International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

DESIGN AND ANALYSIS OF THE PISTON USING COMPOSITE MATERIALS LIKE AA7275 STRUCTURAL AND THERMAL ANALYSIS DONE IN ANSYS SOFTWARE

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Abstract – This project focuses on the design and analysis of a piston utilizing composite materials, particularly AA7275, to enhance structural integrity and thermal efficiency. The study employs ANSYS software to conduct comprehensive structural and thermal analyses. The structural analysis evaluates the mechanical behavior, stress distribution, and deformation characteristics of the piston under varying operating conditions. Meanwhile, the thermal analysis investigates the heat transfer mechanisms, temperature distribution, and thermal stress accumulation within the piston. By integrating composite materials and utilizing advanced simulation techniques, this project aims to optimize the performance and reliability of the piston, contributing to advancements in engine technology.

ANSYS software facilitates Multiphysics simulations, allowing engineers to study the interactions between different physical phenomena such as structural mechanics, fluid dynamics, electromagnetics, and thermal effects. Its robust solvers and algorithms enable accurate prediction of system behavior under various operating conditions, helping engineers optimize performance, reliability, and efficiency. Moreover, ANSYS provides a range of specialized modules tailored to specific industries and applications, including automotive, aerospace, electronics, healthcare, and renewable energy. These modules incorporate domain-specific features and workflows, empowering engineers to address industry- specific challenges and design requirements effectively. Recent advancements in ANSYS software include enhanced computational capabilities, improved user interfaces, and integration with emerging technologies such as artificial intelligence and additive manufacturing. These developments enable engineers to accelerate the design iteration process, reduce time-to-market, and achieve superior product performance. Furthermore, ANSYS supports collaborative engineering workflows through its integration with product lifecycle management (PLM) and computer-aided design (CAD) software. This integration facilitates seamless data exchange between design, simulation, and manufacturing teams, ensuring consistency and accuracy throughout the product development lifecycle.

KEY WORDS : AA7275; Piston; Structural integrity and Thermal Efficiency; Structural analysis; ANSYS; CAD.

INTRODUCTION

In every engine, piston plays an important role in working and producing results.Piston forms a guide and bearing for the small end of connecting rod and also transmits the force of explosion in the cylinder,to the crank shaft through connecting rod. The piston is the single, most active and very critical component of the automotive engine. The Piston is one of the most crucial, but very much behind-the-stage parts of the engine which does the critical work of passing on the energy derived from the combustion within the combustion chamber to the crankshaft. Simply said, it carries the force of explosion of the combustion process to the crankshaft. Apart from the critical job that it does above, there are certain other functions that a piston invariably does -- It forms a sort of a seal between the combustion chambers formed within the cylinders and the crankcase. The pistons do not let the high pressure mixture from the combustion chambers over to the crankcase

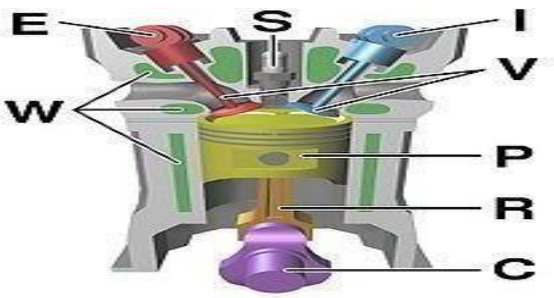

FIG 1.1 PISTON

MATERIALS FOR THE PISTON

Cast Iron, Aluminum Alloy and Cast Steel etc. are the common materials used for piston of Internal Combustion Engine.Cast Iron pistons are not suitable for high speed engines due its more weight. These pistons have greater strength and resistance to wear. The Aluminum Alloy Piston is lighter in weight and enables much lower running temperatures due to its higher thermal conductivity. The coefficient of expansion of this type of piston is about20% less than that of pure aluminum piston but higher than that of cast iron piston and cylinder wall. To avoid seizure because of higher expansion than cylinder wall,more piston clearance required to be provided. It results in piston slap after the engine is started but still warming up andtends to separate the crown from the skirt of the piston. Cutting a vertical slot will avoid this disadvantage. This slot helps in taking up thermal expansion and so the overall diameter of the piston is not required to be so reduced as to obstruct the safe operation between the cylinder walls and the pistons. To increase the life of grooves and to reduce the wear,a ferrous metal rings are inserted in the groovesof high speed engines.

