window selects the geometry and right click it display new geometry /import geometry

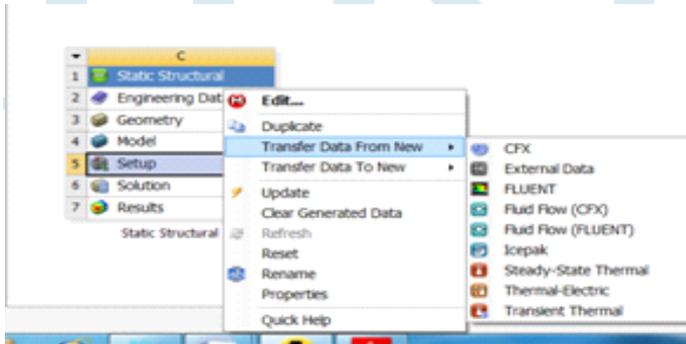
Select the import geometry go to browse the model

In .igs /stp format

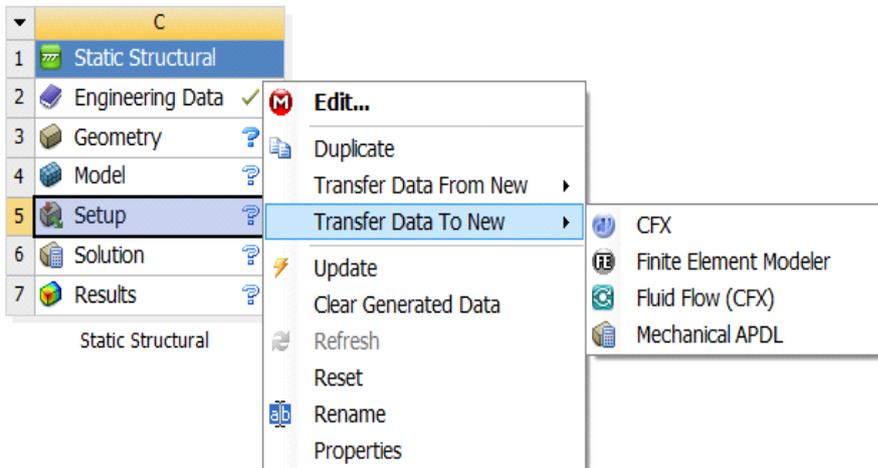


.igs means (initial graphics exchange specifications)

For mixing of two fields go to setup and right click transfer data from new /Transfer data to new

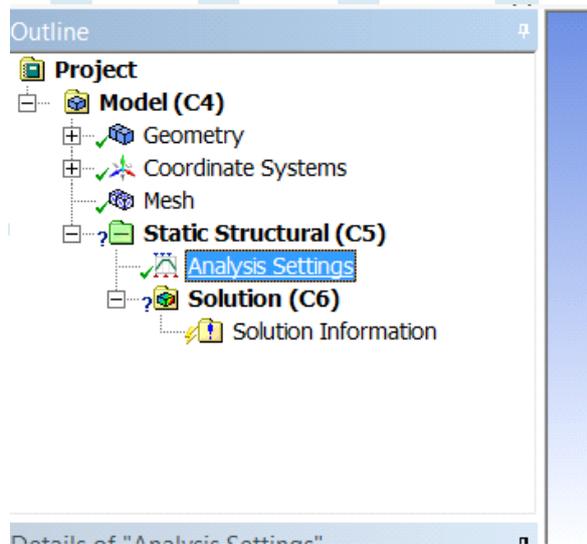


Transfer data from new



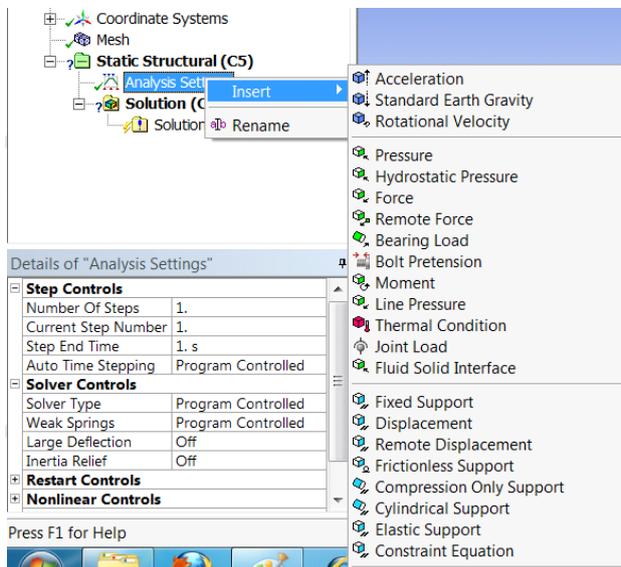
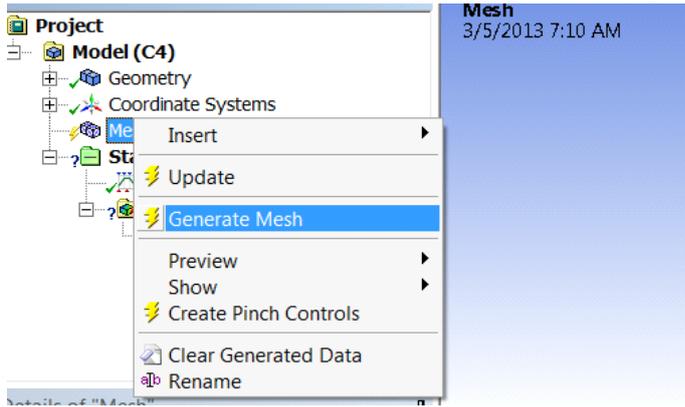
**Step 4:** The setup five is the main in ansys workbench for select two different field..

By boundary conditions (forces and fixing degree of freedom)



**Step 5:**

Mesh and right click generate mesh



Applying for boundary condition loading and

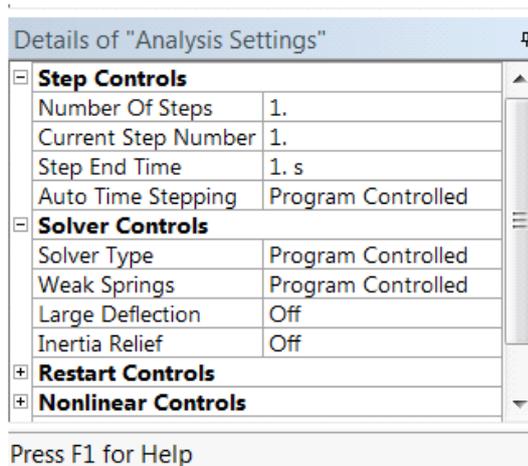
fixing (analysis settings...right click...go to insert..)

Fixed support and forces select the surfaces, edges, volumes..etc

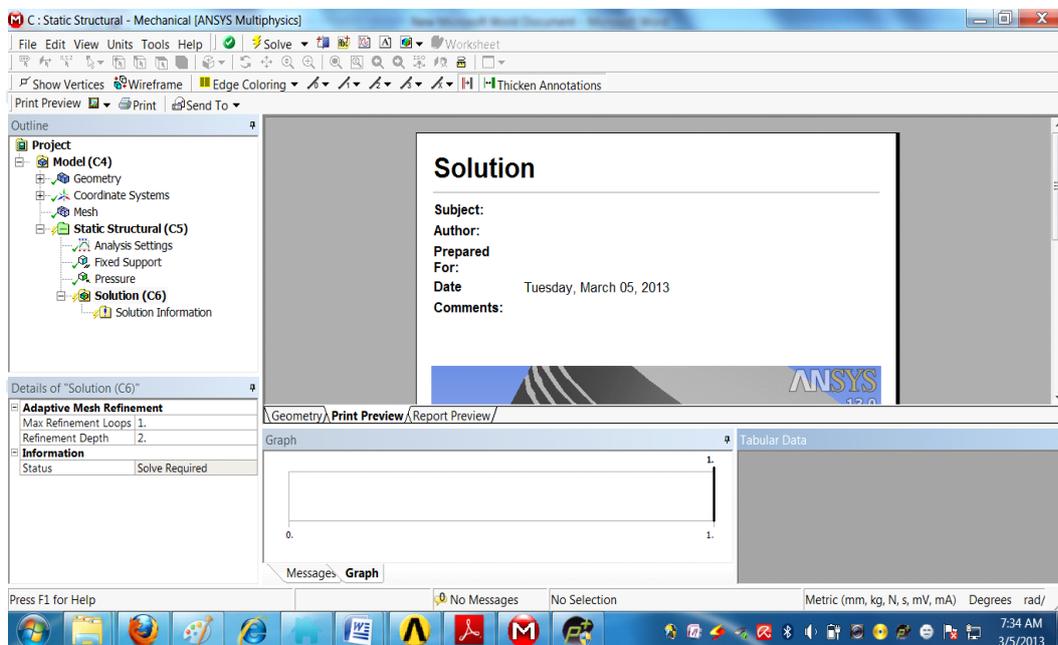
For thermal analysis thermal conditions select the temp,heat flux..etc

For free vibration (modal analysis) only for fixed conditions. No load can be Carried out .

