



## THERMAL ANALYSIS PERFORMED ON SEVERAL MATERIALS, OF THE PISTON DESIGN AND EXAMINED

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### ABSTRACT

An internal combustion engine burns fuel inside the engine cylinder (IC engine). An IC engine may run on either gasoline or diesel as fuel. In gasoline engines, also referred to as S.I. engines, fuel and air are introduced into the carburetor and ignited in the engine cylinder using a spark plug. A four-stroke internal combustion engine operates in four stages: suction, compression, expansion, and exhaust. The piston is a key component of an internal combustion engine. The design of an engine's piston has a significant impact on its performance. The geometry of the combustion chamber, the location of the spark plug, and the placement of the inlet and exhaust valves are all important aspects of a piston design. There are two fundamental criteria for this project. The first prerequisite is to create an I.C. engine piston model in accordance with the requirements. The method of analyzing the I.C. engine piston, such as tracking a track with straight and curved lines, is the second prerequisite. Modeling programs such as Catia are used to create these systems, and Ansys software is used for thermal analysis. Work on several material issues, such as magnesium alloy, aluminum 360 alloy, and forged steel materials, has been undertaken in this project to fill in research gaps and present findings based on methodical investigations using the engine's piston. FEA analysis measures temperature at locations where practical measurement is impossible, observes heat flow, and determines how the piston performs as a result.

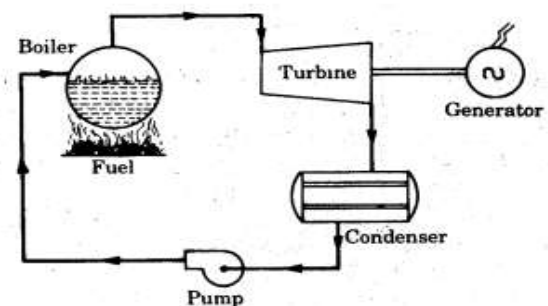
### INTRODUCTION

A heat engine is a device that generates thermal energy from the chemical energy of fuel and uses it to power mechanical motion.

**1.1 It is classified two categories**

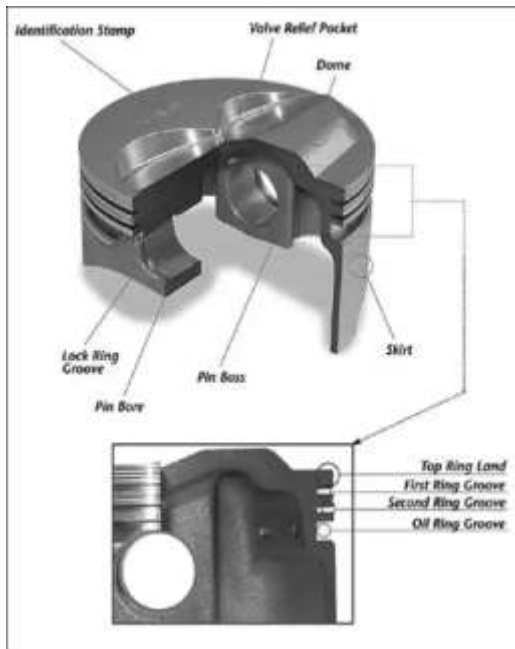
- (a) Engine using external fuel injection
- (b) Engine with internal combustion

**External combustion engine:**



Using fuel and air combustion byproducts, this engine transfers heat to a second fluid known as the working fluid.





It creates brittle inter bimetallic compounds at the reinforcement region when combined with iron. Diffusion of reactive species across the intermetallic layer, not the interfacial chemical interaction, limits the rate of expansion of the intermetallic layer (Vaillant Ph and Petitet J.P. 1995). Notwithstanding, several challenges are presented by the light alloy's poor hardness and the elevated service temperature during piston operation (Snee 1985).

A piston is created by casting around an insert while it is under pressure. The insert is composed of a porous layer that is 20 to 50 times the diameter of the pore and is fully filled with the metal of the piston body, which extends from the body into the insert's pores. The body of the piston is made of aluminum or aluminum alloy. In high load bearing regions of aluminum alloys, steel and cast iron are typically utilized as reinforcement. A porous ceramic insert can also be utilized as reinforcement to increase performance. Liquid aluminum alloy is poured into the ceramic insert's pores during the squeeze casting process (Kohnert 1982).

