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DESIGN OF PISTON AND ANALYSIS WITH DIFFERENT MATERIALS SUBJECTED TO THERMAL ANALYSIS

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Abstract: *An IC engine is one in which the combustion of fuel takes place inside the engine cylinder. IC engine uses either petrol or diesel as their fuel. In petrol engines (S.I engines) the correct proportion of air and petrol is mixed in the carburetor and fed to engine cylinder where it is ignited by means of a spark plug. The steps involved in a 4 stroke IC engine are suction stroke, compression stroke, and expansion stroke and exhaust stroke. One of the main components in an IC engine is the Piston. The design of a Piston has an important influence upon the engine performance. Design of a Piston involves the shape of the combustion chamber, location of the spark plug and the position of the inlet and exhaust valves. For this project, there are two basic requirements. The first requirement is to design of a model of I.C engine Piston as per the standards. The second requirement is to analyze the I.C engine Piston by the method, such as following a track, which consists of straight lines and curves. These systems are done by modeling software's like Catia, and thermal analysis is done by Ansys software. In this project work has been taken up on the different aspects of materials like Magnesium Alloy, Aluminum 360 Alloy and Forged Steel materials to cover the research gaps to present the results based on the systematic studies through the Piston of the engine. FEA analysis of is to measure temperature at the points where it is not possible to find out practically and to observe the heat flow and resulting in performance of the Piston.*

I- INTRODUCTION

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

An Internal Combustion Engine (IC Engine) is a type of combustion engine that converts chemical energy into thermal energy, to produce useful mechanical work. In an IC engine, combustion chamber is an integral part of the working fluid circuit.

Four stroke engine:

Cycle of operation completed in four strokes of the piston or two revolution of the piston.

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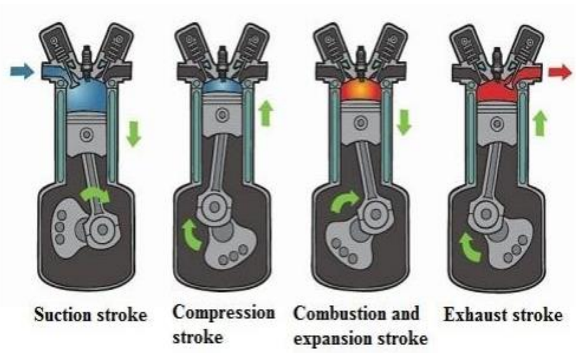


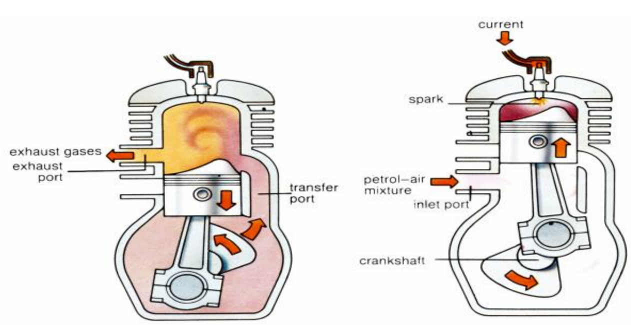
- Suction stroke (suction valve open, exhaust valve closed)-charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.

- Compression stroke (both valves closed)-fresh charge is compressed into clearance volume by the return stroke of the piston and ignited by the spark for combustion. Hence pressure and temperature is increased due to the combustion of fuel.

- Expansion stroke (both valves closed)-high pressure of the burnt gases force the piston towards BDC and hence power is obtained at the crankshaft.

- Exhaust stroke (exhaust valve open, suction valve closed)- burned gases expel out due to the movement of piston from BDC to TDC.

Two stroke engine:



- No piston stroke for suction and exhaust operations
- Suction is accomplished by air compressed in crankcase or by a blower
- Induction of compressed air removes the products of combustion through exhaust ports
- Transfer port is there to supply the fresh charge into combustion chamber

Importance of the Piston in IC Engine:

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.

