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Design and Analysis of Piston Rings by Using Hyper Elastic Materials of Dynamic Engine Assembly

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Abstract: The piston ring is one of the main components of an internal combustion engine. Its main purposes are to seal the combustion chamber of engine. The main objective of this work is to develop the design modeling and then analysis of stress and deformation of the piston rings by using different materials like Grey cast iron, elastomer and Titanium alloy by using ansys software and to investigate these three materials behavior which are used for the piston ring. The project shows the components involved in the single cylinder engine assembly and their operation. Finally we are checking out three materials behaviors which are used for piston rings. This research paper deals with to reduce the friction of a piston ring while maintaining a Large oil film load-carrying capacity, an approach comprising of the inverse method, modeling and analysis of piston rings using Structural and rigid dynamics is deliberated in order to quantify the stress that the rings can bear. Many researchers had considered that the entire surface of the ring was enveloped in an oil film, but much experimental research has discovered that not all the entire surface was soaked. The various parameters studied under structural analysis are displacement and ultimate stress limit using three Different composition materials. A cumulative analysis is performed which considers the combined effect of mechanical and load for determination of the dimensions of the rings.

Keywords: Piston, piston rings, engine cylinder and engine assembly, ansys software.

I. INTRODUCTION

We almost take our Internal Combustion Engines for granted don't we? All we do is buy our vehicles, hop in and drive around. There is, however, a history of development to know about. The compact, well-toned, powerful and surprisingly quiet engine that seems to be purr under your vehicle's hood just wasn't the tame beast it seems to be now. It was loud, it used to roar and it used to be rather bulky. In fact, one of the very first engines that had been conceived wasn't even like the engine we know so well of today.

An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel. The internal combustion engine was conceived and developed in the late 1800s. It has had a significant impact on society, and is considered one of the most significant inventions of the last century. The internal combustion engine has been the foundation for the successful development of many commercial technologies. For example, consider how this type of engine has transformed the transportation industry, allowing the invention and improvement of automobiles, trucks, airplanes and trains.

Internal combustion engines can deliver power in the range from 0.01 kW to 20x103 kW, depending on their displacement. The complete in the market place with electric motors, gas turbines and steam engines. The major applications are in the vehicle (automobile and truck), railroad, marine, aircraft, home use and stationary areas. The vast majority of internal combustion engines are produced for vehicular applications, requiring a power output on the order of 102 kW.

II. TYPES OF ENGINES

There are two major cycles used in internal combustion engines: Otto and Diesel. The Otto cycle is named after Nikolaus Otto (1832 – 1891) who developed a four-stroke engine in 1876. It is also called a spark ignition (**SI**) engine, since a spark is needed to ignite the fuel-air mixture. The Diesel cycle engine is also called a compression ignition (**CI**) engine, since the fuel will auto-ignite when injected into the combustion chamber. The Otto and Diesel cycles operate on either a four- or two-stroke cycle.

Since the invention of the internal combustion engine many pistons-cylinder geometries have been designed. The choice of given arrangement depends on a number of factors and constraints, such as engine balancing and available volume:

1) In line
2) Horizontally opposed
3) Radial
4) V

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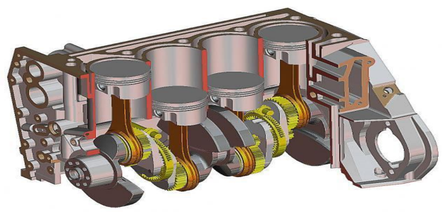
A. In Line

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

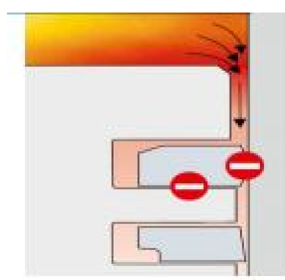
The inline-four layout is in perfect primary balance and confers a degree of mechanical simplicity which makes it popular for economy cars. However, despite its simplicity, it suffers from a secondary imbalance which causes minor vibrations in smaller engines. These vibrations become worse as engine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