## OBJECTIVES AND METHODOLOGY

The successful development of a combustion chamber design for an IC engine is the aim of this project activity. The engine's performance, as well as the characteristics of knock and air swirl, will be significantly impacted by the mechanism. Studying the effects of air swirl and knock in the combustion chamber is the goal of this project. Since the side force felt by the piston in a combustion chamber when it takes a turn is significantly superior performance,

this system is also expected to improve comfort. Our objective also involves increasing the swirl on the piston crown using three distinct model configurations.

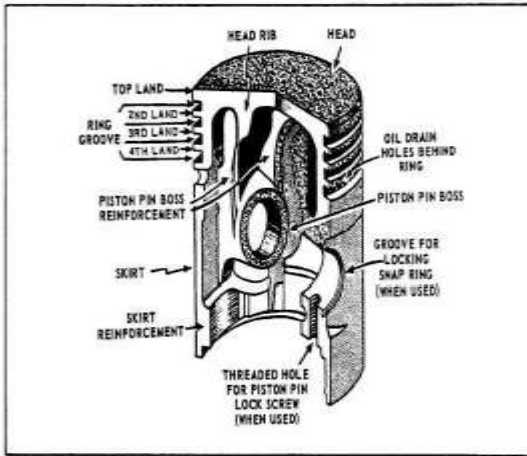
The design process opted to employ current, standard components instead of creating every component from scratch. This approach has the advantage that you can avoid wasting excessive time and resources testing the integrity of each component because their value has already been demonstrated in practical situations.

In the beginning, the mechanism was created using power generated by a combustion chamber; it was based on a piston design that was already in existence, and analysis was done to fit our needs. Later, during the testing phase, this technique was abandoned because of the following drawbacks.

1. Its response time was excessively long, making it unsuitable for a combustion chamber approaching at a very high speed.
2. The piston and contact surface limitations have too much wear and tear to be used in a satisfactory manner.
3. The system that uses high temperatures and torque; when combined with controls, this might increase performance by utilizing various materials. These drawbacks led to the abandonment of the power screw design and the definition of an entirely new one. The identical mechanism setup is also used in the design model. Ansys will be utilized for design testing, while Catia V5 will be used for design work.

## WORKING MECHANISM

A piston is the central component of a reciprocating engine. It consists of a metal moving cylinder with piston rings that, when inserted into the engine cylinder, form an airtight seal. A piston pin connects a connecting rod to the piston and then to the crankshaft.



In four-stroke vehicle engines (gasoline and diesel), all intake, compression, combustion, and exhaust activities occur above the cylinder head. This drives the piston both up and down, within the cylinder (or in and out in a flat engine), rotating the crankshaft.

#### 4.1 What is a piston made of?

Engine efficiency requires a long lifespan and greater durability, as well as minimal weight. Given this, piston rings are composed of cast iron or steel, despite the fact that pistons are typically made of an aluminum alloy. The rings are typically composed of an oil ring, a wiper ring, and a compression ring, arranged top to bottom. When the oil ring and other rings wear down over time, preventing the piston's oil from wiping the cylinder wall, the crankcase oil may enter the combustion chamber. Wear of the piston Rings are characterized by white smoke from the exhaust tailpipes and high oil consumption. Internal combustion engines require only one cylinder to work. Like a result, they can have one piston (like in motorcycles and gas-powered lawnmowers) or up to twelve, although most cars have four or six. Radial engines, which are often used in propeller-driven aircraft, operate more smoothly with an odd number of cylinders and pistons. Additionally, pistons are utilized in external combustion engines, often known as steam engines. In these engines, water is boiled in a boiler, and the steam produced powers two pistons, usually located outside cylinders, which subsequently power the wheels. A rotary engine contains no cylinders or pistons.