DESIGN OF PISTON

For items in a variety of applications, including aerospace equipment, medical devices, semiconductors, vehicles, tools, and dies, among others, a highquality surface with a low value of surface roughness and high dimensional accuracy is needed. The production of components with complicated shapes for various applications requires the use of sophisticated materials, such as alloys of hard materials, glass, ceramics, and composite materials. These materials are challenging to finish because of their extreme hardness and toughness, as well as the goods' intricate shapes. The finishing process is the last step in the manufacture of components, and it accounts for around 15% of the overall production expense. Abrasive finishing is a method for precision surface finishing that shows promise. In order to complete the intricate shapes shows promise.

MATERIALS FOR MANUFACTURING PISTONS

A workpiece holder, an abrasive suspension tank, and Aluminium alloys give light pistons and for better heat dissipation, aluminium alloys are the ideal materials due to their very high thermal conductivity. Aliminium is 3 times lighter than cast iron. Its strength is good at low temperatures but is looses about 50% of its strength at temperatures above about 320 c .Its expansion is about 2 ½ times that of cast iron and the resistance to abrasion is low at hight temperatures. However these disadvantageous properties of aluminium have now been ever come by alloying it with other materials and by developing advanced designs of pistons. The split skirt, T-sotted as well as cam ground, oval sectioned pistons made from aluminium alloys are mostly used which can be tightly fitted into the cylinder born to eliminate ―piston slap‖. A coating of aluminium oxide or tin on aluminium alloys pistons has been found to be protective against ―scuffing‖ or ―partial seizure‖ during running in after overhaul.

For a cast iron piston the temperature at the centre of the piston head (Tc) is about 425c to 450c under full load conditions and the temperatures at the edges of the piston head (Tb) is about 200c to 225c.

For aluminium alloy piston, Tc is about 260c to 290c and Te is about 185c to 215

Since the aluminium alloys are about*** three times lighter than cast iron, Therefore its mechanical strength is good at low temperatures, but they lose their strength(about 50%) at temperatures above 325c.

2.1 DESIGN CALCULATIONS OF PISTON

Pressure Calculation

Suzuki GS 150 R specifications

Engine type : air cooled 4-stroke SOHC

Bore × $stroke(mm)$ = 57 × 58.6

Displacement =149.5CC

Maximum power = 13.8bhp @8500rpm

Maximum torque = 13.4Nm @ 6000 rpm

Compression ratio =9.35/1

Density of petrol C_8H_{18} = 737.22 $\frac{kg}{m^3}$ at 60F

= 0.00073722 kg/cm³

= 0.00000073722 kg/mm³

T = 60F =288.855K =15.55⁰C

Mass = density × $volume$

m = 0.00000073722× 149500

m = 0.11kg

molecularcut for petrol 144.2285 g/mole

PV = mRT

$P = \frac{mRT}{V} = \frac{0.11 \times 8.3143 \times 288.555}{0.11422 \times 0.0001495} = \frac{263.9}{0.00001707}$

P = 15454538.533 j/m³ = n/m²

P =15.454 N/mm²

Mean effective pressure $P_m = \frac{Tnc}{V_d} \times 2\pi$

$= \frac{13.4 \times 2 \times 2 \times 3.14}{149.5}$

= 1.12

Indicated power $IP = \frac{P_m \times l \times A \times n}{60} = \frac{P_m \times l \times \pi \times D^2 \times n}{60} = \frac{1.12 \times 58.6 \times 3.14 \times 57^2 \times 4}{4 \times 60} = 11217.05\ kw$

Brake power $BP = \frac{2\pi NT}{60} = \frac{2\pi \times 6000 \times 13.4}{60} = 8415.2$

Mechanical efficiency $\eta_{mec} = \frac{BP}{IP} = \frac{8415.2}{11217.05} = 0.75 = 75\%$

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Material – Aluminum Alloy A360