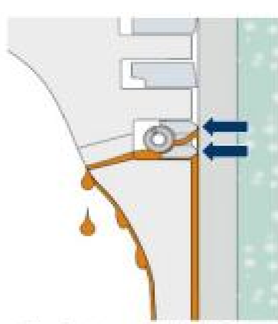
Line Engine Cut Section

III.LITERATURE REVIEW

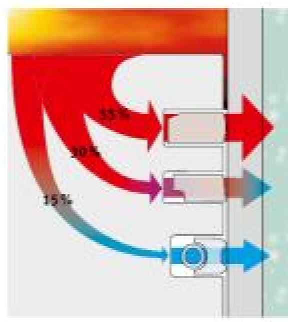
Main functions of piston rings 1) Sealing of combustion gases the main task of compression rings is to prevent the passage of combustion gas between piston and cylinder wall into the crankcase. For the majority of engines, this objective is achieved by two compression rings which together form a gas labyrinth. For design reasons, the tightness of piston ring sealing system in combustion engines is below 100%; as a result a small amount of blow-by gases will always pass by the piston rings in to the crankcase. This is however, a normal state which cannot be completely avoided due to the design. It is essential though, to prevent any excessive transfer of hot combustion gases past the piston and cylinder wall. Otherwise this would lead to power loss, an increase of heat in the components as well as a loss of lubricating effects. The service life and the function of the engine would consequently be impaired



Scraping and distributing oil Next to sealing the area between the crankcase and combustion chamber, the piston rings are also used to control the oil film. The oil is uniformly distributed on to the cylinder wall by the rings. Most excess oil is removed by oil control (3rd ring), although the combined scraper-compression rings (2nd ring) removes the oil. Fig. 3 shows scraper (wiper or 2nd ring) ring as well as oil ring (3rd ring)



Heat dissipation Temperature management for the piston is another essential task of the piston rings. The major portion of the head absorbed by the piston during the combustion process is dissipated by the piston rings to the cylinder surface. The compression rings, in particular, are significantly involved in heat dissipation. 50% of the combustion heat absorbed by the piston is already dissipated to the cylinder wall by the upper compression ring (depending on the engine type). Without this continuous heat dissipation by the rings, a piston seizure in the cylinder bore would occur within a few minutes or the piston even melt. From this perspective, it is evident the piston rings must always have proper contact to the cylinder wall. Whenever out-of-roundness is caused in the cylinder bore or if the piston rings are jammed in the ring groove (carbon fouling, dirt, deformation), it will only be matter of time until the piston suffers from overheating due to a lack of heat dissipation.



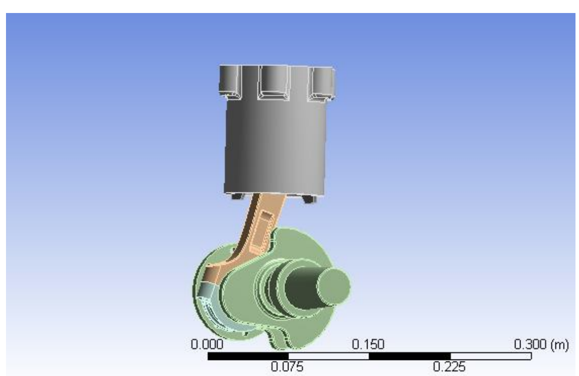
Analytical Models Based on literature review it is observed that traditionally piston ring studies are centered on two physics tribology and CFD. But there are few studies which includes structural design of piston rings. Following section reviews literature in the area of lubrication and flow.

IV. DESIGN PROCES

A. Space Claim

Space Claim Corporation was founded in 2005 to develop 3D solid modeling software for mechanical engineering. Its first CAD application was launched in 2007 and used an approach to solid modeling where design concepts are created by pulling, moving, filling, combining, and reusing 3D shapes.

It was acquired by Ansys in May 2014, Inc, and was integrated in subsequent versions of Ansys Simulation packages as a built-in 3D modeler.



