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Full Length Research Article

Design Optimization And Analysis Of A Piston, Piston Rings And Connecting Rod In Internal Combustion Engine Applications

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Abstract
This project mainly deals with the design and analysis of I.C engine piston, piston rings and connecting rod. 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 or connecting rod. For this project, there are two basic requirements. The first requirement is to design of a model of I.C engine piston, piston rings and connecting rod. The second requirement is to analyze of I.C engine piston, piston rings and connecting rod by the method, such as following a track, which consists of straight lines and curves. These systems are done by modeling software's like CatiaV5, and analysis is done by Ansys software. Specifications of a product are detailed in terms of the product size, speed range, weight and power consumption. Here the piston is designed; analyzed and has been studied. Piston temperature has considerable influence on efficiency, emission, performance of the 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. Even though the program worked well, there were some errors that were identified after testing, resulting in increased performance. In this project work has been taken up on the following aspects to cover the research gaps to present the results based on the systematic studies. Nodal Temperature, Thermal Gradient through the piston of the engine, FEA analysis of the piston to measure Thermal Flux at the points where it is not possible to find out practically and to observe Heat Flow inside the piston.

INTRODUCTION

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 of 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.

Piston

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. 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. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder.

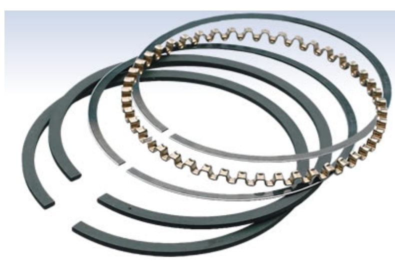
In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall. The petrol enters inside the cylinder and the piston moves upwards and the spark plug produces spark and the petrol is set on fire and it produces an energy that pushes the piston downwards.

Piston ring

A piston ring is a split ring that fits into a groove on the outer diameter of a piston in a reciprocating engine such as an internal combustion engine or steam engine.

The three main functions of piston rings in reciprocating engines are:

1. Sealing the combustion chamber so that there is minimal loss of gases to the crank case.
2. Improving heat transfer from the piston to the cylinder wall.
3. Regulating engine oil consumption by scraping oil from the cylinder walls back to the sump.



The gap in the piston ring compresses to a few thousandths of an inch when inside the cylinder bore. Piston rings are a major factor in identifying if an engine is two strokes or four strokes. Three piston rings suggest that it is a four-stroke engine while two piston rings suggest that it is a two-stroke engine. Most piston rings are made of a very hard and somewhat brittle cast iron.

Connecting rod

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion.

Connecting rods may also convert rotating motion into reciprocating motion. Historically, before the development of engines, they were first used in this way.

As a connecting rod is rigid, it may transmit either a push or a pull and so the rod may rotate the crank through both halves of a revolution, i.e. piston pushing and piston pulling. Earlier mechanisms, such as chains, could only pull. In a few two-stroke engines the connecting rod is only required to push.

Today, connecting rods are best known through their use in internal combustion piston engines, such as automotive engines. These are of a distinctly different design from earlier forms of connecting rods, used in steam engines and steam locomotives.

II - LITERATURE REVIEW

There is a vast amount of literature related to Finite Element Analysis of shape optimization of connecting rod. The literature review presented here considers the major development in implementation of FEA. The main objective of this study was to explore opportunities for a I.C engine piston, piston rings and connecting rod. Typically, an optimum solution is the minimum or maximum possible value the objective function could achieve under a defined set of constraints. The weight of the I.C engine piston, piston rings and connecting rod has little influence on the final component. As a result, in this optimization problem the cost and the weight were dealt with separately. The structural factors considered for weight reduction during the buckling load factor, stresses under the loads, bending stiffness, and axial stiffness. Cost reduction is achieved by using C-70 steel, which is fracture crack able. It eliminates sawing and machining of the rod and cap mating faces and is believed to reduce the production cost by 25%.