II - LITERATURE SURVEY

This work concentrates on processing and machining of pistons. This chapter gives an insight for the thorough understanding of the state-of-art in

- engine performance
- knock and air swirl properties

The work addresses the requirement of a piston industry. It emphasizes on the productivity improvement of the pistons. Due to its industry relevant nature, the literature available for this topic is scarce. Albeit, some limited literature is available; most are patented.

The cast iron pistons were superseded by aluminum alloy piston around the year 1920 (Sarkar 1975). Cole G.S. and Sherman A.M.(1995) explained that a considerable interest had been grown in replacing cast iron and steel in automotive component like piston with light weight aluminum alloy casting to improve the performance and efficiency. Haque M.M and Young J.M. (2001) referred the low expansion group of aluminum–silicon alloy as piston alloy, since this group of alloy provides the best overall balance of properties. Near eutectic aluminum silicon piston alloy exhibit complex fatigue behavior due to their multi component microstructure (Moffat et al 2005). Aluminum alloys are ready to cast by all common casting techniques (Budinski 2001). In order to improve the wear performance, a metal based insert is reinforced with the base alloy. Cast iron and steel inserts normally reinforced with the light weight alloy during the casting process. To achieve the bonding between aluminum and cast iron, special patented processes are used. The presence of dirt and oxide induces trouble to the bonding between insert and alloy. The component was coated with a tin layer by dipping or electro plating and subsequent heat treatments were carried out before casting (Cole and Andrew T 1991). Gravity die casting and the pressure casting methods are used for the Al-Fin process. A special casting technique derived from the so called Al-Fin process is used in the manufacture of piston by gravity die casting and squeeze casting method. Al-Fin process is also known as Al-Fer process which is achieved by diffusion bond between the insert and aluminum alloy. When the liquid aluminum strongly reacts

with iron, it forms brittle inter bimetallic compounds at the reinforcement region. The rate of growth of the inter bimetallic layer is limited by diffusion of reacting species through inter bimetallic layer and not by the interfacial chemical reaction (Vaillant Ph and Petitet J.P. 1995). However, the low hardness of the light alloy and higher service temperature during the piston operation do pose some difficulties (Snee 1985).

A ceramic insert is adapted on the head portion of the piston and connected to the same by mechanical locking. The ceramic insert is provided with pores at least on the portion engaging the piston head. The pores have sizes which enable them to be filled with the light alloy during the manufacture of the piston by the squeeze casting method (Mahrus 1988). Piston can be formed in two parts. The main part is formed by gravity die casting from aluminum or aluminum alloy and a second part of the piston is formed by a squeeze casting process to produce a material which is stronger and more resistant than the gravity die cast aluminum or aluminum alloy. The two parts are then electron beam welded together to form the complete piston. The squeeze cast portion may be reinforced with whiskers or fibers to further improve its properties. This method of construction has the benefit that only a smaller portion of piston is formed by the more expensive and time-consuming squeeze casting process. This is the benefit in large diesel pistons (Avezou 1987). David. J (1985) worked on the provision of a wear resistant insert for pistons of light weight alloys. The insert comprises an annular ring of wear resistant material which has a cylindrical peripheral edge. The annular ring has at least one projection or 15 tab which extends outward from the peripheral edge for positioning and supporting the annular ring in a die cavity during the casting.

III - OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully develop a design of the pistons for a IC Engine Combustion Chamber. The mechanism is to be have an important influence upon the engine performance and its knock and air swirl properties. The aim of this project is to provide study about the influence of knock and air swirl in the combustion chamber. This system is also supposed to enhance the comfort as the side force felt by the piston in a Combustion chamber taking a turn is comparatively better performance. Also in our purpose is to intensification of the swirl on the crown of the piston by three different configurations of models.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and time in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the design was adopted from an already existing piston drawings and analysis were made to suite our purpose, this mechanism first devised was based on using power driven by combustion chamber. This mechanism was later dropped in testing phase due to following disadvantages.