ENGINE ASSEMBLY

B. Rigid Body Dynamics

Dynamic force analysis involves the application of Newton’s three laws of motion. The second law is expressed in terms of rate of change of momentum,

$M = m \times v \qquad F = m \times a$

We can differentiate between two subclasses of dynamics analysis depending upon which quantities are known and which are to be found. The “forward dynamics analysis” is the one in which we know everything about the forces and/or torques being exerted on the system, and we wish to determine the accelerations, velocities, and displacements which result from the application of those forces and torques. Given ‘F’ and ‘m’, solve for ‘a’.

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The second subclass of dynamics analysis, called the "inverse dynamics analysis" is one in which we know the (desired) accelerations, velocities, and displacements to be imposed upon our system and wish to solve for the magnitudes and directions of the forces and torques which are necessary to provide the desired motions and which result from them. This inverse dynamics case is sometimes also called kinetostatics. Given 'a' and 'm', solve for 'F'

For a model of a rigid body to be dynamically equivalent to the original body, the following three conditions must be satisfied

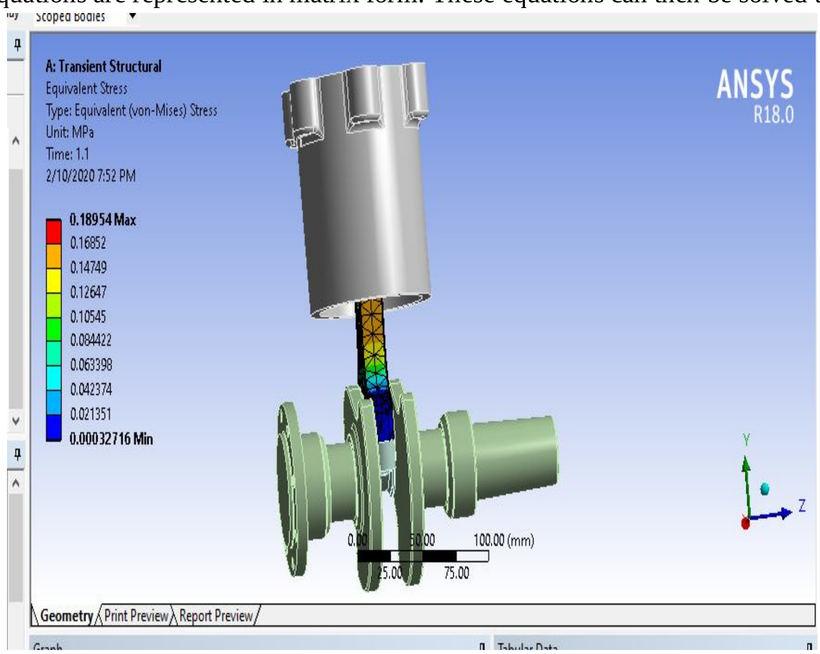
- The mass of the model must equal that of the original body.
- The center of gravity must be in the same location as that of the original body.
- The mass moment of inertia must equal that of the original body.

In static-dynamic force analysis, mechanisms are assumed to be comprising of rigid links connected by frictionless joint without clearance. The angular acceleration of the moving links can be calculated by the methods discuss in section 1.2.3. The objective of the static dynamic analysis is to determine the forces at pin joints and the required input crank torque at different crank angle. Generally dynamic force analysis can be done by the following two techniques:

The superposition method

The linear simultaneous equation solution method

Here, the linear simultaneous equations solution method is used. In this method, all the relevant equations for the mechanism as a set of linear simultaneous equations are represented in matrix form. These equations can then be solved to obtain the results.



C. Transient Structural Analysis

Transient Structural analysis is the determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, vehicles, furniture, attire, soil strata, prostheses and biological tissue. Structural analysis employs the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often precluding physical tests. Structural analysis is thus a key part of the engineering design of structures.

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

Several methods are available to perform a structural analysis, namely—but not limited to—from simplest to most complex:

1) Thrust line analysis
2) Limit state analysis
3) Finite element method.

