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Design and Analysis of IC Engine Piston with Different Materials

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Abstract:

In the present work describes the stress distribution and thermal stresses of Five different materials for piston by using finite element method (FEM), testing of mechanical properties. The parameters used for the simulation are operating gas pressure, temperature and material properties of piston. The specifications used for this study of these pistons belong to four stroke single cylinder engine of Bajaj Kawasaki motorcycle. The results predict the maximum stress and critical region on the different materials piston using FEA.. Design by using catia v5 software and analysis by using Ansys software in Ansys 15 Static and thermal analysis is performed. The suitable material is selected based on results of structural and thermal analysis on these Al-sic graphite, A7075, A6082, A4032, AL-ghy 1250 materials

Key words:

FEA, Piston, Stress.etc,.Keywords

1. Introduction

The Piston is a 'heart' of an automobile engine. It's one of the key components of the engine and it's working the hard condition. The function of the piston is bearing the gas pressure and making the crankshaft rotation through the piston pin. Piston works in high temperature, high pressure, high speed at poor lubrication conditions. Piston contact with high temperature gas directly, the instantaneous temperature can be up to 2500K. Because of the high temperature and the poor cooling condition, the temperature of the top of the piston can be reach 600~700K when the piston working in the engine and the temperature distribution is uneven. The top of the piston bears the gas pressure, in particular the work pressure.

2. Literature Review

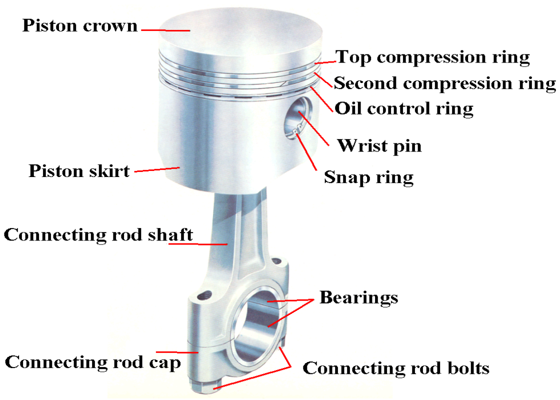
An optimized piston which is lighter and stronger is coated with zirconium for bio-fuel. In this paper[1], the coated piston undergone a Von misses test by using ANSYS for load applied on the top. Analysis of the stress distribution was done on various parts of the coated piston for finding the stresses due to the gas pressure and thermal variations. Vonmisses stress is increased by 16% and deflection is increased after optimization. But all the parameters are well with in design consideration. Design, Analysis and optimization of piston [2] which is stronger, lighter with minimum cost and with less time. Since the design and weight of the piston influence the engine performance. Analysis of the stress distribution in the various parts of the piston to know the stresses due to the gas pressure and thermal variations using with Ansys. With the definite-element analysis software, a three-dimensional definite-element analysis [3] has been carried out to the gasoline engine piston. Considering the thermal boundary condition, the stress and the deformation distribution conditions of the piston under the coupling effect of the thermal load and explosion pressure have been calculated, thus providing reference for design improvement. Results show that, the main cause of the piston safety, the piston deformation and the great stress is the temperature, so itis feasible to further decrease the piston temperature with structure optimization. This paper [4] involves simulation of a 2-stroke 6S35ME marine diesel engine piston to determine its temperature field, thermal, mechanical and coupled thermal-mechanical stress. The distribution and magnitudes of the afore-mentioned strength parameters are useful in design, failure analysis and optimization of the engine piston. The piston model was developed in solid-works and imported into ANSYS for pre-processing, loading and post processing. Material model chosen was 10-node tetrahedral thermal solid 87. The simulation parameters used in this paper were piston material, combustion pressure, inertial effects and temperature. This work [5] describes the stress distribution of the piston by using finite element method (FEM). FEM is performed by using computer aided engineering (CAE) software. The main objective of this project is to investigate and analyze the stress distribution of piston at the actual engine condition during combustion process.. The report describes the mesh optimization by using FEM technique to predict the higher stress and critical region on the component. The impact of crown thickness, thickness of barrel and piston top land height on stress distribution and total deformation is monitored during the study[6] of actual four stroke engine piston. The entire optimization is carried out based on statistical analysis FEA analysis is carried out using ANSYS for optimum geometry. This paper describes the stress distribution and thermal stresses of three different aluminum alloys piston by using finite element method (FEM). The parameters used for the simulation are operating gas pressure, temperature and material properties of piston. The specifications used for the study of these pistons belong to four stroke single cylinder engine. This topic shows review on design analysis of piston on the basis of improving strength according to the material properties. Vibhandik et. al . (2014), studied that Design analysis and optimization of piston and deformation of its thermal stresses using CAE tools, he had selected I.C. engine piston from TATA motors of diesel engine vehicle. He had performed thermal analysis on conventional diesel piston and secondly on optimized piston made of aluminum alloy and titanium alloy material. Conventional diesel piston made of structural steel. The main objective of this analysis is to reduce the stress concentration on the upper end of the piston so as to increase life of piston. After the analysis he conclude that titanium has better thermal property, it also help us to improve piston qualities but it is expensive for large scale applications, due to which it can be used in some special cases. Ch. Venkata Rajam et. al . (2013), focused on Design analysis and optimization of piston using CATIA and ANSYS. He had optimized with all parameters are within consideration. Target of optimization was to reach a mass reduction of piston. In this analysis a ceramic coating on crown is made. In an optimization of piston, the length is constant because heat flow is not affected the length, diameter is also made constant due to same reason. The volume varied after applying temperature and pressure loads over piston as volume is not only depending on length and diameter but also on thickness which is more affected. The material is removed to reduce the weight of the piston with reduced material. The results obtained by this analysis shows that, by reducing the volume of the piston, thickness of barrel and width of other ring lands, Von mises stress is increased by and Deflection is increased after optimization. But all the parameters are with in design consideration.V. V. Mukkawar et. al . (2015), describes the stress distribution of two different Al alloys by using CAE tools. The piston used for this analysis belongs to four stroke single cylinder engine of Bajaj Pulsar 220 cc motorcycle. He had concluded that deformation is low in AL-GHY 1250 piston as compare to conventional piston. Mass reduction is possible with this alloy. Factor of safety increased up to 27% at same working condition. He used Al-GHY 1250 and conventional material Al-2618 and results were compared, he found that Al-GHY 1250 is better than conventional alloy piston. Manjunatha T. R. et. al. (2013), underlook specification for both high pressure and low pressure stages and analysis is carried out during suction and compression stroke and identify area those are likely to fail due to maximum stress concentration. The material used foe the cylinder is cast-iron and for piston aluminum alloy for both low and high pressure. He concluded that the stress developed during suction and compression stroke is less than the allowable stress. So the design is safe. Swati S. chougule et. al. (2013), focused on the main objective of this paper is to investigate and analyze the stress distribution of piston at actual engine condition during combustion process the parameters used for simulation is operating gas pressure and material properties of piston. She concluded that there is a scope for reduction in a scope for reduction in thickness of piston and therefore 0ptimization of piston is done with mass reduction by 24.319% than non-optimized piston. The static and dynamic analysis is carried out which are well below the permissible stress value. The study of Lokesh Singh et. al . (2015) is related to the material for the piston is aluminum silicon composites. The high temperature at piston head, due to direct contact with gas, thermal boundary conditions is applied and for maximum pressure mechanical boundary conditions are applied. After all these analysis all values obtained by the analysis is less than permissible value so the design is safe under applied loading condition. The study of R. C. Singh et. al. (2014), discussed about failure of piston in I.C. engines, after all the review, it was found that the function coefficient increases with increasing surface roughness of liner surface and thermal performance of the piston increases. The stress values obtained from FEA during analysis is compared with material properties of the piston like aluminum alloy zirconium material. If those value obtained are less than allowable stress value of material then the design is safe.