1. It had a very large response time, this was not suitable for a combustion chamber approaching at a very high performance.

2. Wear and tear of piston and contact surface limits is too high to be satisfactorily used.

3. The system used for high torque and temperatures; this along with controls could shoot up the performance by using different materials.

Due to these disadvantages, the power screw design was dropped and a fully new design was defined. The design model also uses the same mechanism setup. The software to be used in design is Catia V5 and testing of design is Ansys.

3.1 Summary of capabilities

Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product.

Catia Elements is a software application within the CAID/CAD/CAM/CAE category, along with other similar products currently on the market.

Catia Elements is a parametric, feature-based modeling architecture incorporated into a single database philosophy with advanced rule-based design capabilities. The capabilities of the product can be split into the three main heading of Engineering Design, Analysis and Manufacturing. This data is then documented in a standard 2D production drawing or the 3D drawing standard ASME Y14.41-2003.

3.2 Engineering Design

Catia Elements offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools.

3.3 Analysis

Ansys Elements has numerous analysis tools available and covers thermal, static, dynamic and fatigue FEA analysis along with other tools all designed to help with the development of the

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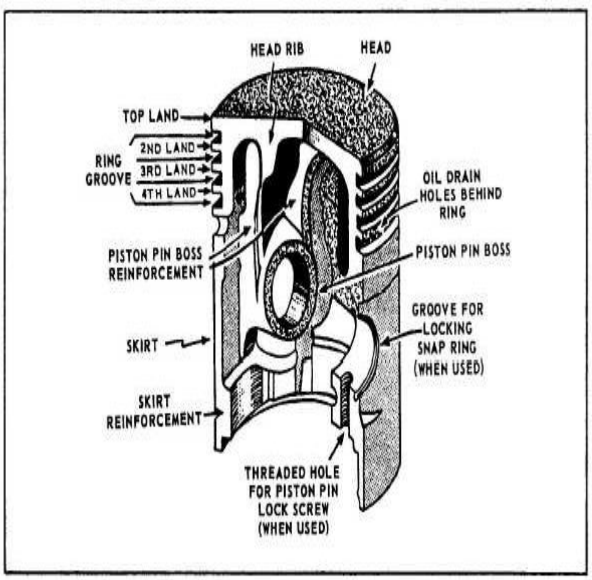
product. These tools include human factors, manufacturing tolerance, mould flow and design optimization. The design optimization can be used at a geometry level to obtain the optimum design dimensions and in conjunction with the FEA analysis.

IV - WORKING MECHANISM

A piston is at the heart of a reciprocating engine. It consists of a moving cylinder of metal with piston rings to achieve an air-tight seal once it is installed within the engine cylinder. The piston is attached via a piston pin to a connecting rod, which in turn is connected to the crankshaft.



In four-stroke (gasoline and diesel) car engines, the intake, compression, combustion and exhaust process takes place above the cylinder head, which forces the piston to move up and down (or in and out in a flat engine) within the cylinder, thereby causing the crankshaft to turn.

What is a piston made of?

Engine components need to be hardwearing for longevity and lightweight to improve efficiency.
As a result, pistons are usually made from an aluminium alloy but the piston rings (usually comprising, from top to bottom, a compression ring, a wiper ring and an oil ring) are made from cast iron or steel.

The oil ring wipes oil from the cylinder wall when the piston is moving but over time it and the other rings can wear, allowing oil from the crankcase to move into the combustion chamber.

Excessive oil consumption and white smoke from the exhaust tailpipes indicate piston ring wear.
Internal combustion engines can operate with a single cylinder - and therefore one piston (motorbikes and petrol lawnmowers) or as many as 12, but most automobiles have four or six. Radial engines, commonly used in propeller-driven planes, have an odd number of cylinders and pistons for a smoother operation.