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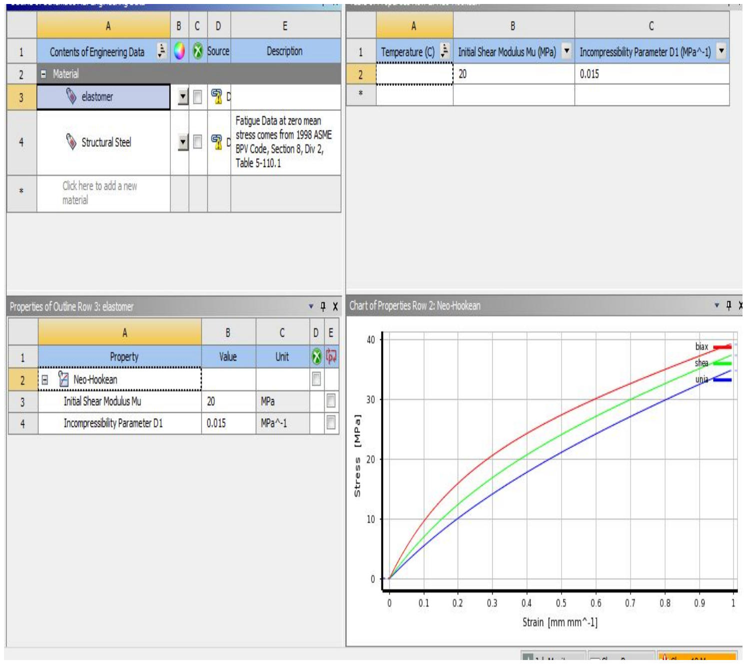
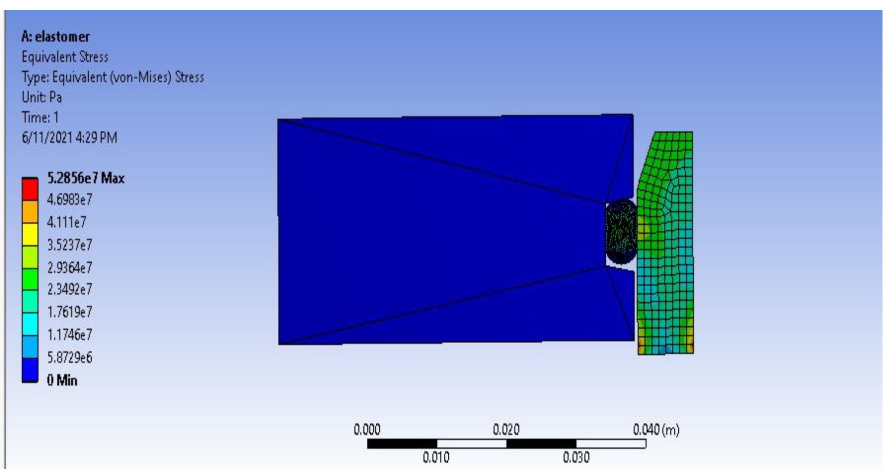
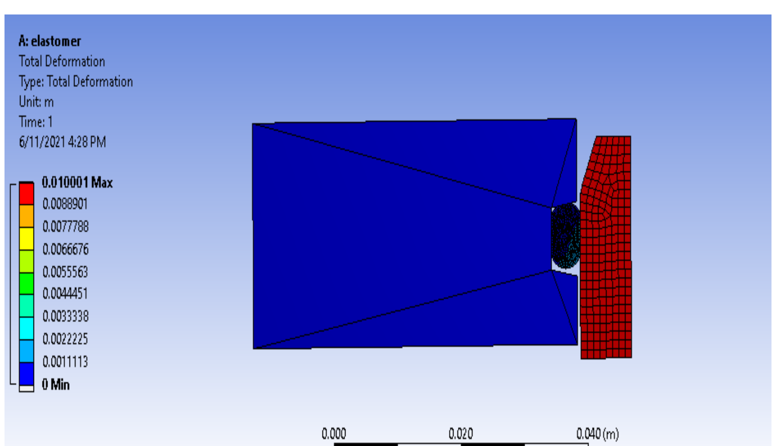
V. BOUNDARY CONDITIONS