The left said window indicates linear and non linear analysis for the object.

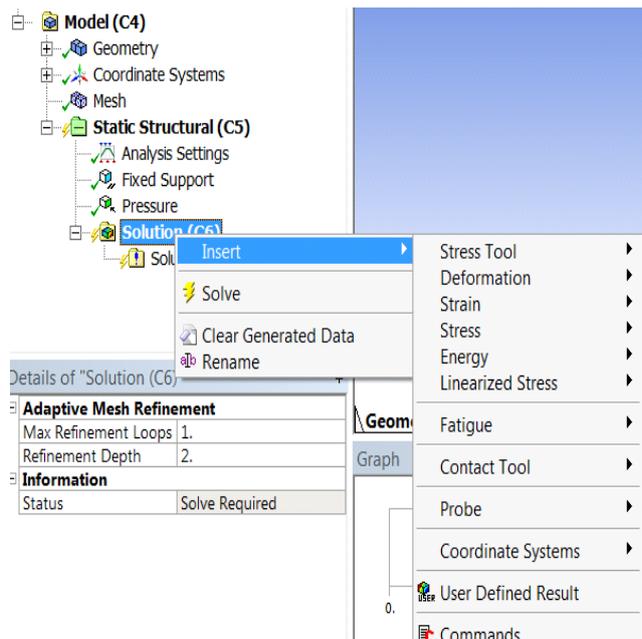


In analysis settings .....solver controls....large deformation



on---non-linear analysis (geometric nonlinearity)

off--- linear analysis



After the above settings go to solution ..in

right window

Insert the stress, deformation etc

Then solver.....

After solver the results can capture in Microsoft Office Word .....

Go to print review select ...and send to Microsoft word.....

## **DESIGN PROCEDURE FOR PISTON**

### **PISTON DESIGN**

The piston is designed according to the procedure and specification which are given in machine design and data

hand books. The dimensions are calculated in terms of SI Units. The pressure applied on piston head,

temperatures of various areas of the piston, heat flow, stresses, strains, length, diameter of piston and hole, thicknesses, etc., parameters are taken into considerations.

### **A. Design Considerations for a Piston**

In designing a piston for an engine, the following points should be taken into consideration:

- Ø It should have enormous strength to withstand the high pressure.
- Ø It should have minimum weight to withstand the inertia forces.
- Ø It should form effective oil sealing in the cylinder.
- Ø It should provide sufficient bearing area to prevent undue wear.
- Ø It should have high speed reciprocation without noise.
- Ø It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
- Ø It should have sufficient support for the piston pin.

### **B. Procedure for Piston Design parameters:**

The procedure for piston designs consists of the following steps:

- Ø Thickness of piston head (tH)
- Ø Heat flows through the piston head (H)
- Ø Radial thickness of the ring (t1)
- Ø Axial thickness of the ring (t2)
- Ø Width of the top land (b1)
- Ø Width of other ring lands (b2)

#### **(i). Thickness of Piston Head (tH):**

The piston thickness of piston head calculated using the following Grashoff's formula,

$$t_H = D \sqrt{\frac{3}{16}} * \left(\frac{P}{\sigma_T}\right) D \sqrt{\frac{3}{16}} * \left(\frac{P}{\sigma_T}\right)$$

( in mm)

Where

P= maximum pressure in N/mm<sup>2</sup>

D= cylinder bore/outside diameter of the piston in mm.

$\sigma_T$  = permissible tensile stress for the material of the piston.\

Here the material is a particular grade of AL alloy whose permissible stress is 50 Mpa-90Mpa before

calculating thickness of piston head, the diameter of the piston has to be specified. The piston size that has been

Considered here has an L\*D specified as 152\*140.

### **(ii). Heat Flow through the Piston Head (H):**

The heat flow through the piston head is calculated using the formula

$$H = 12.56 * t_H * K * T_c - T_e$$

KJ

Sec

Where,

K=thermal conductivity of material which is 174.15W/mk

T<sub>c</sub> = temperature at centre of piston head in °C.

T<sub>e</sub> = temperature at edges of piston head in °C.

The temperature difference for aluminium (T<sub>c</sub> – T<sub>e</sub>)=75°C

### **(iii). Radial Thickness of Ring (t<sub>1</sub>)**

$$t_1 = D \sqrt{3 * P_w / \sigma_t} D \sqrt{3 * P_w / \sigma_t}$$

( in mm)

Where,

D = cylinder bore in mm

P<sub>w</sub>= pressure of fuel on cylinder wall in N/mm<sup>2</sup>. Its value is limited from 0.025N/mm<sup>2</sup> to 0.042N/mm<sup>2</sup>. For aluminium material,  $\sigma_t$  is 90Mpa

**(iv). Axial Thickness of Ring (t2)**

The thickness of the rings may be taken as

$$t_2 = 0.7t_1 \text{ to } t_1$$

Let assume  $t_2 = 5\text{mm}$

Minimum axial thickness (t2)

$$t_2 = d/10 * n_r, n_r$$

Where  $n_r$  = number of rings

**(v). Width of the top land (b1)**

The width of the top land varies from

$$b_1 = 0.05 \text{ to } 0.1 * d$$

**(vi). Width of other lands (b2)**

Width of other ring lands varies from

$$b_2 = 0.05 \text{ to } 0.1 * d$$

**(vii). Maximum Thickness of Barrel (t3)**

$$t_3 = 0.05 * d + 0.05 + 0.05$$

Where,

b = Radial depth of piston ring groove

**STANDARD VALUES FROM DATA BOOK :**

In the design of the piston, it is used parameters of already existing engines as elements are calculated strength, without taking into account variable methods of loads.

The main structural dimensions of a piston shall be adopted within:

Thickness of piston crown  $\delta$

$$(0.05 - 0.10).D \quad \delta = 7mm$$

Height of the piston  $H$

$$(0.8 - 1.3).D \quad H = 75mm$$

Distance from the front to the axis of piston pin  $h_1$

$$(0.45 - 0.47).D \quad h_1 = 38mm$$

Diameter of thickening of piston pin  $d$

$$(0.3 - 0.5).D \quad d = 38mm$$

Size  $b$

$$(0,3 \div 0,5).D \quad b = 33mm$$

Wall thickness of leading part  $\delta_1$

$$(1,5 \div 4,5)mm \quad \delta_1 = 3mm$$

Thickness of the sealing part  $s$

$$(0,03 \div 0,8).D \quad s = 3mm$$

Distance from the front to the first channel  $e$

$$(0,06 \div 0,12).D \quad e = 7mm$$

Wall thickness between channels  $h_2$

$$(0,03 \div 0,05).D \quad h_2 = 3.5mm$$

Number of oil holes  $n_2$

$$6 \div 12 \quad n_2 = 8$$

Diameter holes for oil  $d_2$

$$(0,03 \div 0,05)d_c \quad d_2 = 1.5mm$$

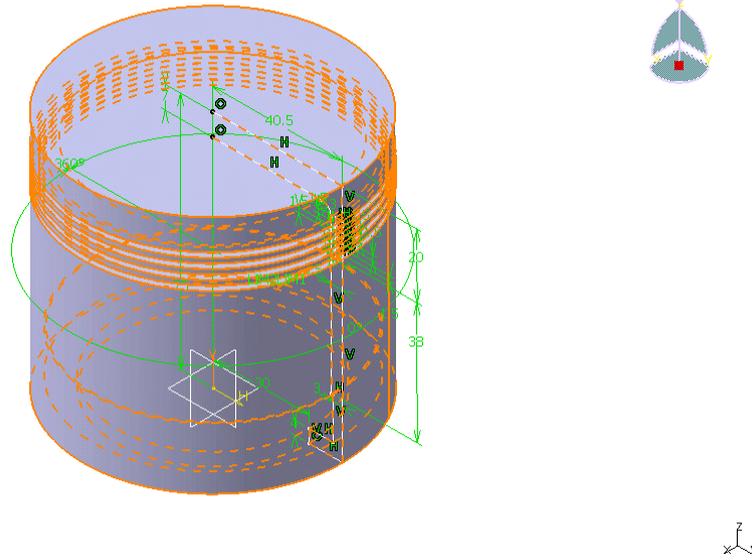
Hole diameter of piston pin  $d_c$

$$(0,22 \div 0,28).D \quad d_c = 23mm$$

Height of the leading part  $h_1$

$$(0,6 \div 0,8).D \quad h_1 = 55mm$$





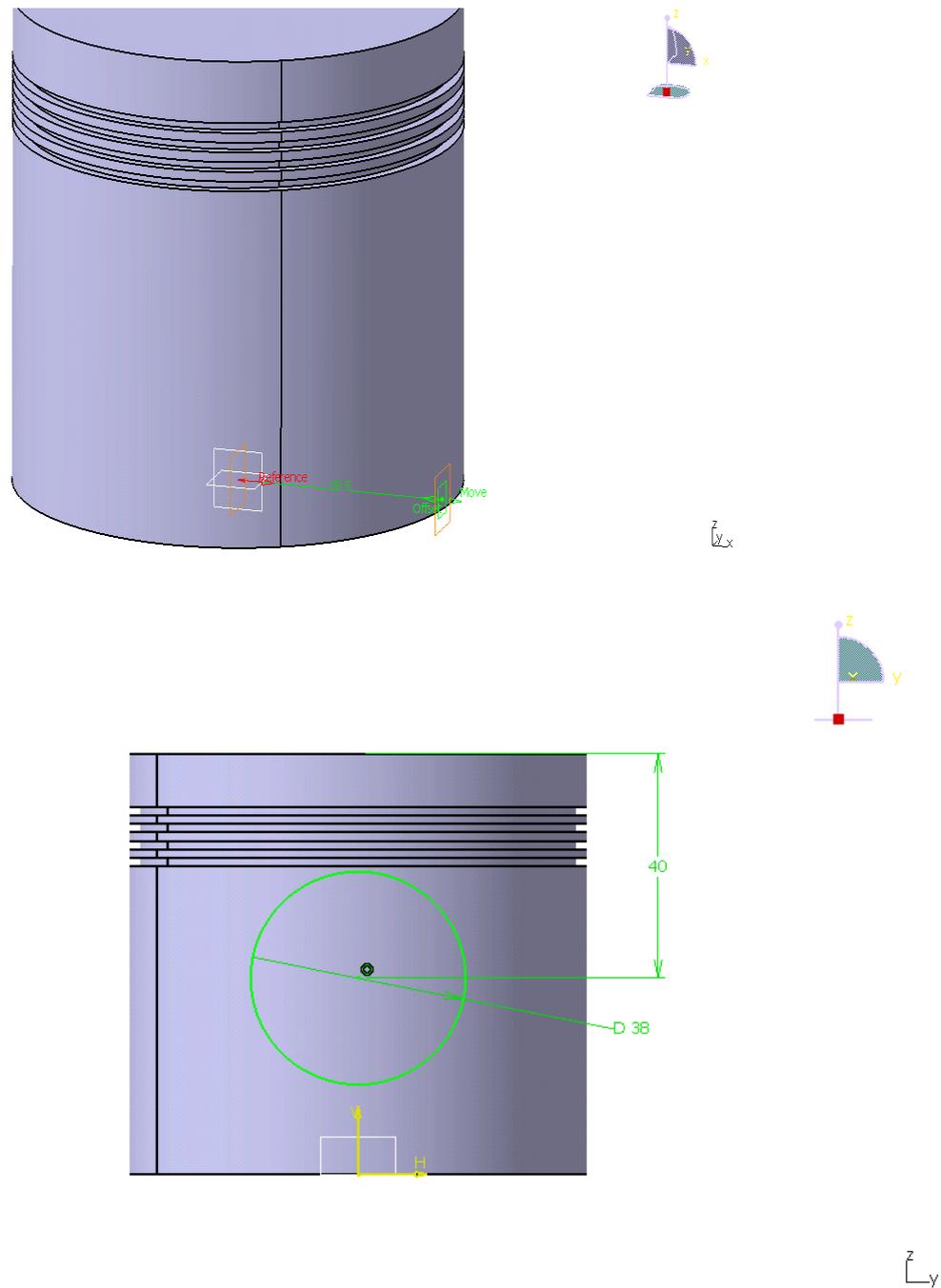
# IJRDO



**Fig-5.2**

**By the shaft definition the piston**

**For hub creation to create offset plane 38.5 mm :**

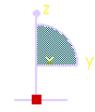
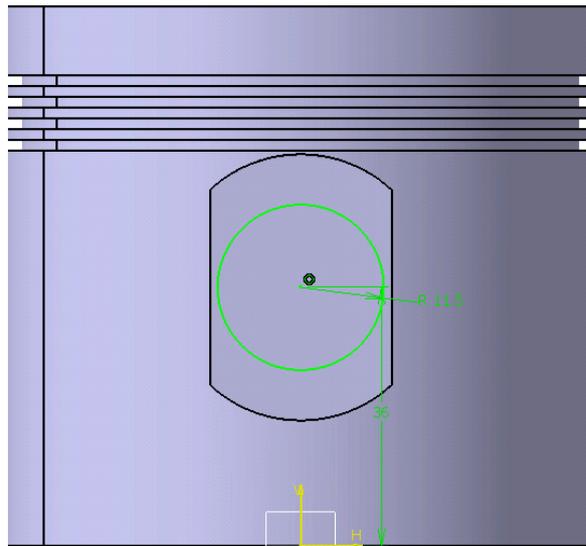