Pistons also feature in external combustion engines, otherwise known as steam engines, where water is heated in a boiler and the resulting steam is used to propel a pair of pistons (typically) in external cylinders, which then drive the wheels. Rotary engines do not have cylinders or pistons.

V - DESIGN METHODLOGY OF 4 STROKE IC ENGINE PISTONS

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).

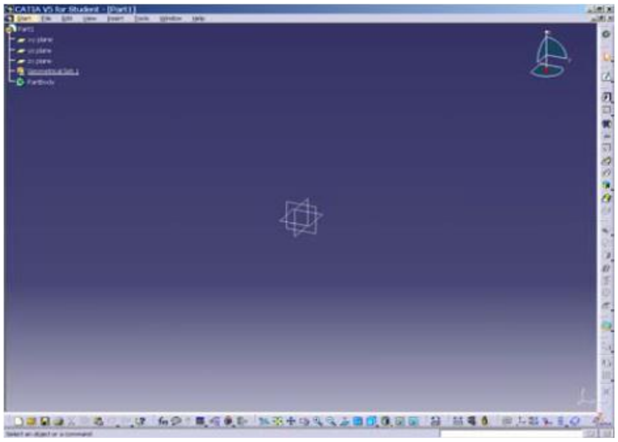


Fig: 5.1: Home Page of CatiaV5

Modeling 4 Stroke IC Engine Pistons in CATIA V5

These **4 STROKE IC ENGINE PISTONS** 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.

The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

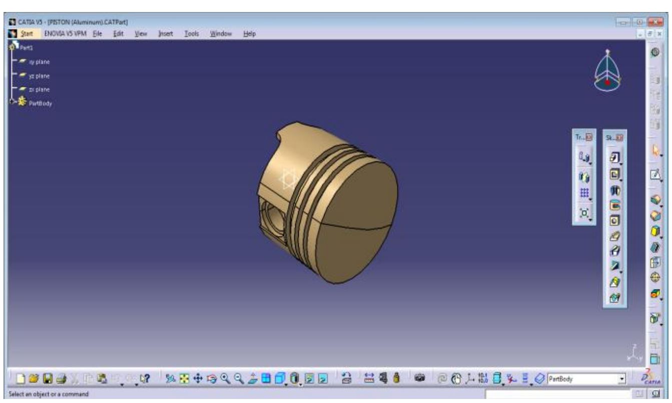


Fig: 5.2: Model design of piston- Aluminum in CATIA-V5

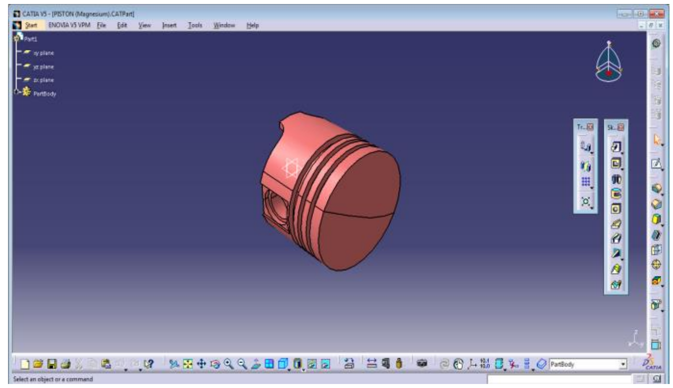


Fig: 5.3: Model arrangement piston- Magnesium in CATIA-V5

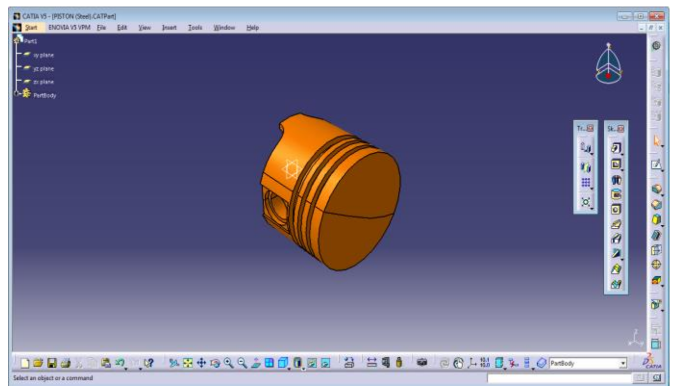


Fig: 5.4: Model arrangement piston- Steel in CATIA-V5

VI - ANALYSIS OF 4 STROKE IC ENGINE PISTONS

6.1 Procedure for FE Analysis Using ANSYS:
The analysis of the different model pistons is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the location along which axis we need to mention. Fixing location is bottom legs.