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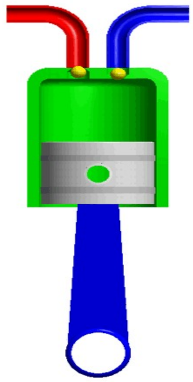
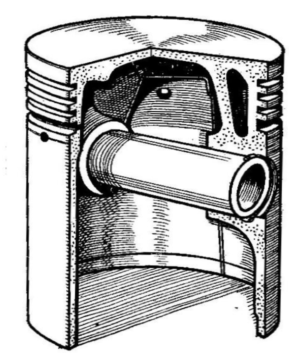


An internal combustion engine is acted upon by the pressure of the expanding combustion gases in the combustion chamber space at the top of the cylinder. This force then acts downwards through the connecting rod and onto the crankshaft. The connecting rod is attached to the piston by a swiveling gudgeon pin (US: wrist pin). This pin is mounted within the piston: unlike the steam engine, there is no piston rod or crosshead (except big two stroke engines).

The pin itself is of hardened steel and is fixed in the piston, but free to move in the connecting rod. A few designs use a 'fully floating' design that is loose in both components. All pins must be prevented from moving sideways and the ends of the pin digging into the cylinder wall, usually by circlips.



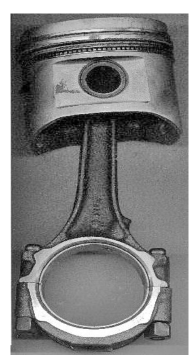
Gas sealing is achieved by the use of piston rings. These are a number of narrow iron rings, fitted loosely into grooves in the piston, just below the crown. The rings are split at a point in the rim, allowing them to press against the cylinder with a light spring pressure. Two types of rings are used: the upper rings have solid faces and provide gas sealing; lower rings have narrow edges and a U-shaped profile, to act as oil scrapers. There are many proprietary and detail design features associated with piston rings.

III - PRINCIPLE OF I.C ENGINE PISTON, PISTON RINGS AND CONNECTING ROD

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

Reciprocating engines

The base of a reciprocating internal combustion engine is the engine block, which is typically made of cast iron or aluminum. The engine block contains the cylinders. In engines with more than one cylinder they are usually arranged either in 1 row (straight engine) or 2 rows (boxer engine or V engine); 3 rows are occasionally used (W engine) in contemporary engines, and other engine configurations are possible and have been used. Single cylinder engines are common for motorcycles and in small engines of machinery. Water-cooled engines contain passages in the engine block where cooling fluid circulates (the water jacket). Some small engines are air-cooled, and instead of having a water jacket the cylinder block has fins protruding away from it to cool by directly transferring heat to the air. The cylinder walls are usually finished by honing to obtain a cross hatch, which is better able to retain the oil. A too rough surface would quickly harm the engine by excessive wear on the piston.



The pistons are short cylindrical parts which seal one end of the cylinder from the high pressure of the compressed air and combustion products and slide continuously within it while the engine is in operation. The top wall of the piston is termed its crown and is typically flat or concave. Some two-stroke engines use pistons with a deflector head. Pistons are open at the bottom and hollow except for an integral reinforcement structure (the piston web). When an engine is working the gas pressure in the combustion chamber exerts a force on the piston crown which is transferred through its web to a gudgeon pin. Each piston has rings fitted around its circumference that mostly prevent the gases from leaking into the crankcase or the oil into the combustion chamber. A ventilation system drives the small amount of gas that escape past the pistons during normal operation (the blow-by gases) out of the crankcase so that it does not accumulate contaminating the oil and creating corrosion. In two-stroke gasoline engines the crankcase is part of the air–fuel path and due to the continuous flow of it they do not need a separate crankcase ventilation system.

Piston rings

Piston rings have been an area of considerable focus and development for internal combustion engines. The needs of diesel engines and small piston-ported two-stroke engines have been particularly difficult. Piston rings may account for a considerable proportion of the total friction in the engine, as much as 24%. This high friction is a result of the design compromises needed to achieve good sealing and long lifetime. Sealing is achieved by multiple rings, each with their own function, using a metal-on-metal sliding contact.