#### 4.2 Engine Efficiency

In comparison to the beginning having a higher chemical energy, the compressed fuel-air mixture, the combustion products' hot gases, once ignited and burnt, have greater thermal energy. The engine is capable of converting tremendous heat and pressure into energy that may be used. The cylinders of a reciprocating engine contain

high-pressure gases that power the pistons. When all of the energy has been used, the exhaust outlet or valve is released to release the residual hot gases, letting the piston to return to top dead center, or TDC. Then, depending on the engine, the next part of the piston's cycle might begin. A liquid or air cooling system is commonly used to remove waste heat from engines, which refers to any heat that is not transformed into work. Idealized thermodynamics. Cycles are used to determine the theoretical efficiency of internal combustion engines, which primarily function as heat engines. The Carnot cycle's efficiency is governed by the difference between the engine's lowest and top operating temperatures. It has more efficiency than the theoretical cycle. The thermal stability of the materials used to manufacture the terrestrial engine limits its maximum working range.

All metals and alloys eventually melt or break down, thus much research is being done on ceramic materials that have better structural qualities and increased heat stability. A higher temperature differential between the lower and upper operating temperatures is made possible by higher thermal stability, which increases thermodynamic efficiency. The engine is assumed to be working in an ideal environment with perfect insulators, ideal gases, frictionless environments, and endless operation times according to the thermodynamic limits. Complexities introduced by real-world applications lower efficiency. For instance, an actual engine performs best at a particular load known as its power band.

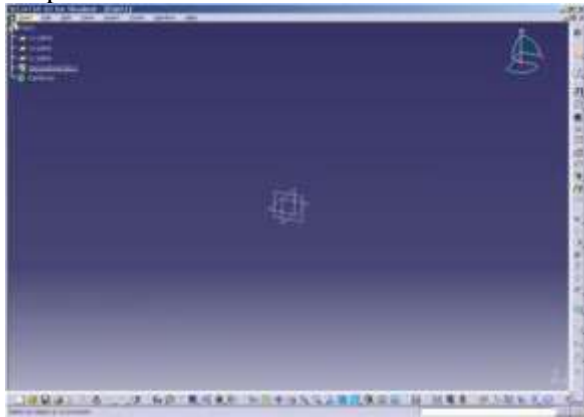
When driving on a highway, the engine of a car is often running much less than optimally because it is meant to handle larger loads needed for quick acceleration. Furthermore, elements like wind diminish the system's total efficiency. Miles per 100 kilometers or liters per 100 miles are two ways to measure an engine's fuel efficiency. A standard energy content is assumed for the hydrocarbon volume. The majority of steel engines have a 37% thermodynamic limit. Most engines maintain an average energy retention of roughly 18%–20% even with the help of turbochargers and stock efficiency enhancements.

### DESIGN METHODOLOGY OF 4 STROKE IC ENGINE PISTONS

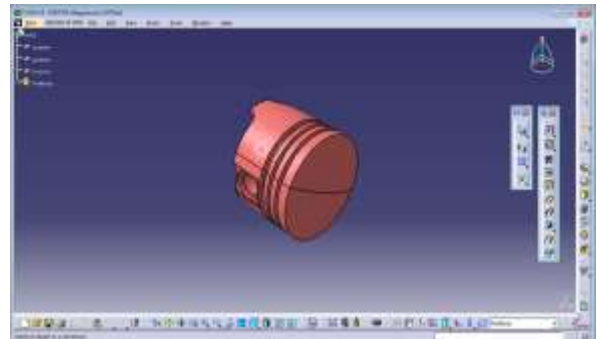
#### 5.1 Introduction to CATIA

The French business Dassault Systems developed CATIA, or Computer Aided Three-dimensional Interactive Application, is the name of the commercial CAD/CAM/CAE software system. Several platforms are supported by the software. CATIA is a C++ programming language program that forms the basis of Dassault Systems' series of product lifecycle management tools.

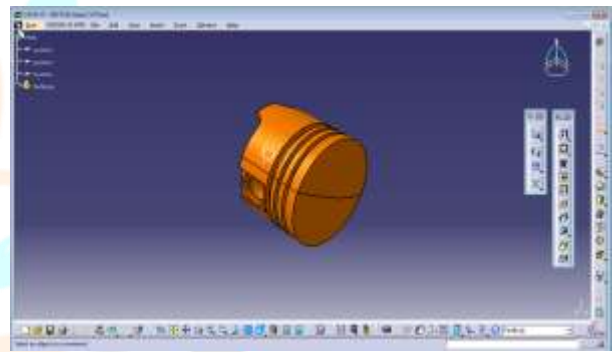
Cero Elements/Pro and NX (Unigraphics) are competitors of CATIA in the high-end CAD/CAM/CAE sector. Dassault Systems released CATIA V5, a 3D CAD system, in 1999. It offered a whole new design tool that differed fundamentally from CATIA V4, and it replaced the latter. Depending on the IT environment, the user interface, which now has an MS Windows layout, makes it simple to integrate popular software packages like Microsoft Office, a number of graphic applications, or SAPR3 products.