6.2 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

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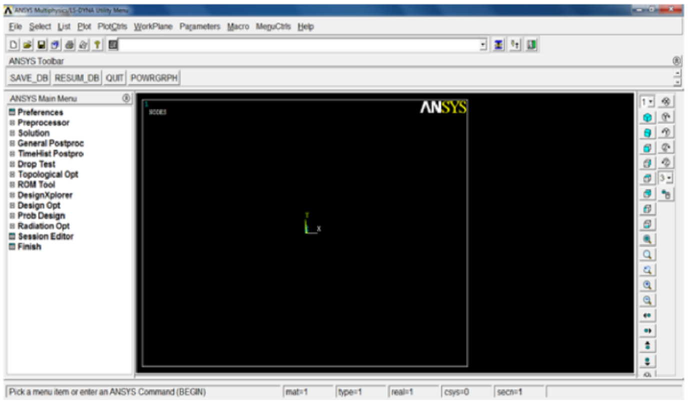

Fig.6.1: Import panel in Ansys.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Results for Piston – Aluminum Alloy:

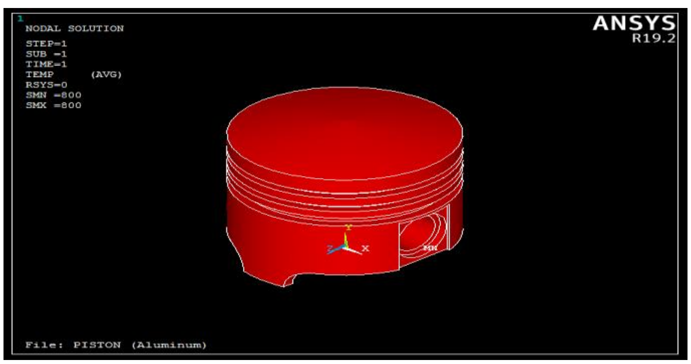

Fig. 7.1: Nodal Temperature of Piston – Aluminum Alloy

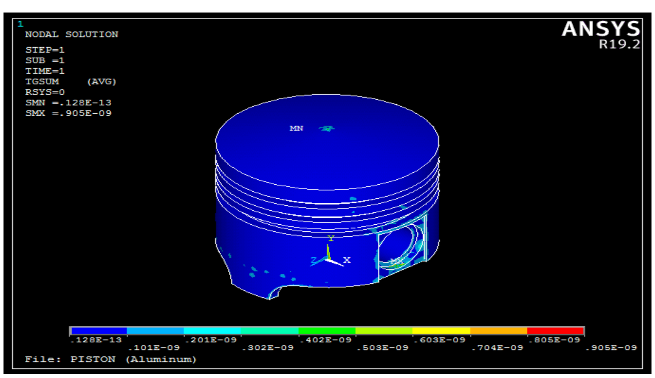

Fig. 7.2: Thermal Gradient of Piston – Aluminum Alloy

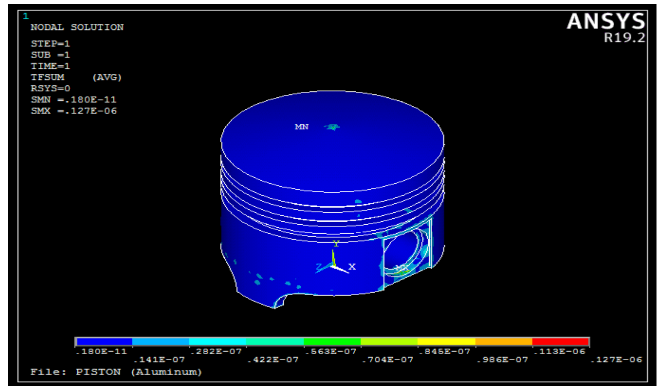

Fig. 7.3: Thermal Flux of Piston – Aluminum Alloy

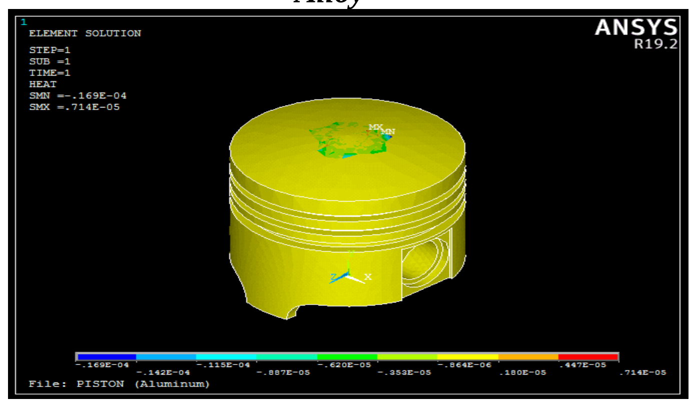

Fig. 7.4: Heat Flow of Piston – Aluminum Alloy

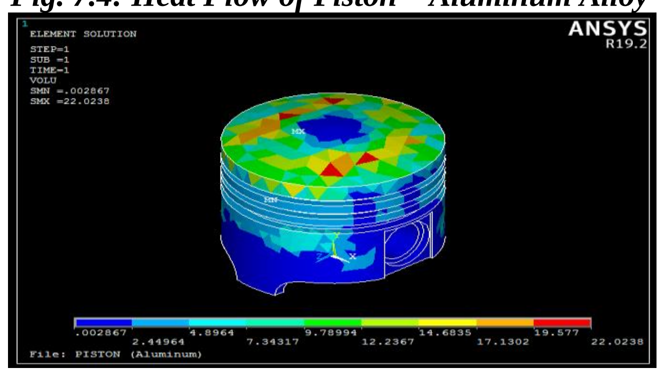

Fig. 7.5: Geometry Volume of Piston – Aluminum Alloy

7.2 Results for Piston – Magnesium Alloy:

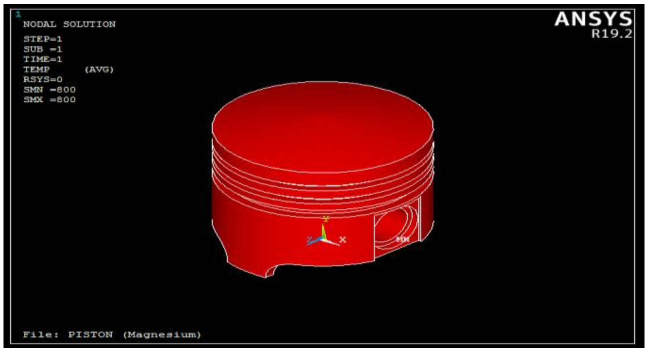

Fig. 7.6: Nodal Temperature of Piston – Magnesium Alloy

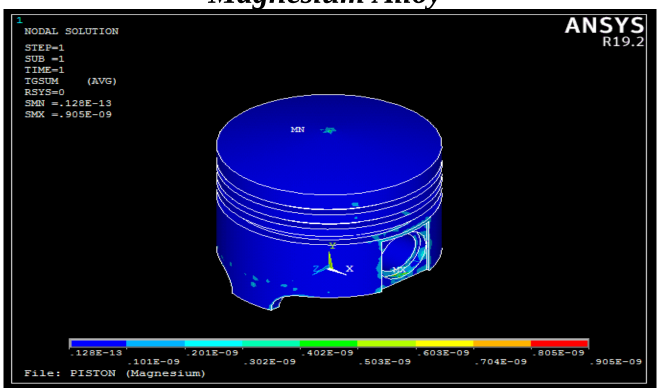

Fig. 7.7: Thermal Gradient of Piston – Magnesium Alloy

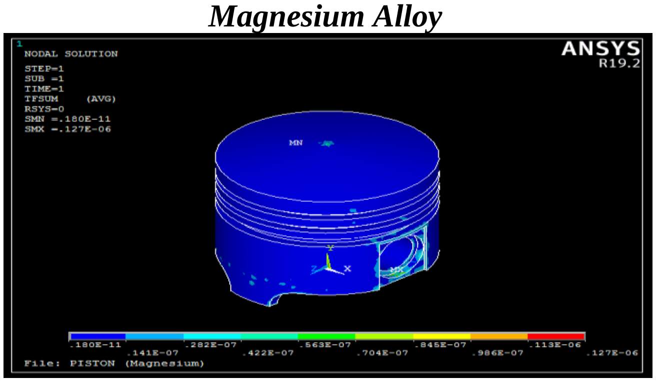

Fig. 7.8: Thermal Flux of Piston – Magnesium Alloy

Fig. 7.9: Heat Flow of Piston – Magnesium Alloy

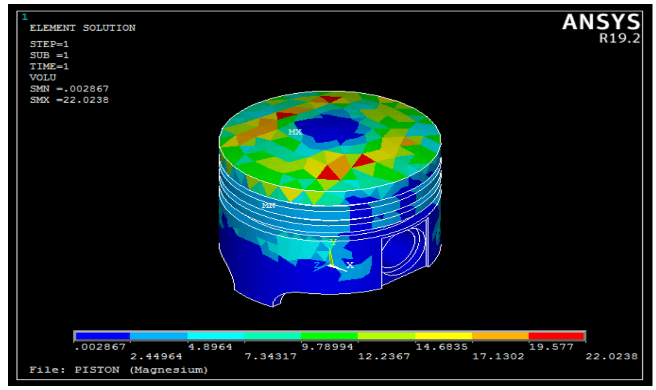

Fig. 7.10: Geometry Volume of Piston – Magnesium Alloy

7.3 Results for Piston – Forged Steel:

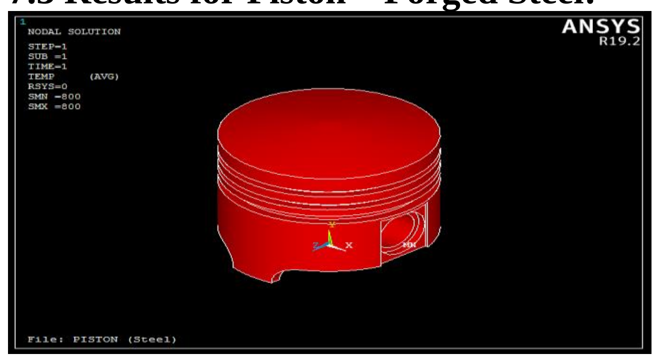

Fig. 7.11: Nodal Temperature of Piston – Forged Steel

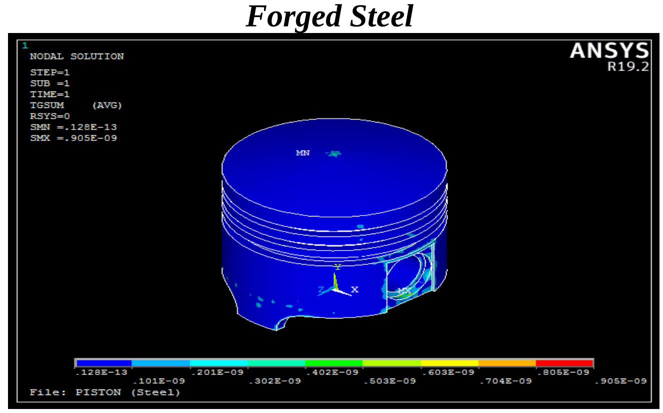

Fig. 7.12: Thermal Gradient of Piston – Forged Steel

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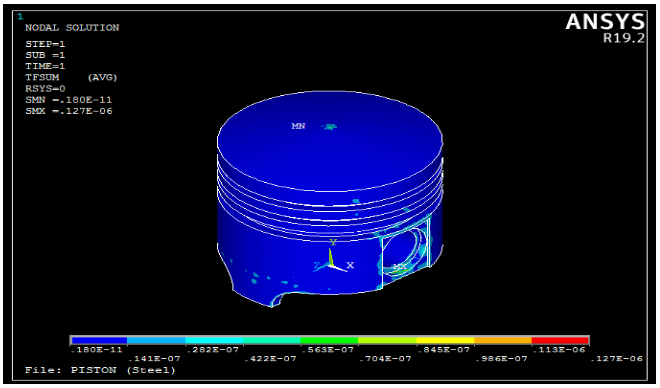