Temperature at the center of piston head $T_c = 260^0c$ to 290^0c

Temperature at the edge of piston head $T_e = 185^0c$ to 215^0c

Maximum gas pressure $p = 6N/mm^2$

Bore or outside diameter of piston = 57mm

1. Thickness of piston head

$$t_h = \sqrt{\frac{3p\,D^2}{16\sigma_t}}$$

$$a_t = 317Mpa$$

$$t_h = (\frac{3\times15.454\times57^2}{16\times317}$$

$$t_h = \sqrt{29.6983}$$

$$= 5.45mm \qquad or$$

Considering heat transfer

$$t_h = (\frac{\square}{12.56k\,(t_c - t_e)})$$

heat conductivity force = 174.75w/m/^{0}c

T_c-T_e = 75^0c

H = C×HCV ×m ×B.P(in KW)

C = constant = 0.05

HCV = 47×10^3KJ/kg for petrol

m = mass of fuel for brake power per second

BP = brake power

$H = C\times HCV\times (\frac{\ }{BP})\times BP$

$H = 0.05\times47\times10^3\times0.11$

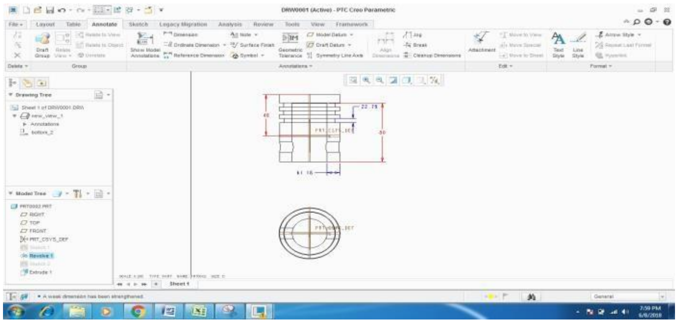
H = 258.5

$$t_h = (\frac{\square}{12.56k\,(t_c - t_e)})$$

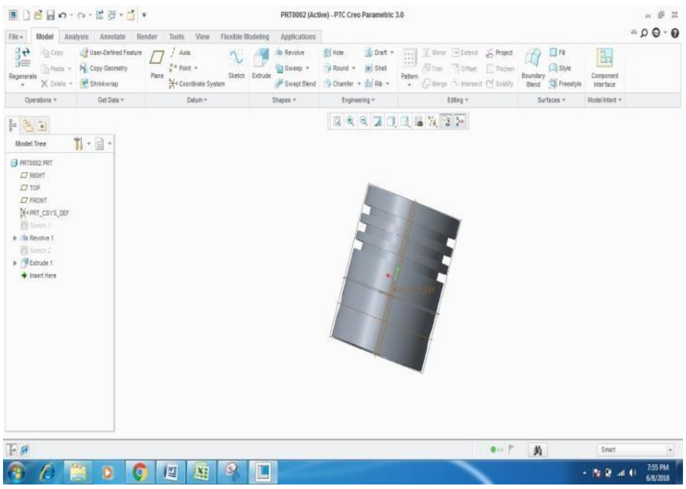
$t_h = 258.5/(12.56\times 174.75\times 75)$