**Fig-5.4**

After creation the plane select the plane as a sketch plane

And draw the above sketch

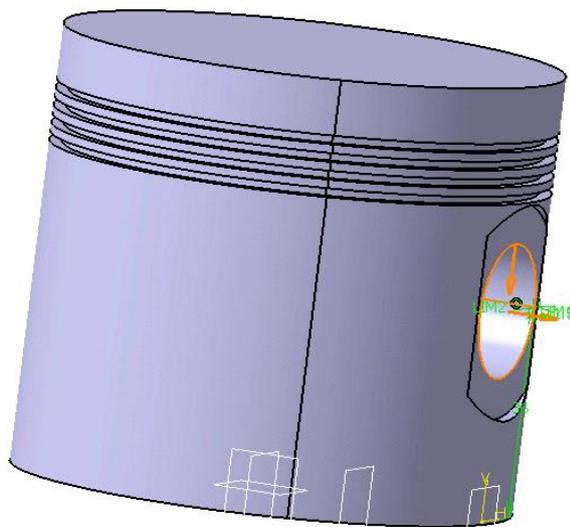
**To create piston pin hub:**



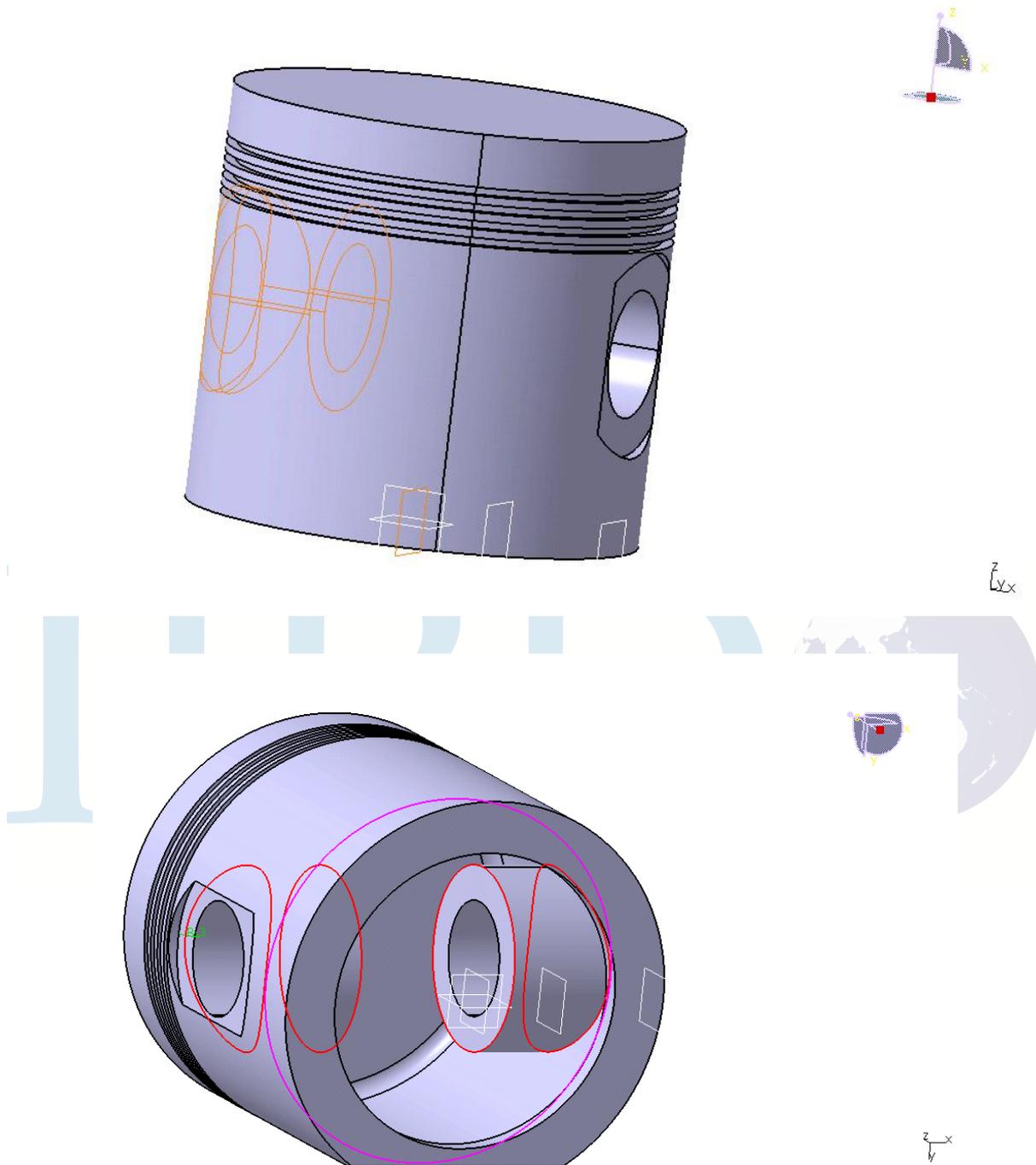
IJRDO

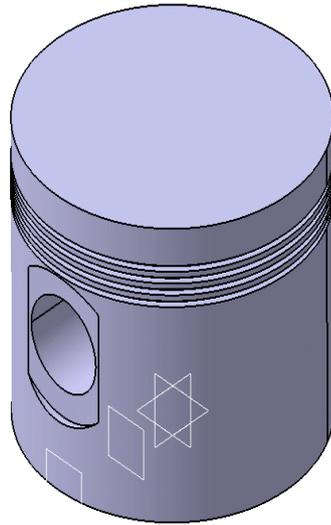


Z<sub>y</sub>

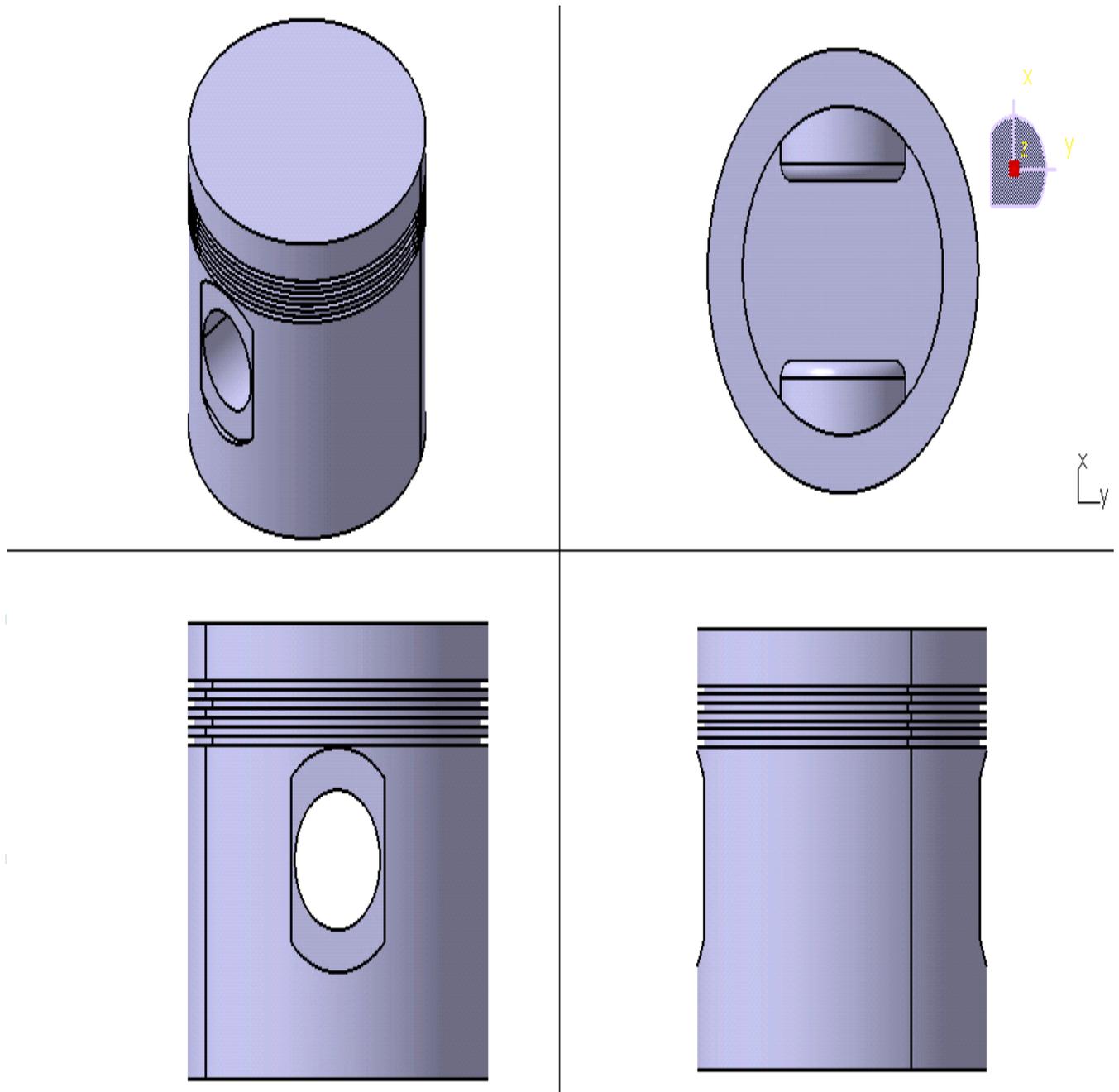


Z<sub>yx</sub>





# IJRDO



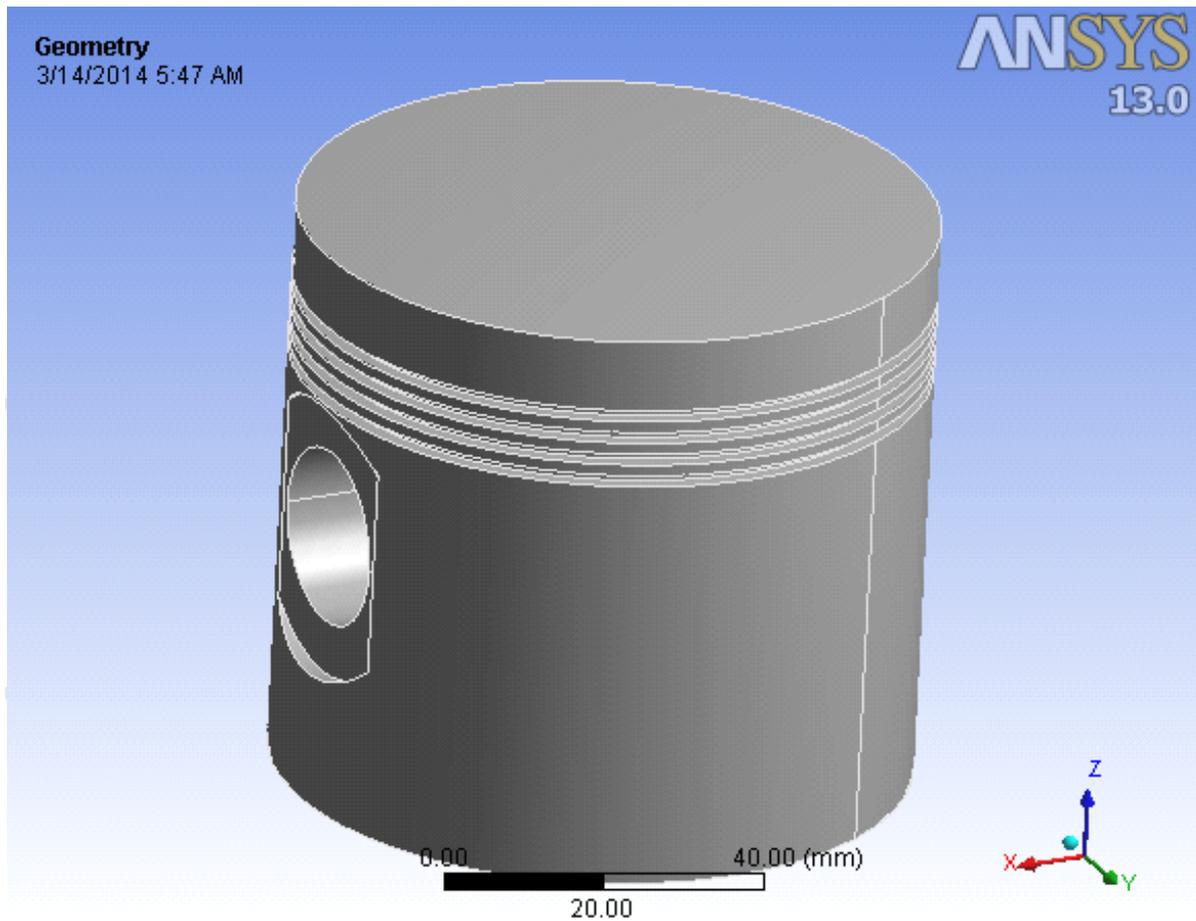
**Various Views of the Designed Piston**

## **ANALYZING THE PISTON IN ANSYS WORKBENCH**

Subject:

Date Friday, March 14, 2014

Comments:



Mesh

Subject:

Date Friday, March 14, 2014

Comments:

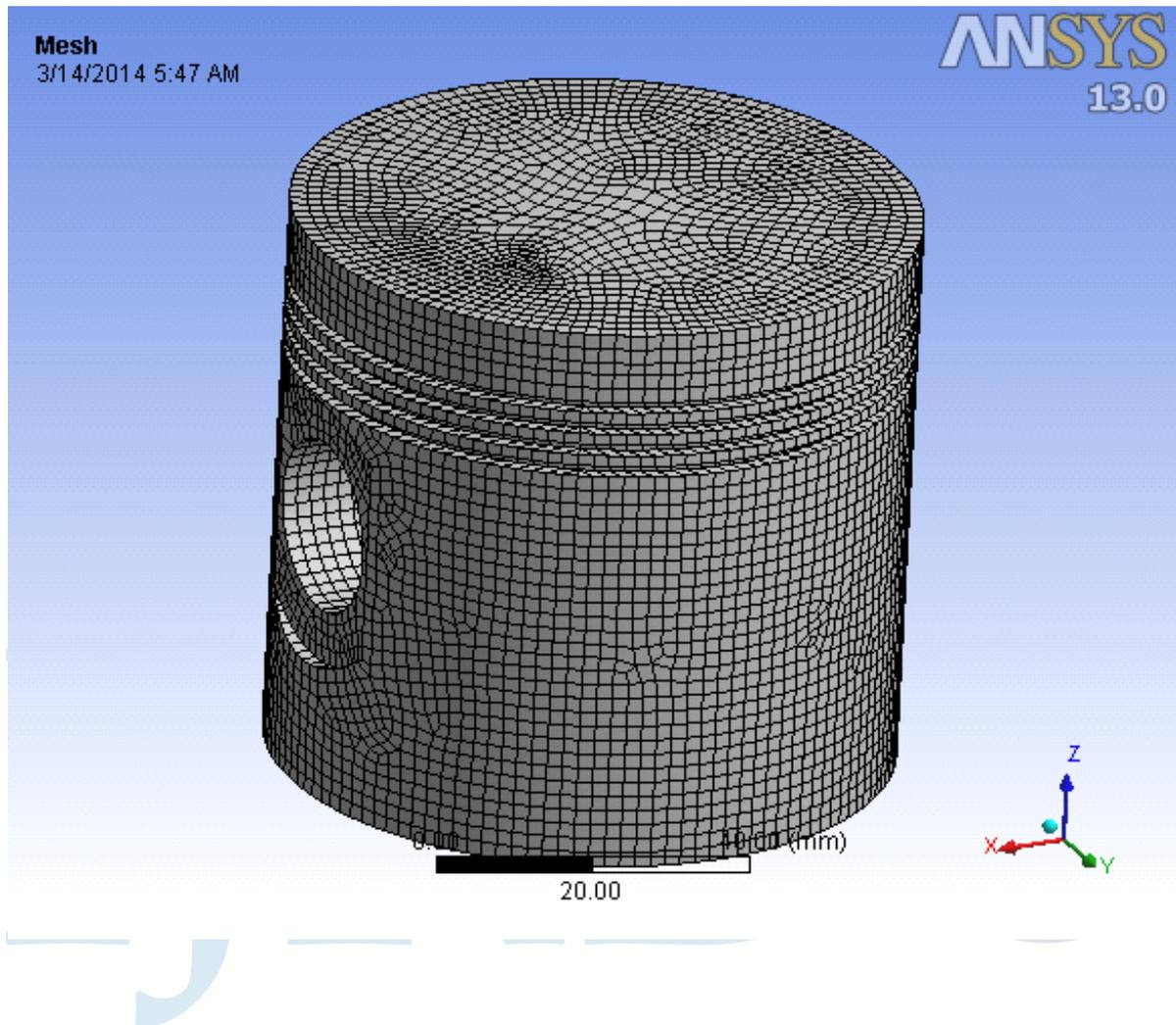
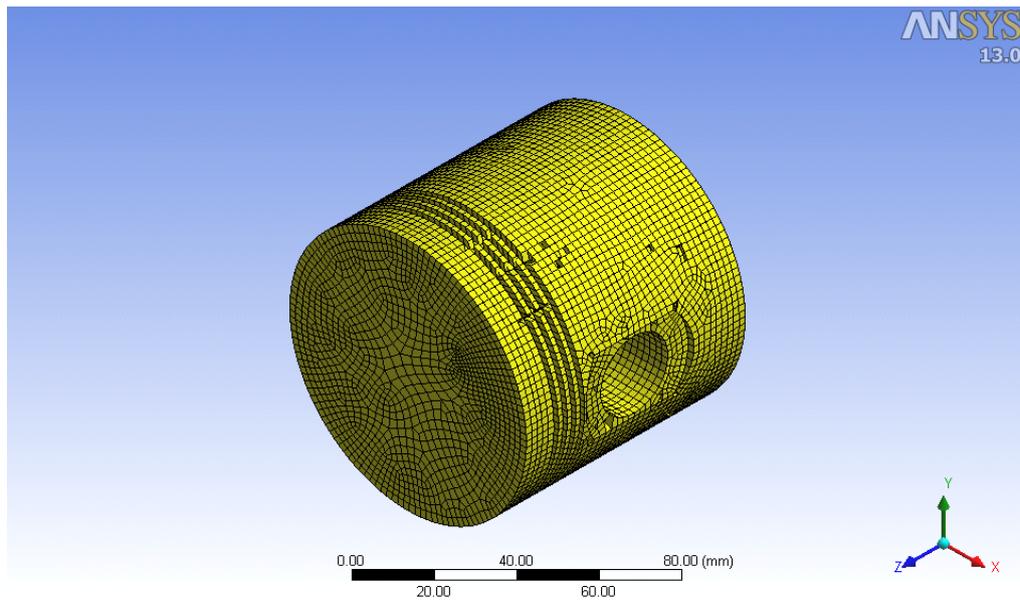


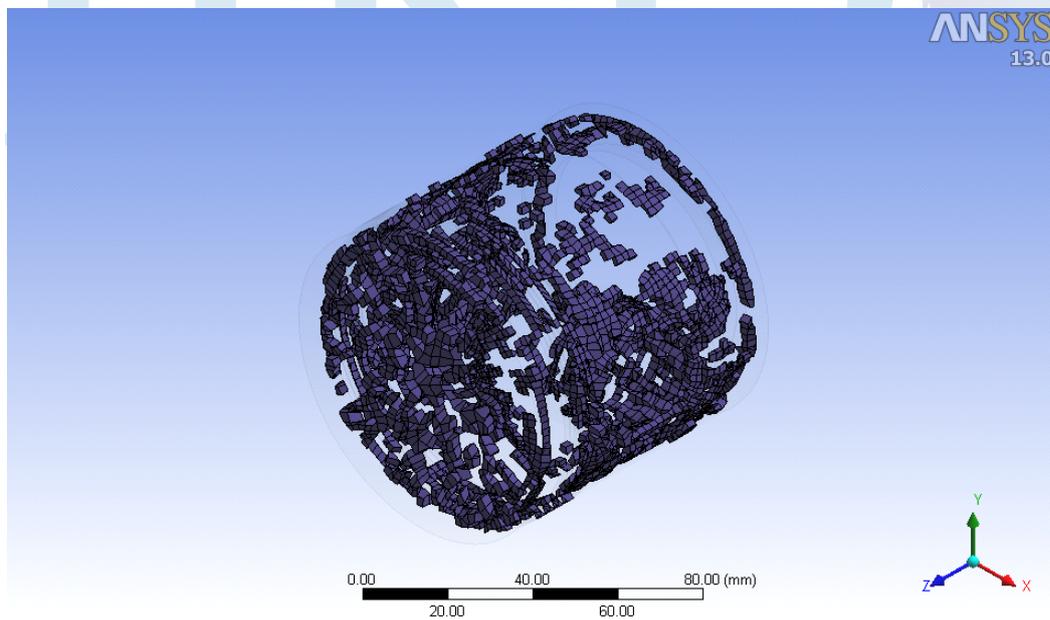
TABLE 1—FE Model Summary

Description	Quantity
Total Nodes	121099
Total Elements	33235
Total Body Elements	33235