**Fig: 5.1: Home Page of CatiaV5**



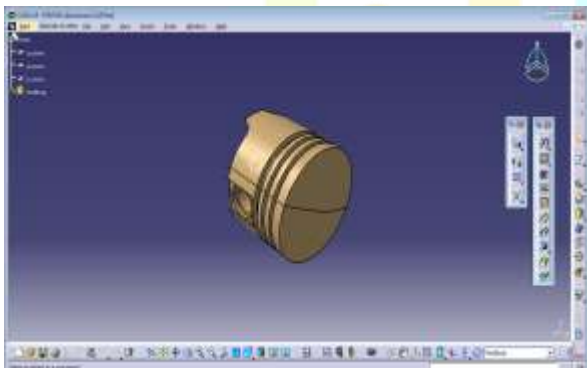
**Fig: 5.3: Model arrangement piston- Magnesium in CATIA-V5**



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

**5.4 Modeling 4 Stroke IC Engine Pistons in CATIA V5**

CATIA V5 software was used in the design of these four-stroke IC engine pistons. Heavy engineering, consumer products, automotive, and aerospace industries all employ this software. For creating intricate 3D models, this program is incredibly potent. It is compatible with CATIA Version 5 and may be used for tasks like part and assembly design. For reference, the identical CATIA V5 R20 3D model and 2D sketch model are displayed below. Measurements are extracted from. CATIA V5 is used for the 3D model design process. The software listed below is used for testing.



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

**ANALYSIS OF 4 STROKE IC ENGINE PISTONS**

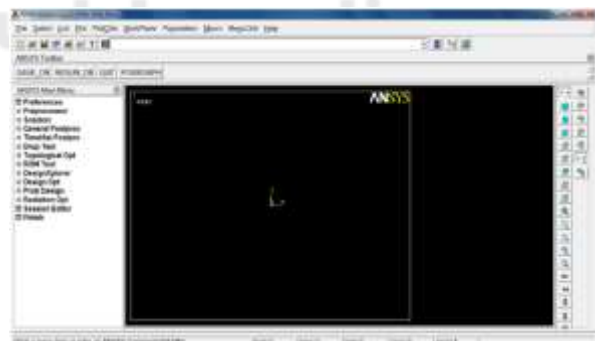
**6.1 FE Analysis Process with ANSYS:**

Utilizing ANSYS, the various model pistons are analyzed. Complete assembly can be completed Through the application of moments at the required place along the axis, it is not necessary to do so. Lower legs are the fixation point.

**6.2 Preprocessor**

At this point, the subsequent actions were carried out:

- Import the file in the ANSYS window.
- Import > Step > File Menu. After clicking "OK" in the resulting dialog box, select "Browse" and locate the file saved from CATIAV5R20. To import the file, choose "OK".



**Fig.6.1: Import panel into Ansys.**

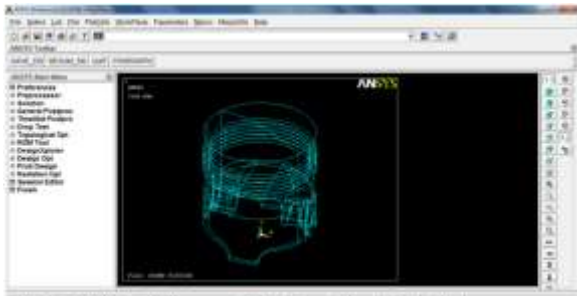
**6.2.1 Meshing.**

. "Grid generation" is a term that's frequently used interchangeably. Rendering to a computer screen for computational fluid dynamics or finite element analysis are common applications. While there is a wide range of possible input model forms, prominent sources include CAD, STL (file format), NURBS, and B-rep. With contributions from computer science, engineering, and mathematics, the area is quite interdisciplinary.