COMPUTER-AIDED DESIGN (CAD) USING

2D MODEL



3D MODEL

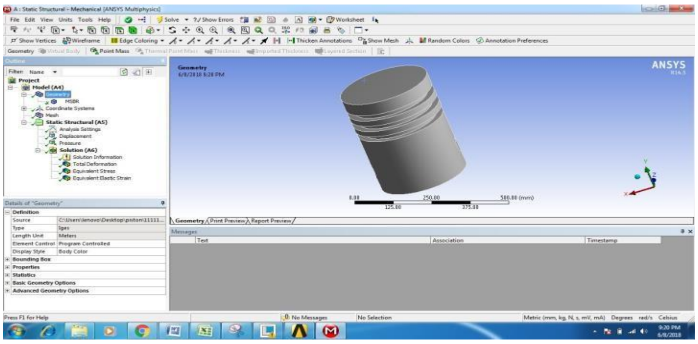


STATIC ANALYSIS OF DIESEL ENGINE

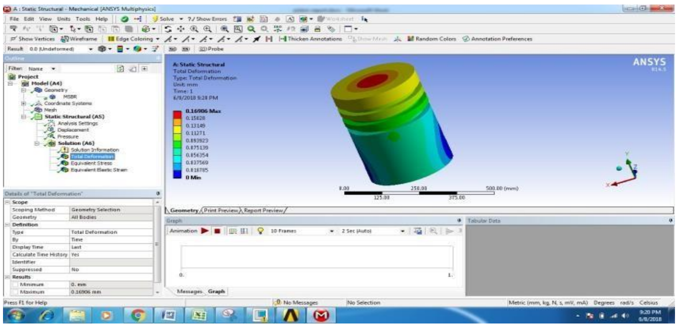
PISTON

ALUMINUM ALLOY 7475

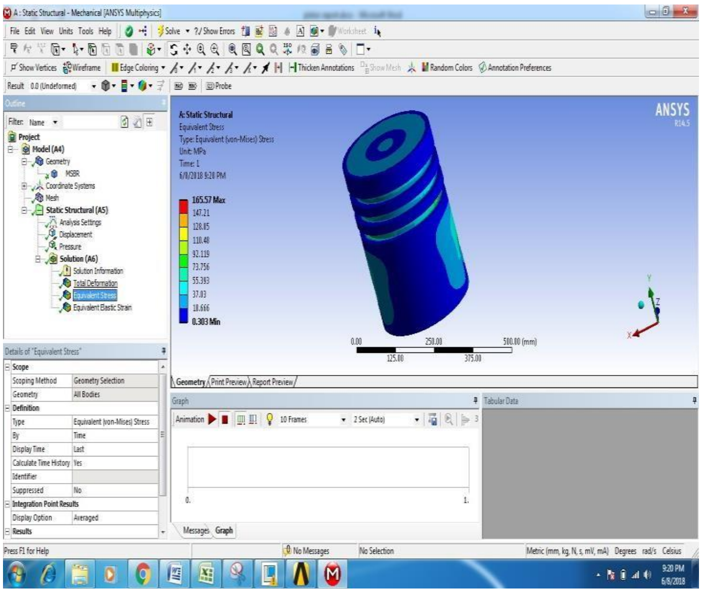
Young's modulus	**=**	**68.940 GPa**
Poisson's ratio	**=**	**0.329**
Density	**=**	**2751kg/ mm^3**
Thermal conductivity	**=**	**225.3w/m -k**



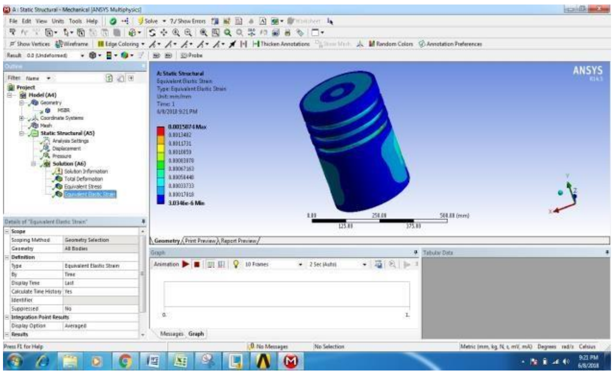
CREO Model of Aluminum Alloy 7275



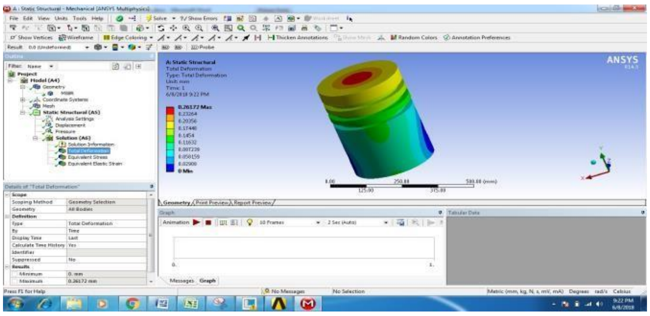
CREO Model of Material – Cast Iron Total Deformation