Connecting rod

In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of T6-2024 and T651-7075 aluminum alloys (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of lightness with strength, at higher cost) for high-performance engines, or of cast iron for applications such as motor scooters. They are not rigidly fixed at either end, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around the crankshaft. Connecting rods, especially in racing engines, may be called "billet" rods, if they are machined out of a solid billet of metal, rather than being cast or forged.

IV - DESIGN METHODLOGY OF I.C ENGINE COMBUSTION SYSTEM

Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

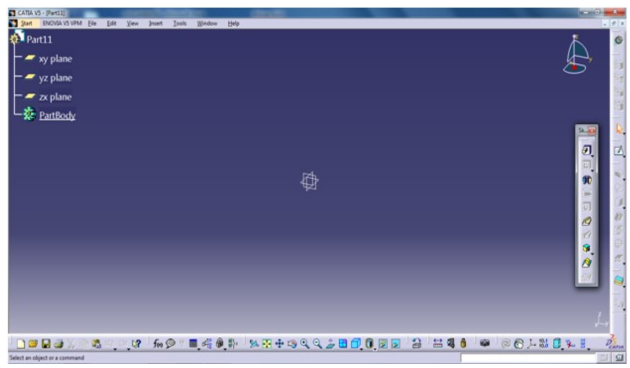


Fig: Home Page of CatiaV5

Modeling of I.C engine piston, piston rings and connecting rod in CATIA V5

This I.C engine piston, piston rings and connecting rod is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

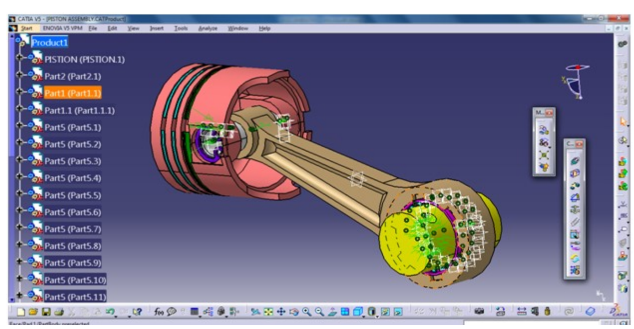


Fig: Model design of I.C engine piston, piston rings and connecting rod in CATIA-V5

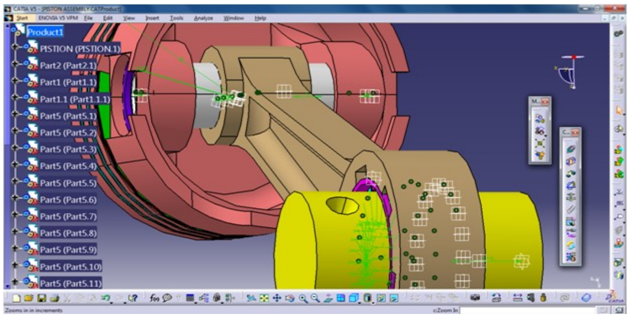


Fig: Model arrangement of I.C engine piston, piston rings and connecting rod mechanism

Multi View: This is the command in which all the views of the component / model can be displayed on the screen at a same time, they can be edited under the workbench.

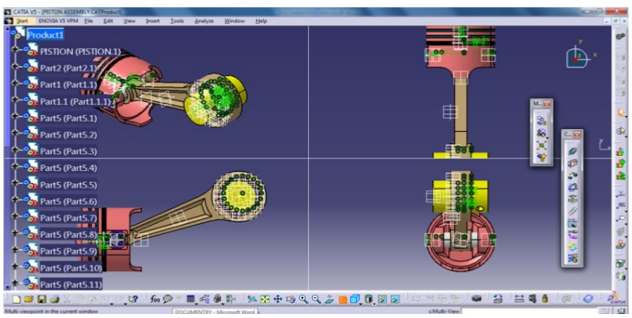


Fig: Using Multi View Command

V - ANALYSIS OF I.C ENGINE COMBUSTION SYSTEM

Procedure for FE Analysis Using ANSYS:

The analysis of the Skirt, Air cushion, cabin, blower fan, pulleys, v-belt is done using ANSYS. For compete assembly is not required, motor and attached system is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of assembly of the craft.

Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

  File Menu > Import> STEP > Click ok for the popped-up dialog box > Click

  Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

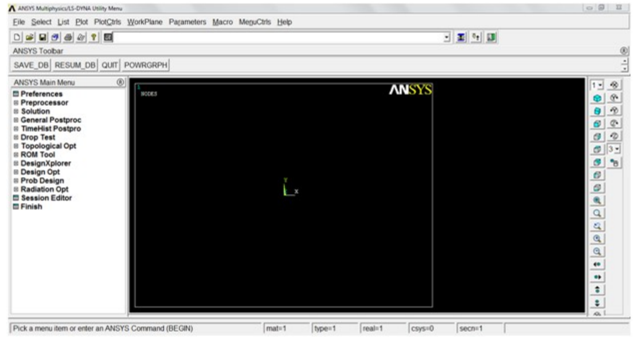


Fig: Import panel in Ansys.

Meshing:

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen as finite element analysis or computational fluid dynamics. The input model form can vary greatly but common sources are CAD, NURBS, B-rep and STL (file format). The field is highly interdisciplinary, with contributions found in mathematics, computer science, and engineering. Three-dimensional meshes created for finite element analysis need to consist of tetrahedral, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedral. Those used for finite difference methods usually need to consist of piecewise structured arrays of hexahedra known as multi-block structured meshes.

Meshing is an integral part of the computer-aided engineering (CAE) simulation process. The mesh influences the accuracy, convergence and speed of the solution. Furthermore, the time it takes to create a mesh model is often a significant portion of the time it takes to get results from a CAE solution. Therefore, the better and more automated the meshing tools, the better the solution. From easy, automatic meshing to a highly crafted mesh, ANSYS provides the ultimate solution. Powerful automation capabilities ease the initial meshing of a new geometry by keying off physics preferences and using smart defaults so that a mesh can be obtained upon first try. Additionally, users are able to update immediately to a parameter change, making the handoff from CAD to CAE seamless and aiding in up-front design. Once the best design is found, meshing technologies from, ANSYS provide the flexibility to produce meshes that range in complexity from pure hex meshes to highly detailed Hybrid meshes.

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IJESR/April-June. 2026/ Vol-16/Issue-2/84-92

Mohammed Moinuddin *et. al.*, / International Journal of Engineering & Science Research

VI - DISCUSSION ON ANALYSYS RESULT

Results of Nodal Temperature:

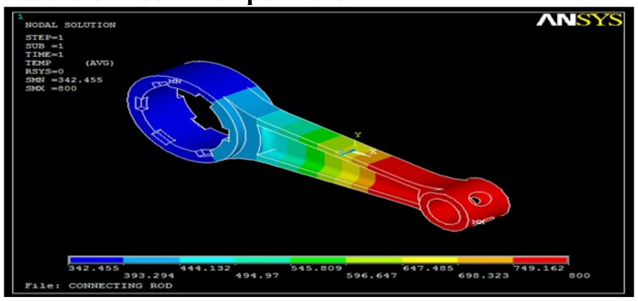


Fig: Nodal Temperature of Connecting Rod

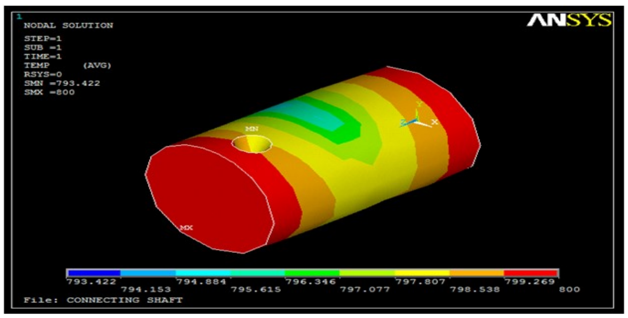


Fig: Nodal Temperature of Connecting Shaft

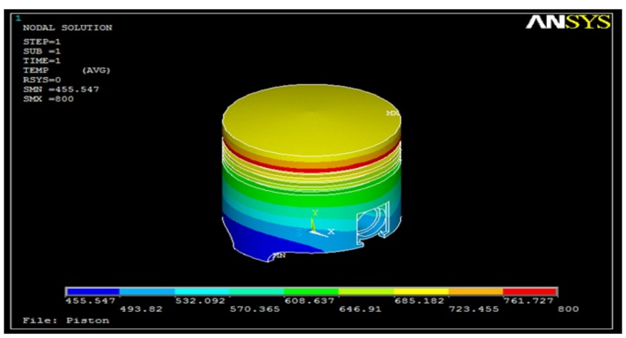


Fig: Nodal Temperature of Piston

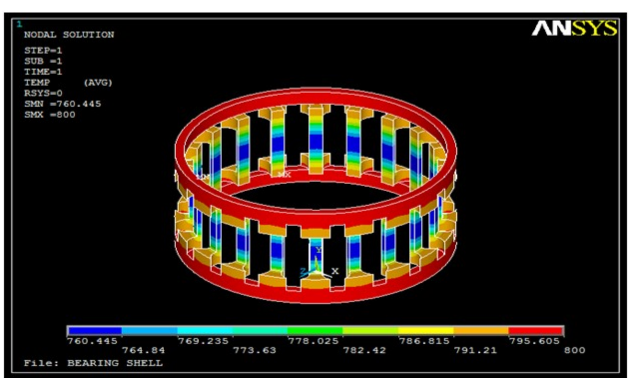


Fig: Nodal Temperature of Bearing Shell

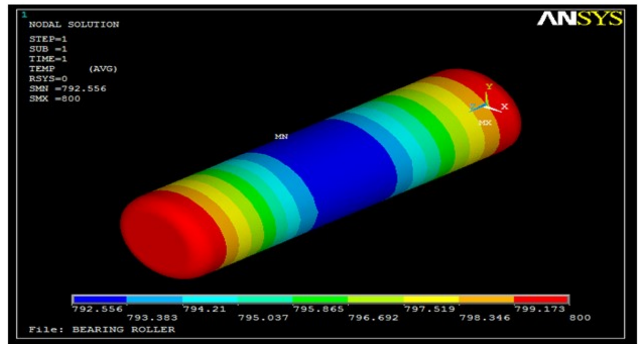


Fig: Nodal Temperature of Bearing Roller

Results of Thermal Gradient:

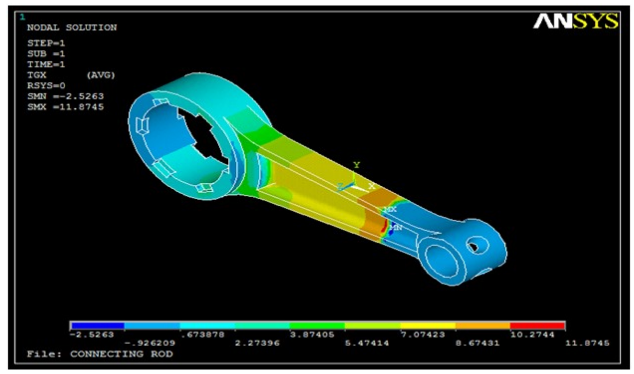


Fig: Thermal Gradient of Connecting Rod

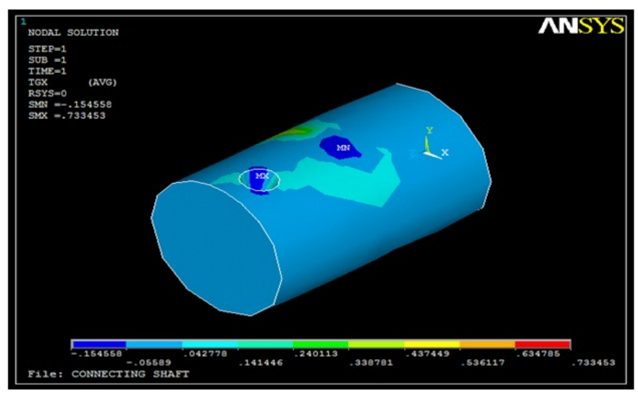
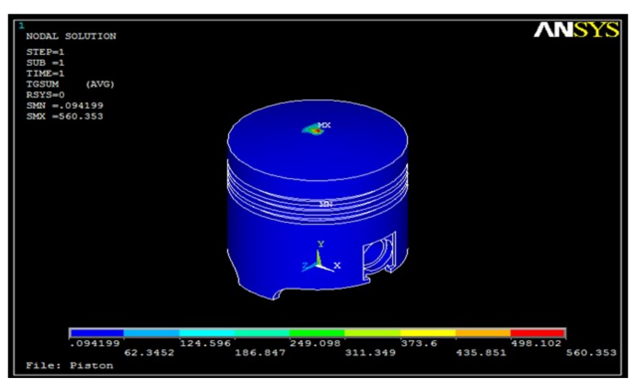


Fig: Thermal Gradient of Connecting Shaft



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IJESR/April-June. 2026/ Vol-16/Issue-2/84-92
Mohammed Moinuddin *et. al.,* / International Journal of Engineering & Science Research

Fig: Thermal Gradient Analysis of Piston

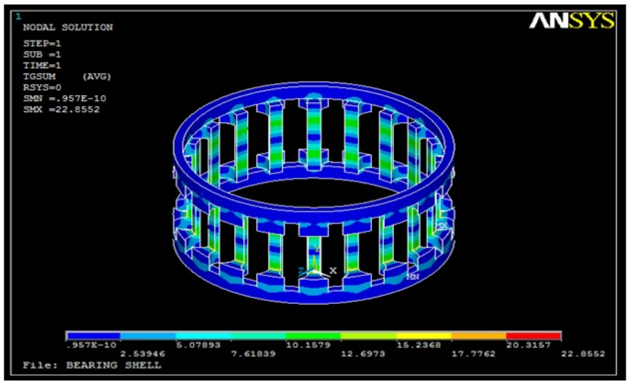

Fig: Thermal Gradient Analysis of Bearing Shell

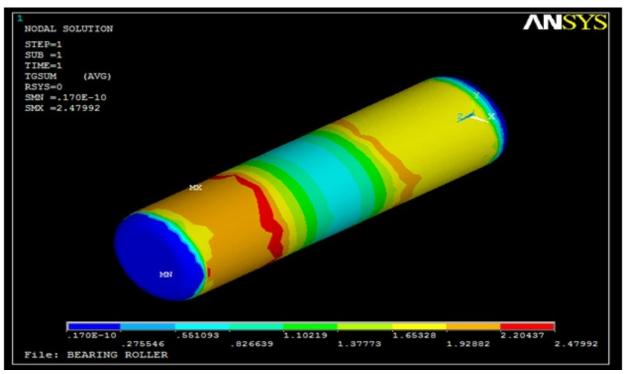

Fig: Thermal Gradient Analysis of Bearing Roller

Results of Thermal Flux:

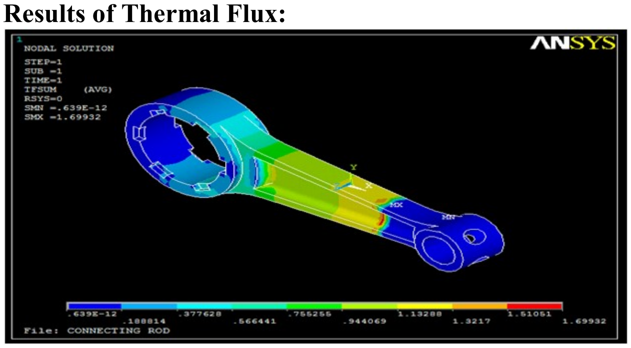

Fig: Thermal Flux Analysis of Connecting Rod

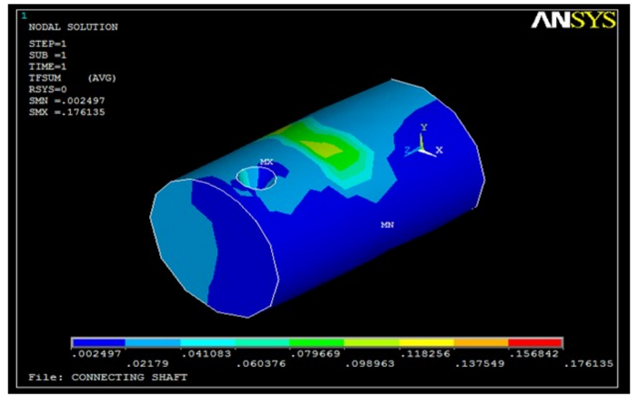

Fig: Thermal Flux Analysis of Connecting Shaft

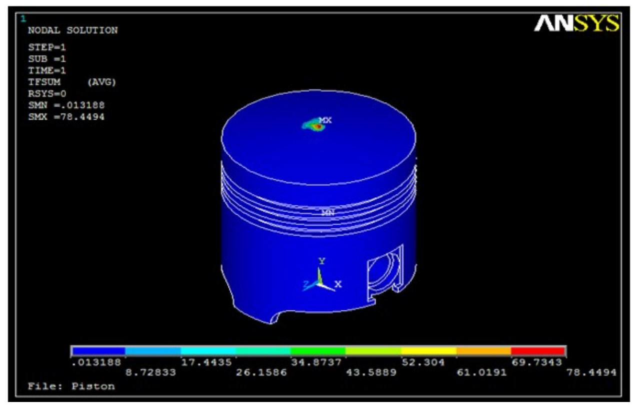

Fig: Thermal Flux Analysis of Piston

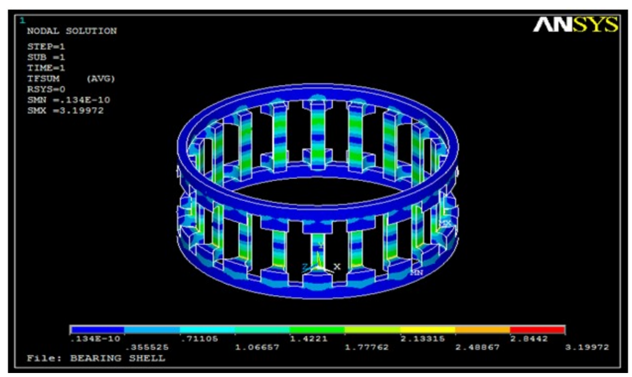

Fig: Thermal Flux Analysis of Bearing Shell

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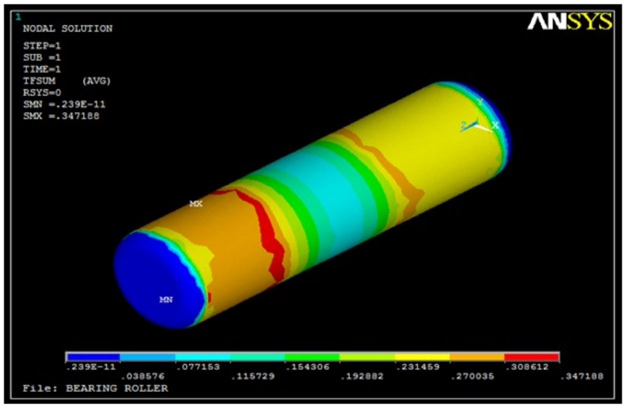

Fig: Thermal Flux Analysis of Bearing Roller

Results of Heat Flow:

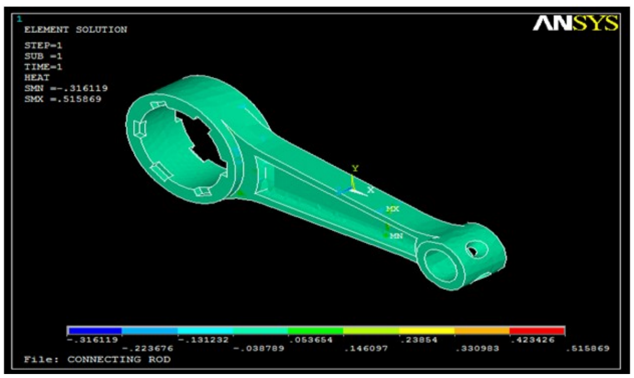

Fig: Heat Flow Analysis of Connecting Rod

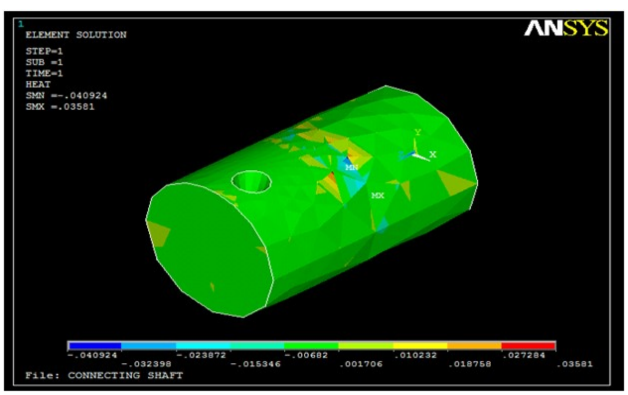

Fig: Heat Flow Analysis of Connecting Shaft

Fig: Heat Flow Analysis of Piston

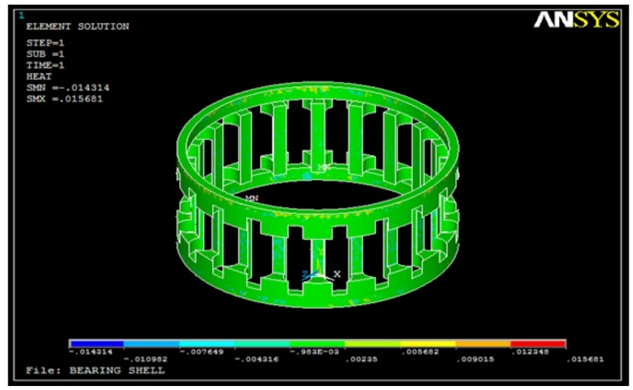

Fig: Heat Flow Analysis of Bearing Shell

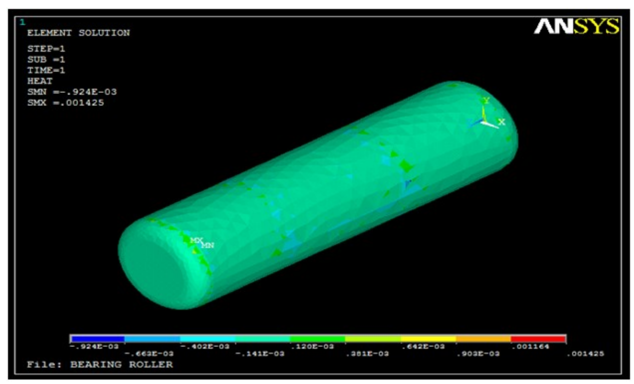

Fig: Heat Flow Analysis of Bearing Roller

VII - CONCLUSION

A highly nonlinear model for the dynamic behavior is considered. A parametric study to investigate the influence of the control parameters on the dynamic response is conducted. The control parameters that influence the transient response are found to be dimensionless equation is developed to predict the settling time of the response. Based on the developed equation, the Optimum values of the control parameters are obtained.

As shown above figures the Nodal Temperature of the complete design is meshed and solved using Ansys and Nodal Temperature is from 800 to 342.42. This is showing us that clearly each component in assembly. The maximum Thermal gradient is coming, this solution solving with the help of Ansys software so that the maximum Thermal gradient is 560.35 to 1.25. The maximum Thermal flux is coming, this solution solving with the help of Ansys software so that the maximum Thermal flux is 78.44 to 0.17. The maximum Heat flow is 3.5 to 0.001. So, we can conclude our design parameters are approximately correct.

The design of the IC Engine Combustion System mechanism worked flawlessly in analysis as well; all these facts point to the completion of our objective in high esteem.

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