**Fig: Window for solving the matrices problem, as done**

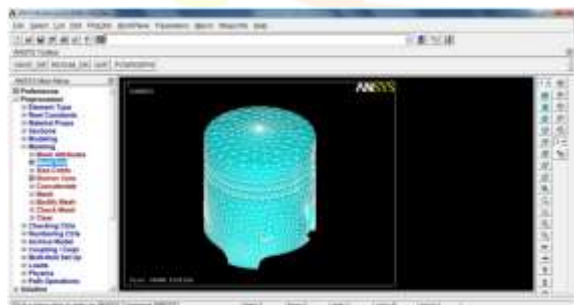
Pistons are constructed using additional parts and modeled using the elements as seen above. To check the tension and displacements during reciprocating, these components are solved using thermal force analysis. The next step after finishing each component's meshing is to analyze the data using the OEM (Original Equipment of Manufacturer) program. For correct findings according to the original component, we must therefore include all of the models that are assessed in the Ansys program.



**Fig: Replotting (Refresh) the component from the menu bar.**

**DISCUSSION ON ANALYSIS RESULT**

**7.1 Results for Piston – Aluminum Alloy:**



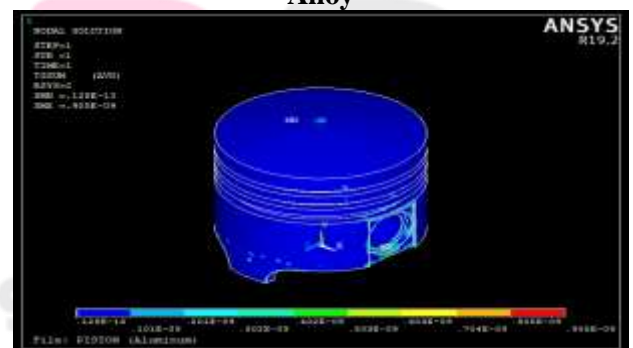
**Fig: Entering into preprocessor for Meshing.**