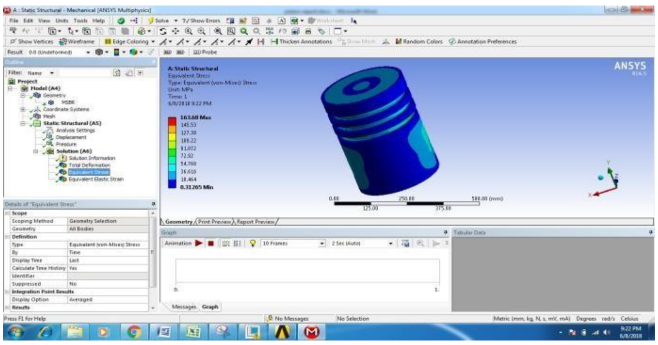
CREO Model of Material – Cast Iron Von-Mises Stress



CREO Model of Material – Cast Iron Von-Mises Strain

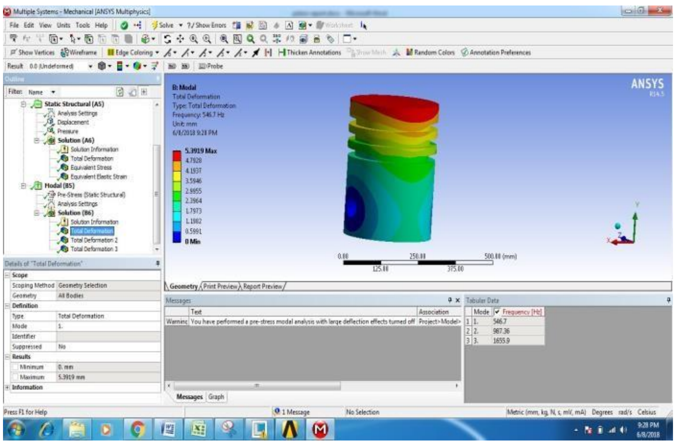


CREO Model of Material – Aluminum Alloy 7275 Total Deformation

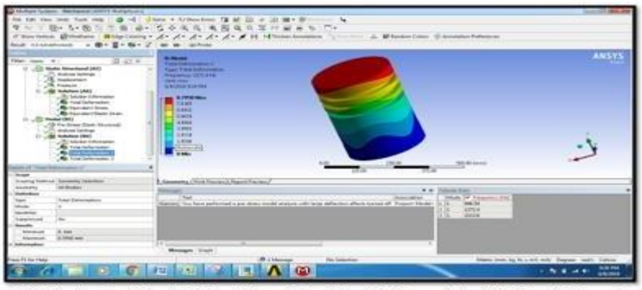


CREO Model of Material – Aluminum Alloy 7275 Von-Mises Stress

MODAL ANALYSIS OF DIESEL ENGINE PISTON MATERIAL –CAST IRON

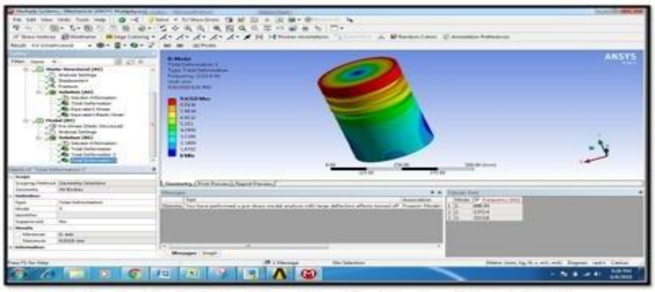


Total Deformation 2



Modal Analysis of Diesel Engine Piston Material – Aluminum Alloy 7275 TotalDeformation 2

2 Total Deformation 3

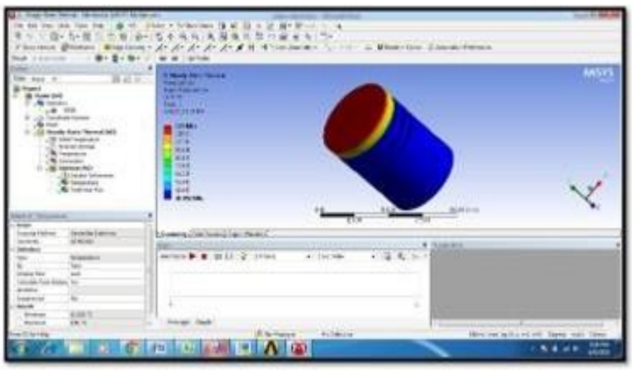


Modal Analysis of Diesel Engine Piston Material – Aluminum Alloy 7275 Total Deformation 3.