Fig. 7.13: Thermal Flux of Piston – Forged Steel

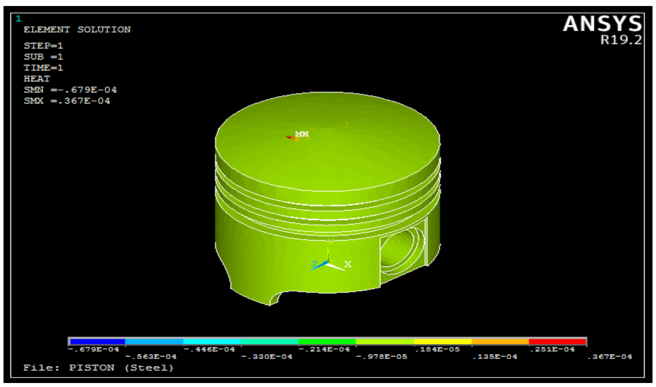

Fig. 7.14: Heat Flow of Piston – Forged Steel

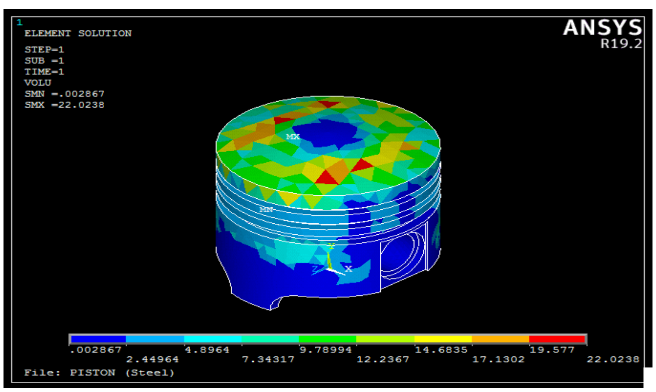

Fig. 7.15: Geometry Volume of Piston – Forged Steel

VIII - CONCLUSION

It can be seen from the above result that, our objective to analyze the combustion chamber piston by using by the design of the piston with different materials has been successful. As shown above figures the displacement of the complete design assembly is meshed and solved using Ansys which is very less. This is showing us that clearly each component in assembly is having minor values at selected location of the elements.

From the Thermal Analysis Result we can assure that the pistons are Efficient than other two models as shown in the results. The turbulence is increased compared to other models results better burning of fuel during the combustion operation in IC Engine Piston. Due to the burning efficiency there is high combustion rate in the internal combustion engine. When the combustion is increased the speed of the piston stroke is increased which results in increase of torque on Crank Shaft.

The design of the piston models have intensificated the swirl and knocking on the crown of the piston in the combustion chamber by three different configurations of models are done successfully and worked flawlessly in analysis as well. All these facts point to the completion of our objective in high esteem.

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