**Fig. 7.1: Nodal Temperature of Piston – Aluminum Alloy**



**Fig: Image of Element where Loads are applied**



**Fig. 7.2: Thermal Gradient of Piston – Aluminum Alloy**

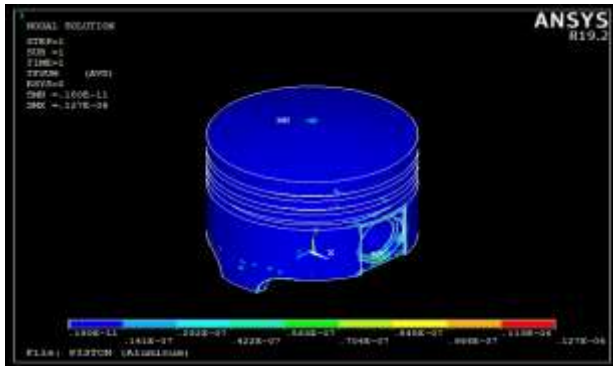


Fig. 7.3: Thermal Flux of Piston – Aluminum Alloy

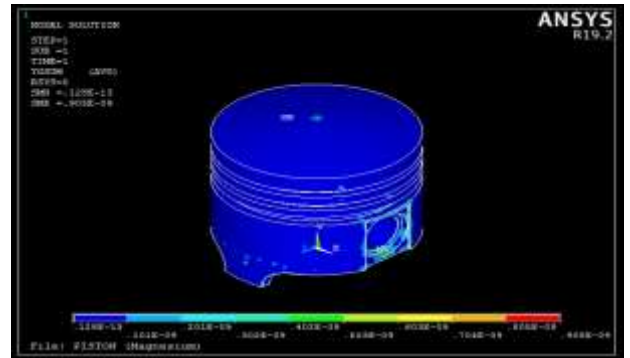


Fig. 7.7: Thermal Gradient of Piston – Magnesium Alloy

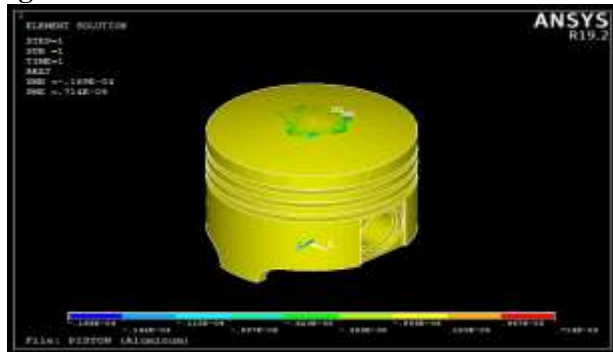


Fig. 7.4: Heat Flow of Piston – Aluminum Alloy

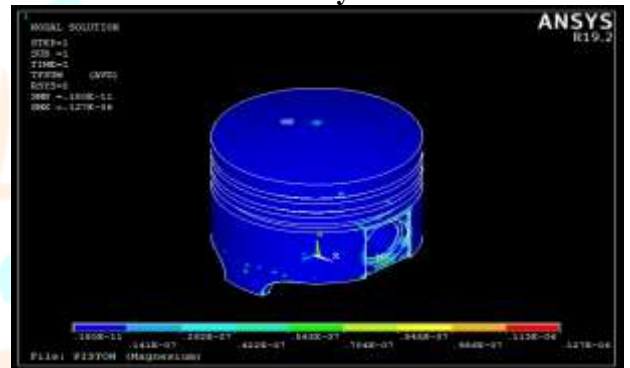


Fig. 7.8: Thermal Flux of Piston – Magnesium Alloy

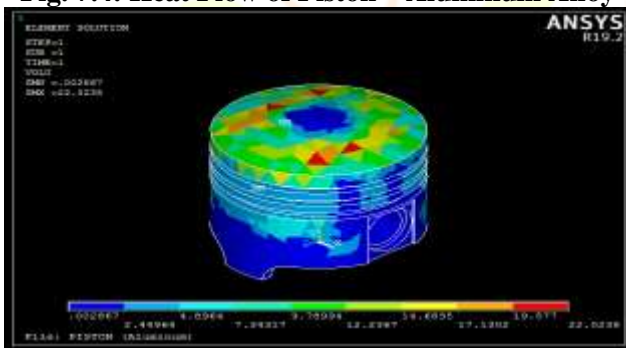


Fig. 7.5: Geometry Volume of Piston – Aluminum Alloy

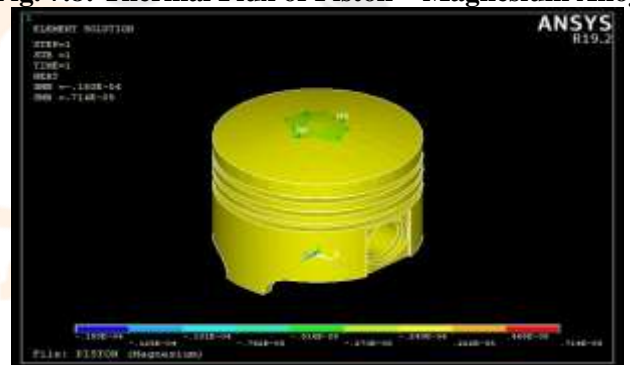


Fig. 7.9: Heat Flow of Piston – Magnesium Alloy

7.2 Results for Piston – Magnesium Alloy:



Fig. 7.6: Nodal Temperature of Piston – Magnesium Alloy

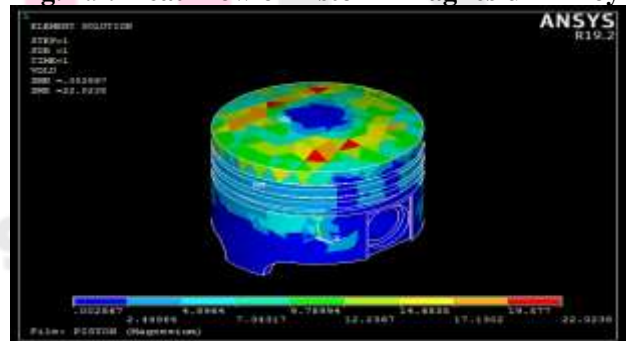
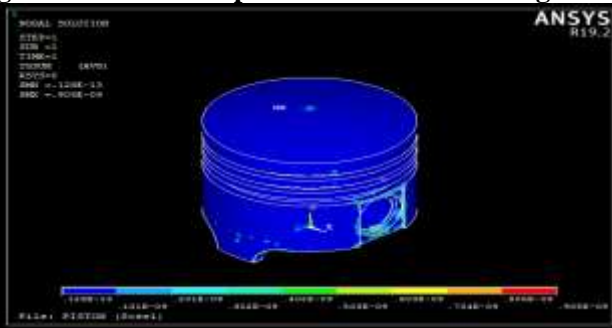