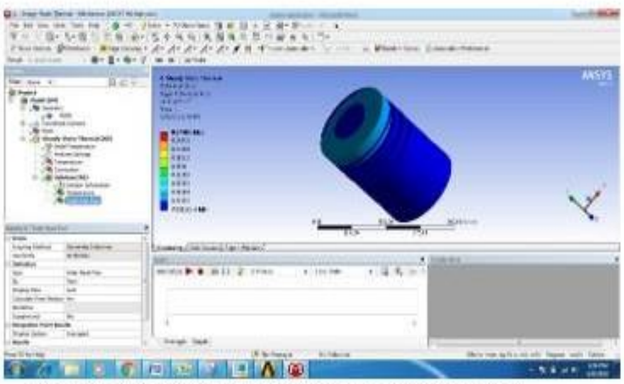
Modal Analysis of Diesel Engine Piston Material –Cast Iron Total Deformation 1

MATERIAL – ALUMINUM ALLOY 7275

THERMAL ANALYSIS OF DIESEL ENGINE PISTON



Thermal analysis of diesel engine piston temperature behavior of cast iron



Thermal analysis of diesel engine piston heat flux behaviour of cast iron

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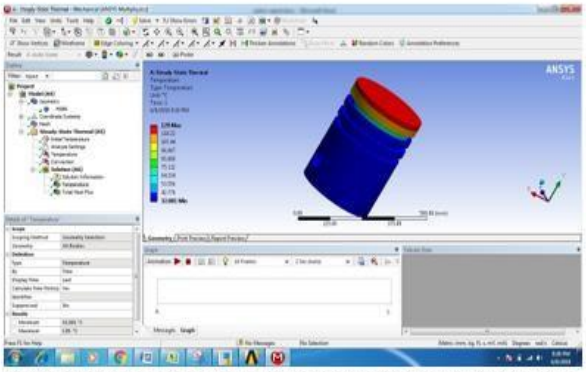

Fig. 6.3 Thermal analysis of diesel engine piston temperature behaviour of aluminum alloy 7275

HEAT FLUX

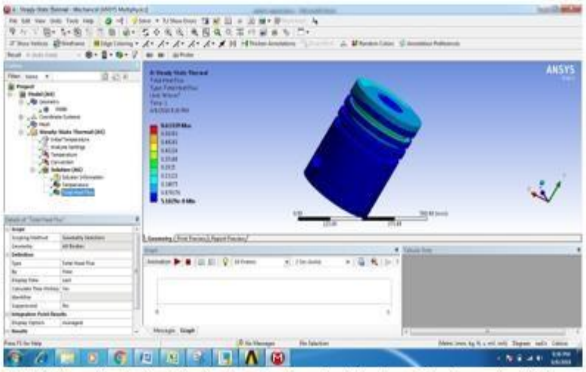

Fig. 6.4 Thermal analysis of diesel engine piston heat flux behaviour of aluminum alloy 7275

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RESULT

RESULT TABLES

Table -7.1 STATIC ANALYSIS

MATERIAL	DEFORMATION(mm)	STRESS(N/mm2)	Strain
CAST IRON	0.16906	165.37	0.0015047
ALUMINUM ALLOY 7275	0.26172	163.68	0.0023182

Table -7.2 MODAL ANALYSIS

MATERIAL	frequency (hz)	deformation1 (mm)	frequency (hz)	deformation2(mm)	frequency (hz)	deformation 3(mm)
CAST IRON	546.7	5.3919	989.36	5.4786	1655.9	5.946
ALUMINUM ALLOY 7275	696.54	8.6726	1272.4	8.7958	2113.8	9.6318