A. Elastomer







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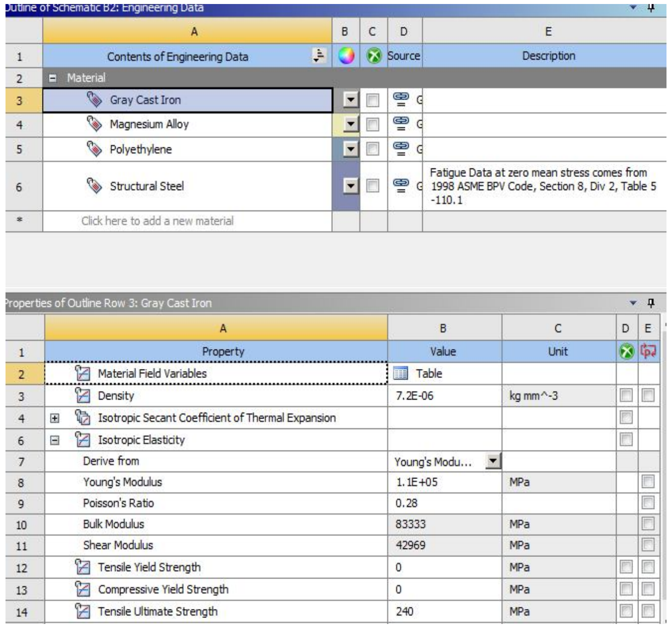
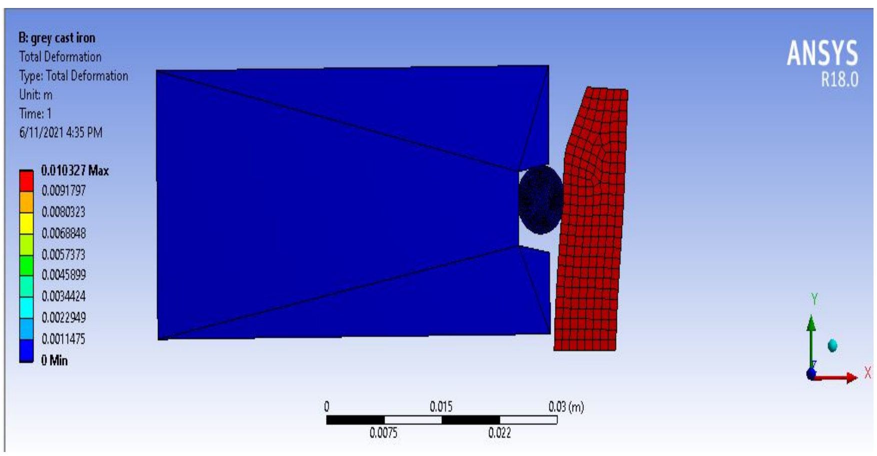
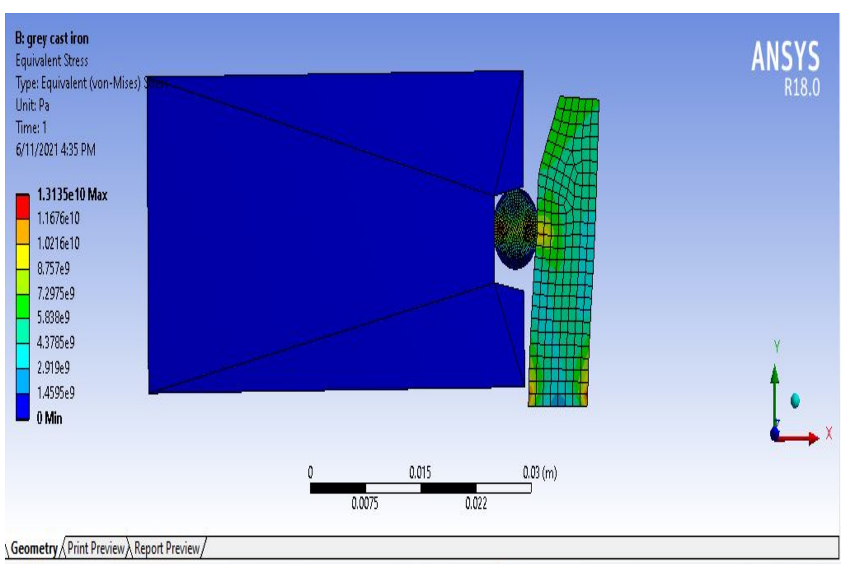