Fig. 7.10: Geometry Volume of Piston – Magnesium Alloy

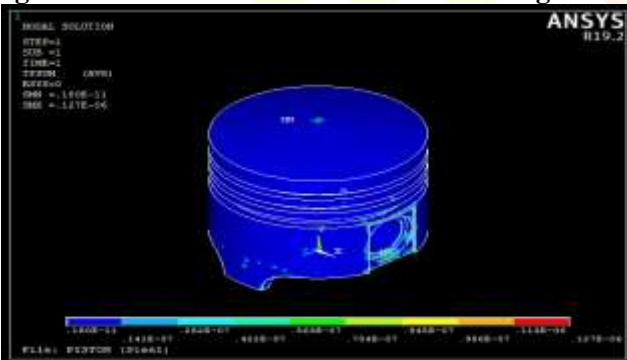
7.3 Results for Piston – Forged Steel:



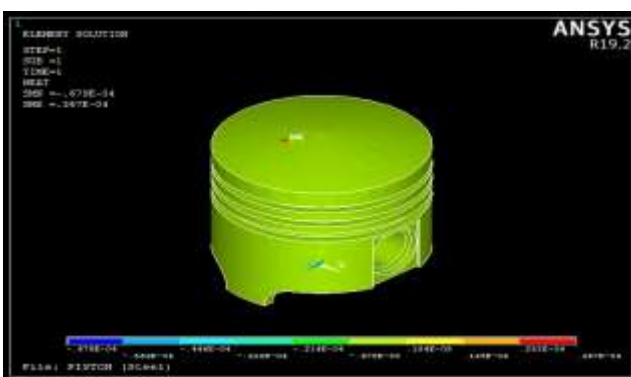
**Fig. 7.11: Nodal Temperature of Piston – Forged Steel**



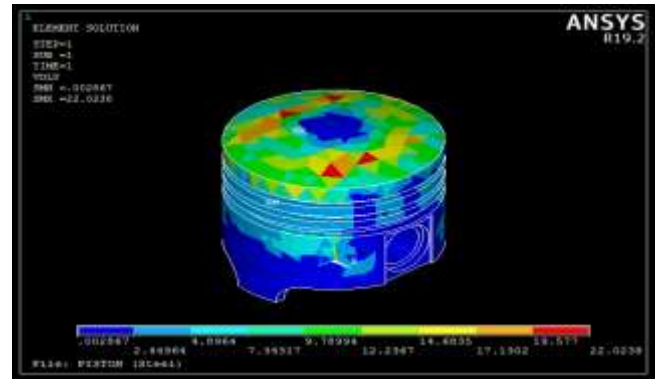
**Fig. 7.12: Thermal Gradient of Piston – Forged Steel**



**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**

## CONCLUSION

The above result makes it clear that we were successful in our goal of analyzing the combustion chamber piston using the piston's design with various materials. As can be seen in the preceding pictures, there is very little displacement when the entire design assembly is meshed and solved with Ansys. This demonstrates to us that every assembly component has minute values at specific element locations. We can be certain that the pistons are more efficient than the other two types based on the findings of the thermal analysis. When compared to other types, the IC engine piston's greater turbulence promotes better fuel burning during combustion. The combustion rate of an internal combustion engine is high due to its high burning efficiency. With increased combustion, the speed of the piston stroke rises, as does the torque of the crankshaft. Three separate model configurations were employed to effectively and flawlessly analyze the piston models, resulting in enhanced swirl and banging on the piston's crown in the combustion chamber. All of this evidence suggests that our mission will be met with tremendous respect.

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