7.3 THERMAL ANALYSIS

MATERIAL	Temperature (0C)		Heat flux(W/mm^2)
	MIN	MAX	
CAST IRON	31.859	129	0.27468
ALUMINUM ALLOY 7275	32.001	129	0.6339

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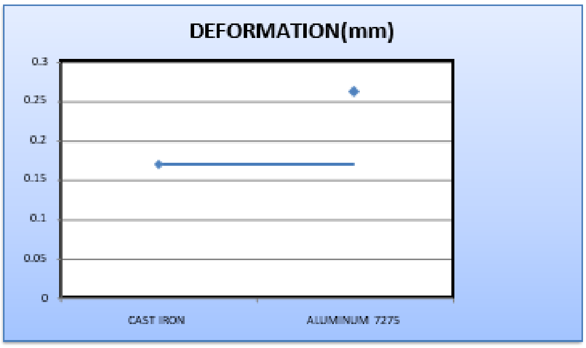
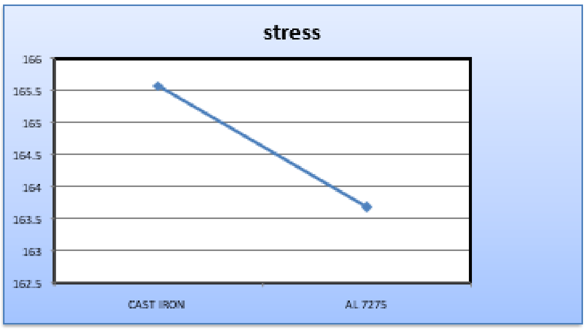
Graphs

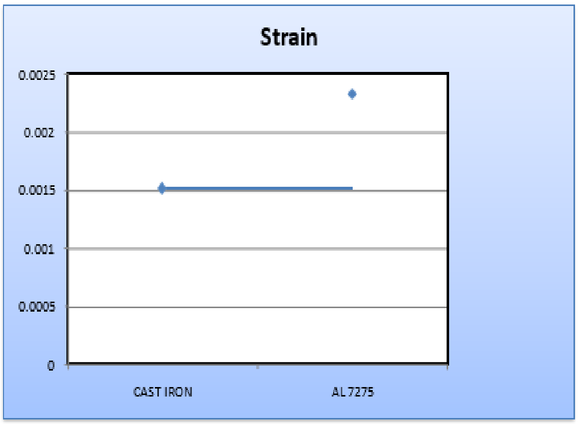


Graph 7.1 Deformation

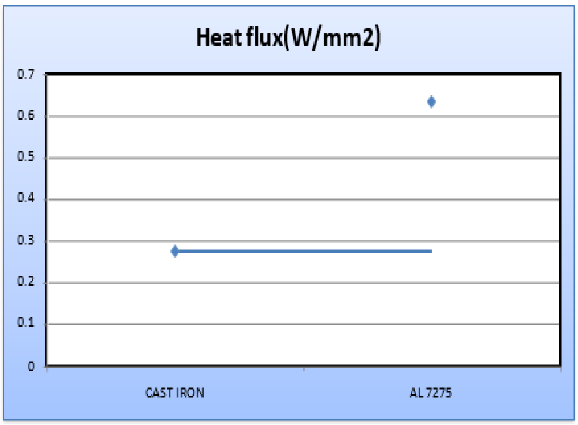
Stress



Strain



Graph 7.3 Strain



Graph 7.4 heat flux

CONCULSION

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. The piston transforms the energy of the expanding gasses into mechanical energy. The piston rides in the cylinder liner or sleeve. Pistons are commonly made of aluminum or cast iron alloys.The main aim of the project is to design a piston for two composite materials cast iron&aluminum 7275. The design of the piston is modeled using CREO parametric software.By observing the static analysis the deformation increase and stress will decrease for aluminum alloy 7275 material. By observing the modal analysis the deformation increases for magnesium aluminum alloy 7275 material and by observing the thermal analysis the heat flux value more for aluminum alloy 7275. So it can be concluded the aluminum alloy 7275 material is the better material for pistion.

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