Outline of Schematic B2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Gray Cast Iron			G	
4	Magnesium Alloy			G	
5	Polyethylene			G	
6	Structural Steel			G	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5 -110.1
*	Click here to add a new material				

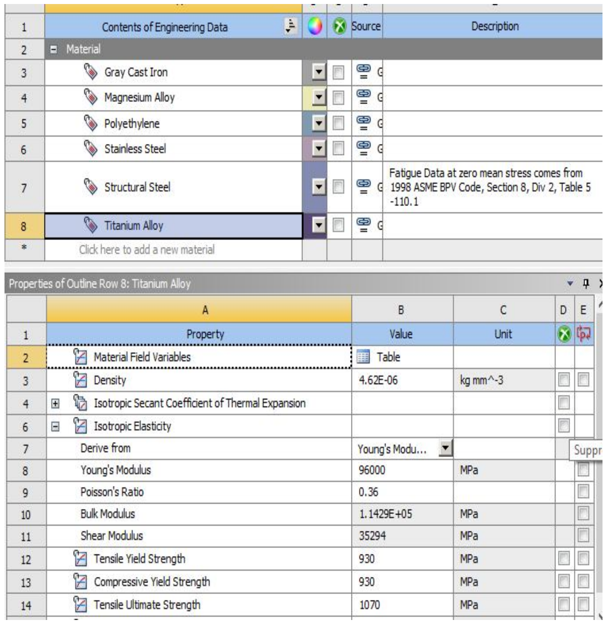
Properties of Outline Row 3: Gray Cast Iron

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7.2E-06	kg mm^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modu...			
8	Young's Modulus	1.1E+05	MPa		
9	Poisson's Ratio	0.28			
10	Bulk Modulus	83333	MPa		
11	Shear Modulus	42969	MPa		
12	Tensile Yield Strength	0	MPa		
13	Compressive Yield Strength	0	MPa		
14	Tensile Ultimate Strength	240	MPa		