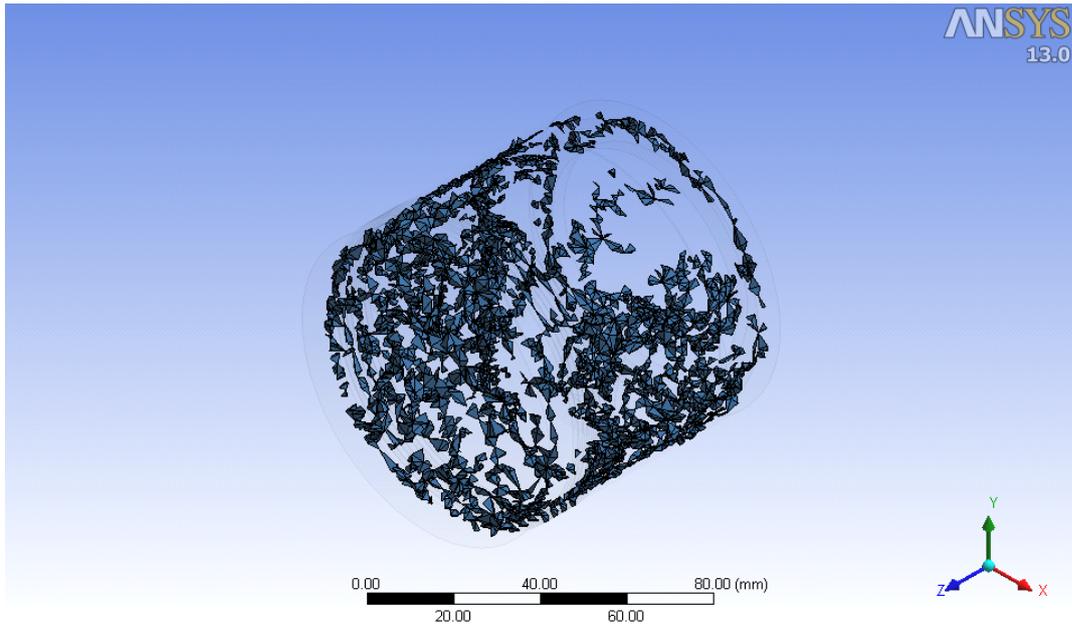




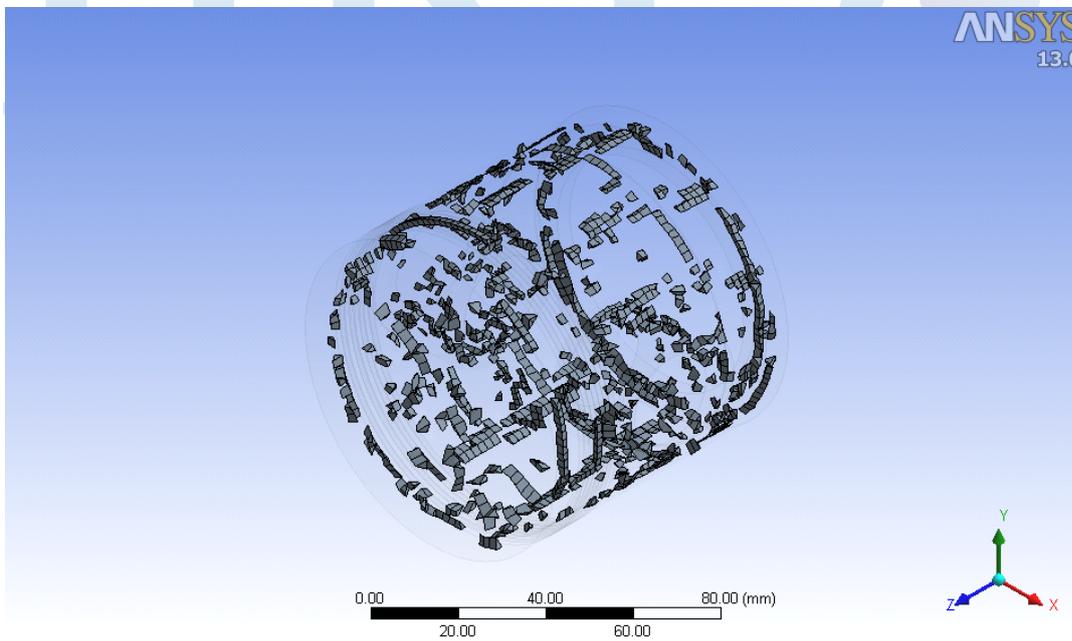
Quadratic Hexahedron for piston



Quadratic Pyramid for piston



Quadratic Tetrahedron for piston

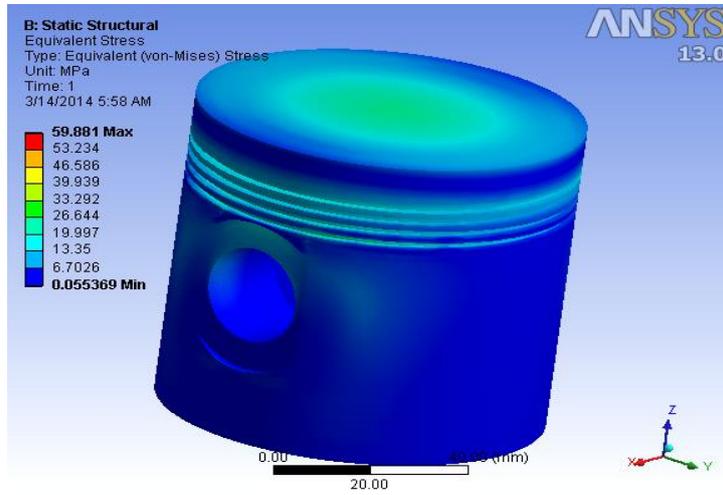


Quadratic Wedge for piston

Equivalent Stress

Subject:

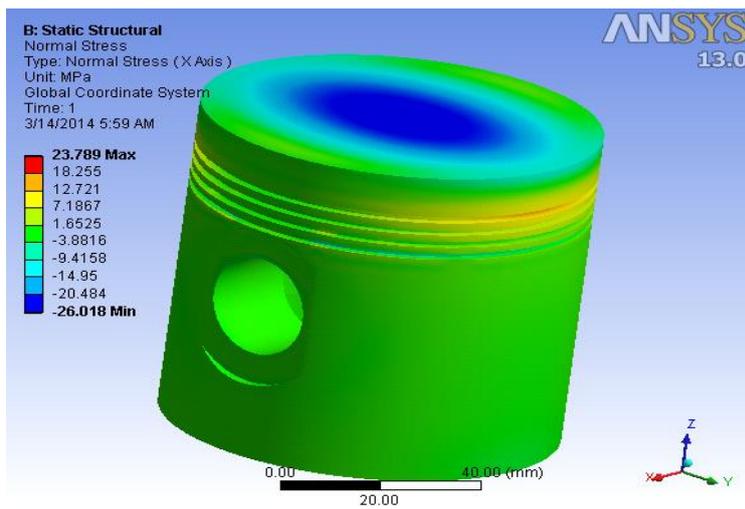
Date Friday, March 14, 2014



Normal Stress

Subject:

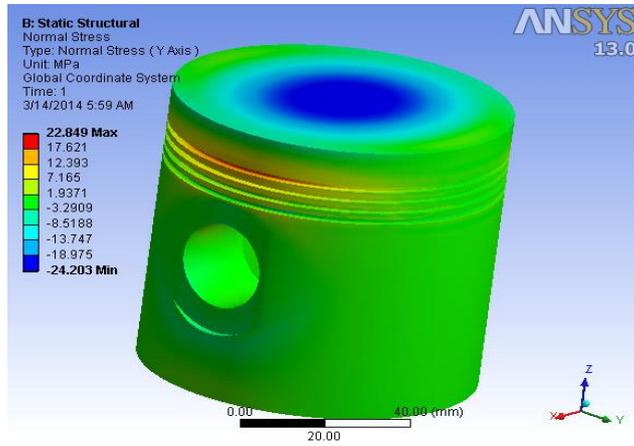
Date Friday, March 14, 2014



Normal Stress

Subject:

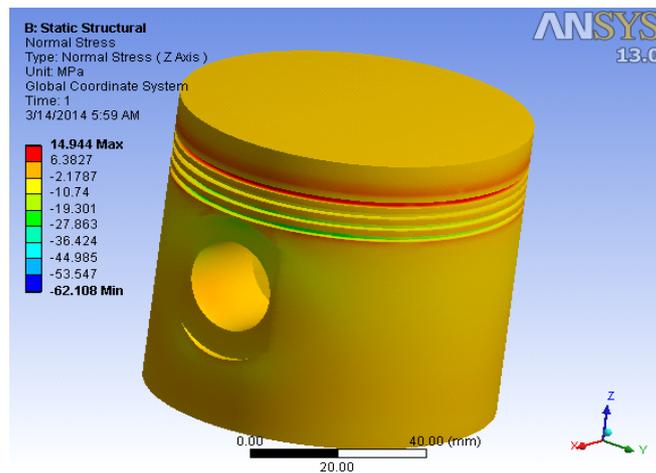
Date Friday, March 14, 2014



Normal Stress

Subject:

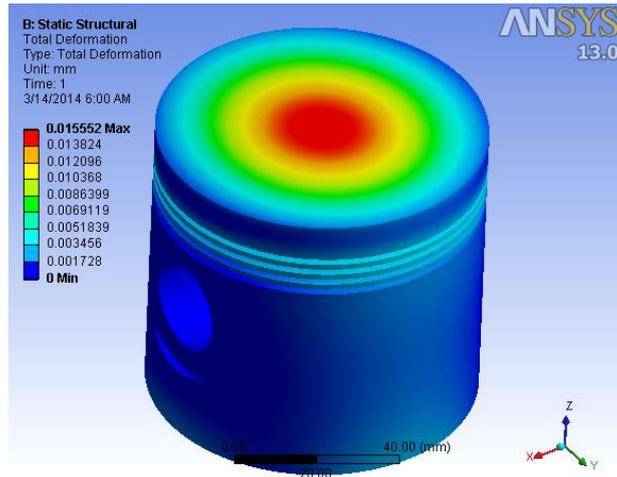
Date Friday, March 14, 2014



Total Deformation

Subject:

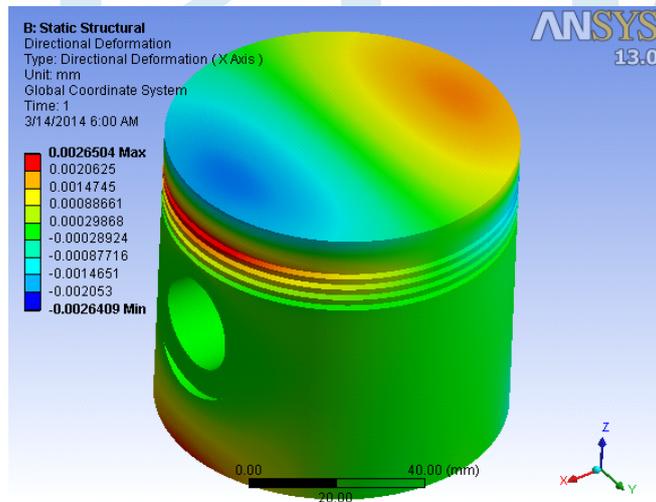
Date Friday, March 14, 2014



Directional Deformation

Subject:

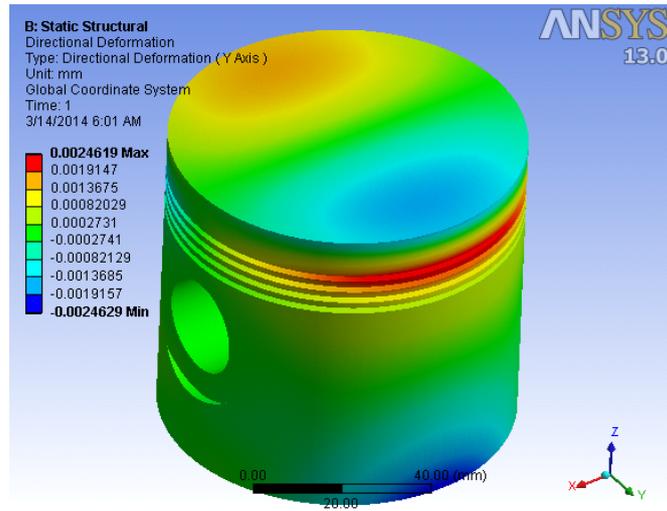
Date Friday, March 14, 2014



Directional Deformation

Subject:

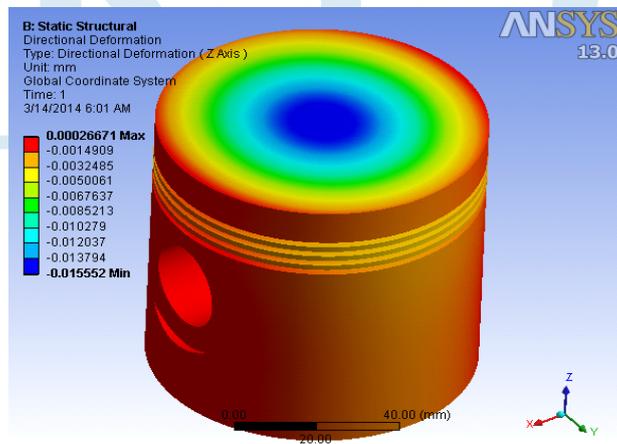
Date Friday, March 14, 2014



Directional Deformation

Subject:

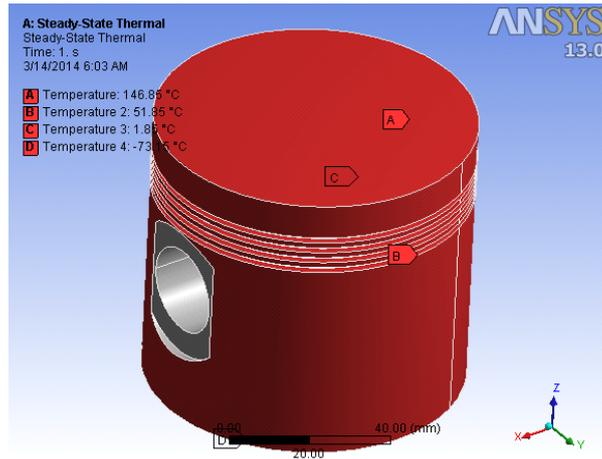
Date Friday, March 14, 2014



Steady-State Thermal

Subject:

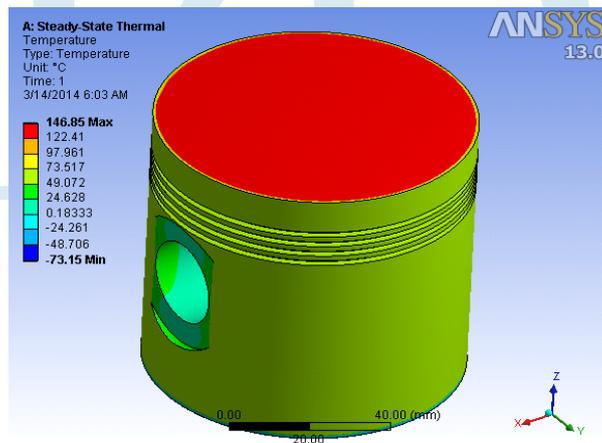
Date Friday, March 14, 2014



Temperature

Subject:

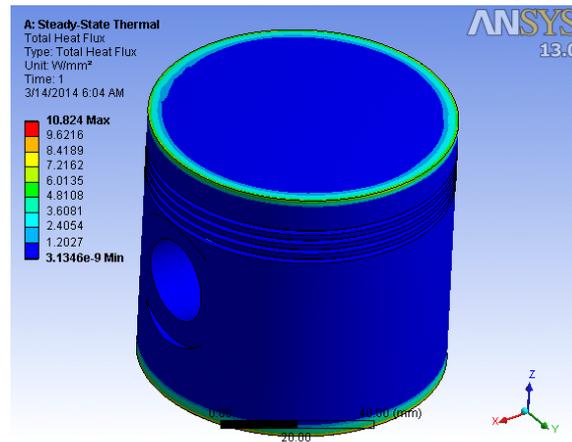
Date Friday, March 14, 2014



Total Heat Flux

Subject:

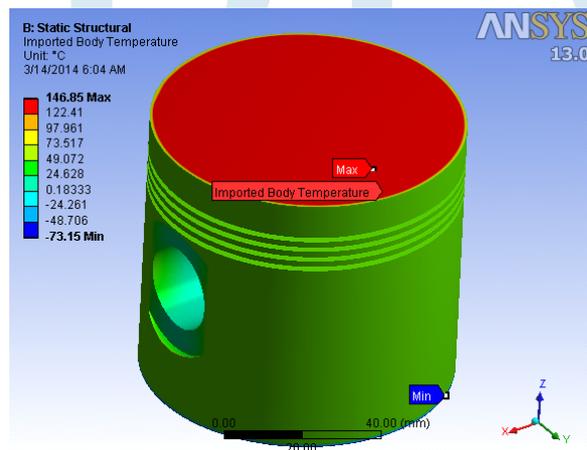
Date Friday, March 14, 2014



Imported Body Temperature

Subject:

Date Friday, March 14, 2014

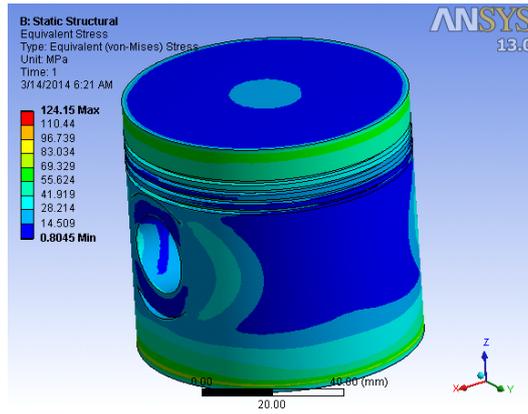


Equivalent Stress

Subject:

Date Friday, March 14, 2014

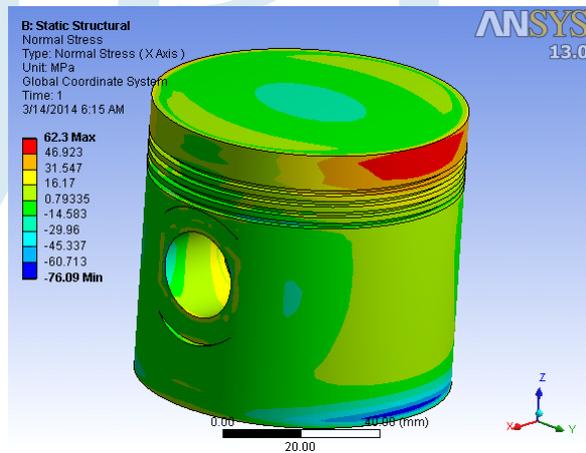
Comments:



Normal Stress

Subject:

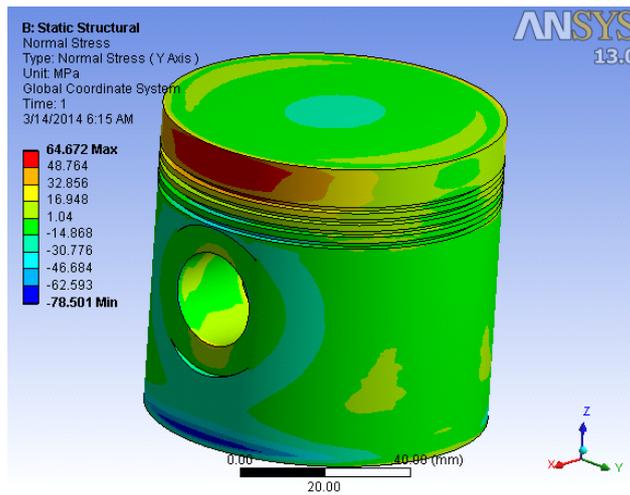
Date Friday, March 14, 2014



Normal Stress

Subject:

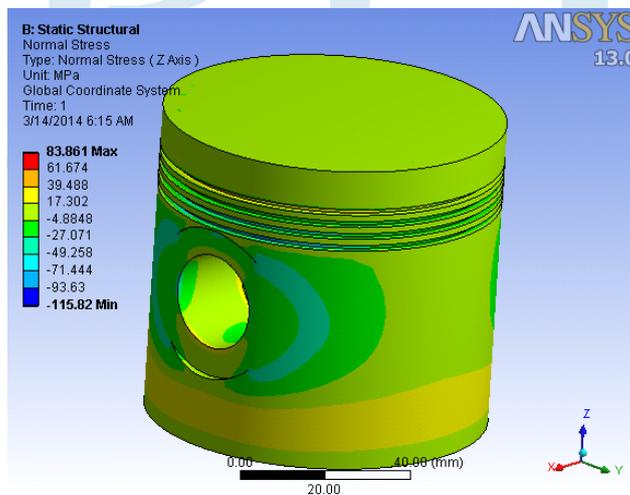
Date Friday, March 14, 2014



Normal Stress

Subject:

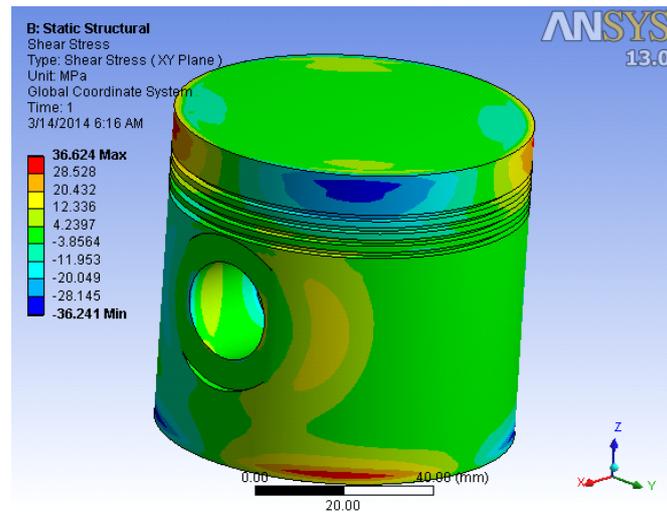
Date Friday, March 14, 2014



Shear Stress

Subject:

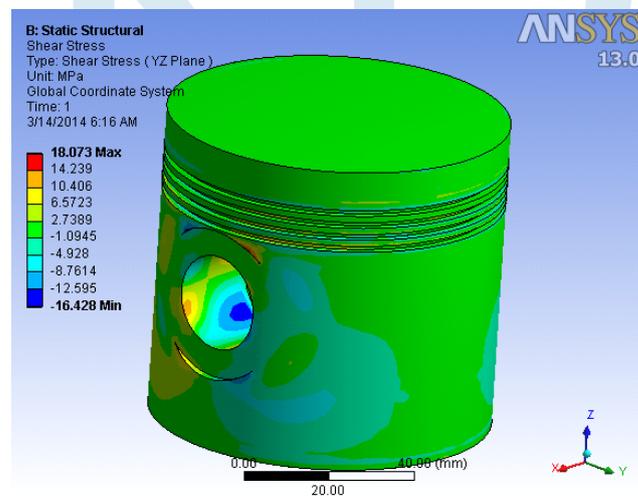
Date Friday, March 14, 2014



Shear Stress

Subject:

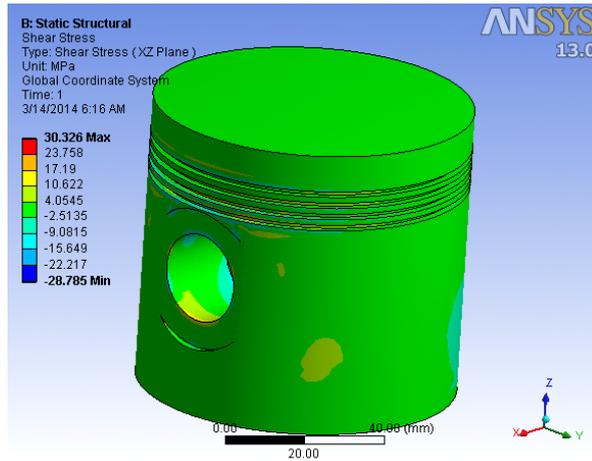
Date Friday, March 14, 2014



Shear Stress

Subject:

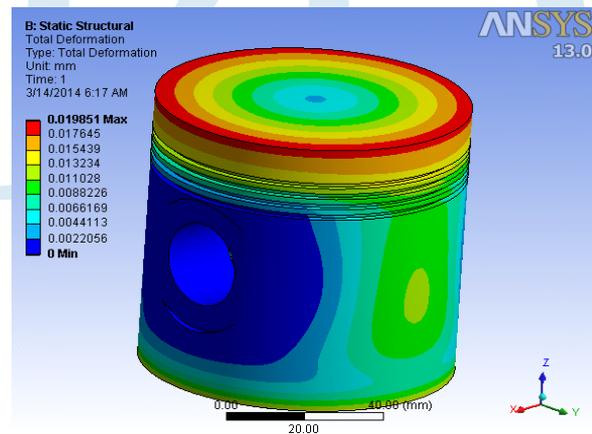
Date Friday, March 14, 2014



Total Deformation

Subject:

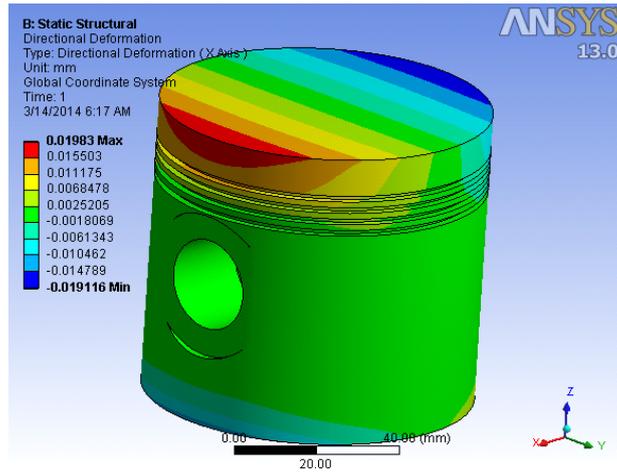
Date Friday, March 14, 2014



Directional Deformation

Subject:

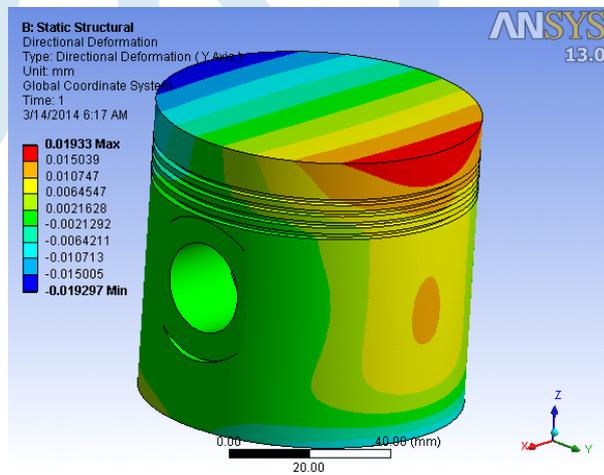
Date Friday, March 14, 2014



Directional Deformation

Subject:

Date Friday, March 14, 2014



Directional Deformation

Subject:

Date Friday, March 14, 2014