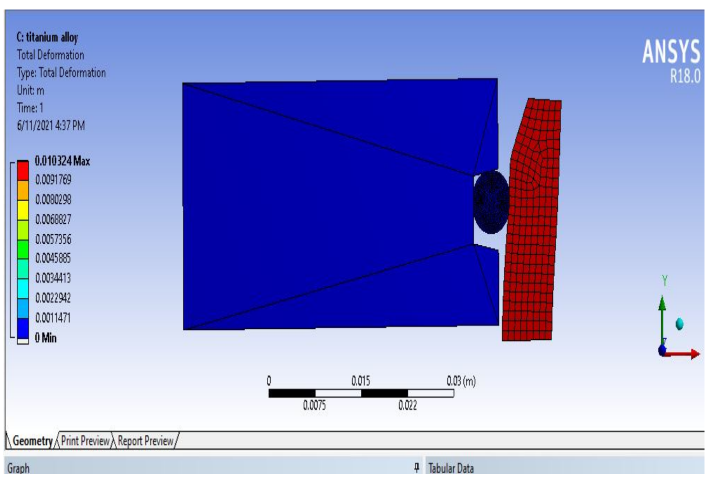
B. Gray Cast Iron

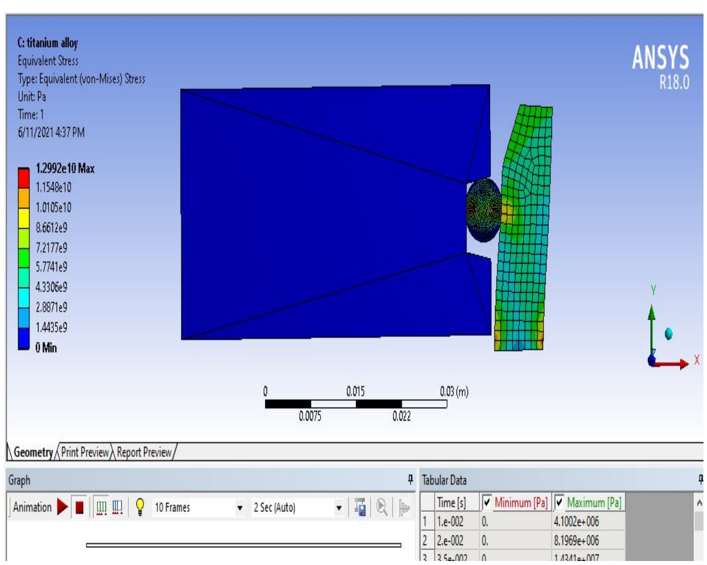


	Contents of Engineering Data		Source	Description
2	Material			
3	Gray Cast Iron		G	
4	Magnesium Alloy		G	
5	Polyethylene		G	
6	Stainless Steel		G	
7	Structural Steel		G	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5 -110.1
8	Titanium Alloy		G	
*	Click here to add a new material			

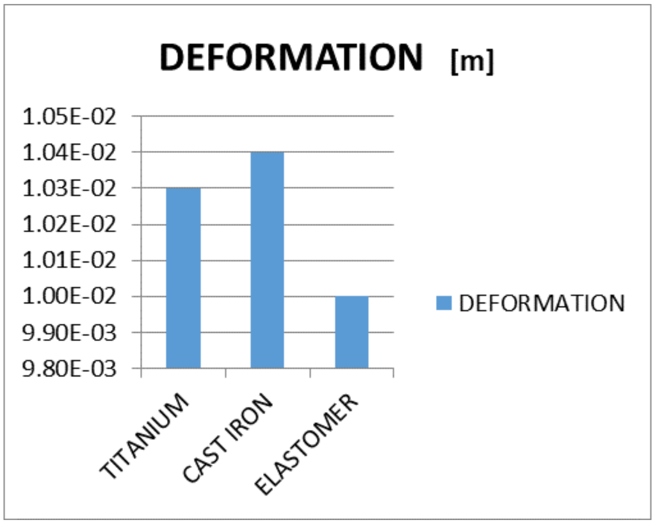
Properties of Outline Row 8: Titanium Alloy

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	4.62E-06	kg mm^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modu...			Suppr
8	Young's Modulus	96000	MPa		
9	Poisson's Ratio	0.36			
10	Bulk Modulus	1.1429E+05	MPa		
11	Shear Modulus	35294	MPa		
12	Tensile Yield Strength	930	MPa		
13	Compressive Yield Strength	930	MPa		
14	Tensile Ultimate Strength	1070	MPa		





C. Titanium Alloy



MATERIAL	STRESS [Pa]
GREY CAST IRON	1.3*E10
TITANIUM	1.2*E10
ELASTOMER	5.3*E7

VI. CONCLUSION

In this paper finite element analysis for static and dynamic conditions of the engine piston with different materials was performed. The main objective of this project was to study the response of aluminium alloy and SiC reinforced ZrB2 composite material for the applied temperatures and pressure. From the results it is concluded that the piston with SiC reinforced ZrB2 composite material is having less defections, while the piston with aluminium alloy and grey cast iron is having more deflections for t he applied temperatures and pressures. It is also observed that the stress for all the materials is within the allowable limits of the respective material. In this paper finite element analysis for static and dynamic conditions of the engine piston with different materials was performed. The main objective of this project was to study the response of titanium alloy, grey cast iron and elastomer for the load. From the results it is concluded that the piston with elastomer material is having less defections, while the piston with titanium alloy and grey cast iron is having more deflections for the applied load. It is also observed that the stress for all the materials is within the allowable limits of the respective material. In the is project for complex designs it is recommended the use of the stress analyses software because complex geometries may cause larger errors in the analytical procedure. In this project for complex designs it is recommended the use of the stress analyses software because complex geometries may cause larger errors in the analytical procedure.

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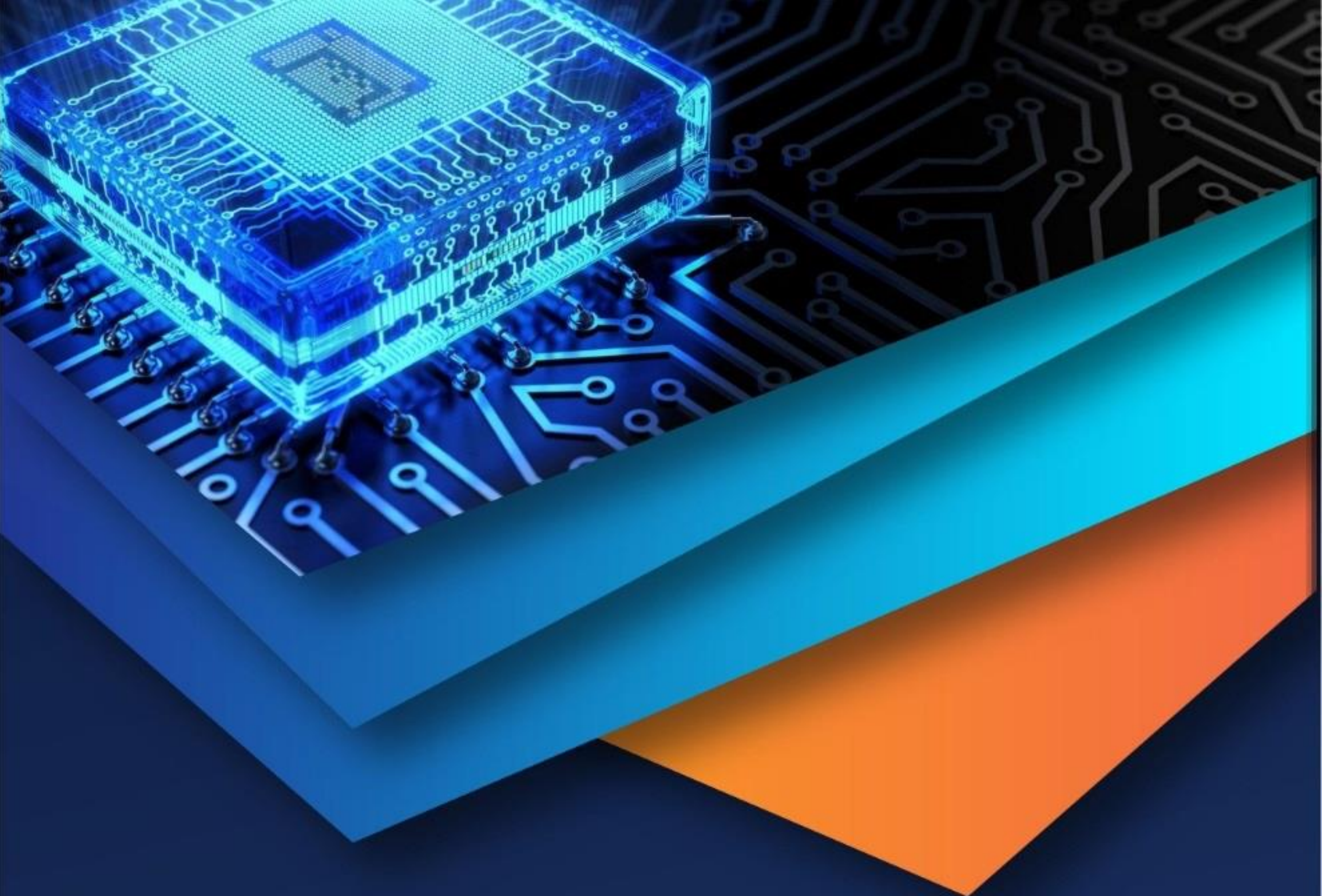

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