3. Project Overview

3.1 Piston Design Features

1. Have sufficient mechanical strength and stiffness.

2. Can effectively block the heat reached the piston



head.

Figure 3.1 Piston

3. High temperature corrosion resistance.

4. Dimensions as compact as possible, in order to reduce the weight of the piston.

3.2 Engine Specifications:

The engine used for this work is a single cylinder four stroke air cooled type Bajaj Kawasaki petrol engine. The engine specifications are given in below table

3.2 Properties of Materials:

3.2.1 AL4032:

Aluminum alloys are known for strong corrosion resistance. These alloys are sensitive to high temperatures ranging between 200 and 250°C (392 and 482°F), and tend to lose some of its strength. However, the strength of Aluminium/Aluminum alloys can be enhanced at subzero temperatures, making them ideal low-temperature alloys. Aluminium/Aluminum 4032 alloy is a wrought alloy type. The following datasheet will provide more details about Aluminium/Aluminum 4032 alloy.4032 aluminum is an alloy of aluminum, further classified within the AA 4000 series (aluminum-silicon wrought alloy). It is typically furnished in the T6 temper. 4032 is the Aluminum Association (AA) designation for this material. In European standards, it will typically be given as EN AW-4032. Additionally, the EN chemical designation is AlSi12,5MgCuNi. And the British Standard (BS) designation is DTD324B

S.No	Parameters	Values
1	Engine type	Four stroke, petrol engine
2	No. of cylinder	Single cylinder engine
3	Maximum pressure	$15 N/mm^2$
4	Bore	50mm
5	Stroke length	81.25.mm
6	Speed	5000rpm
7	Brake power	8Bhp
8	Compression ratio	8.4
9	Maximum torque	8.05Nm at 5500
10	Maximum horse power	6.0. kw at 7500 rpm

Table 1 Engine Specifications

3.1.1. AL6082:

Aluminium alloy6082 aluminium alloy is an alloy in the wrought aluminium-magnesium-silicon family (6000 or 6xxx series). It is one of the more popular alloys in its series (alongside alloys 6005, 6061, and 6063), although it is not strongly featured in ASTM (North American) standards. It is typically formed by extrusion and rolling, but as a wrought alloy it is not used in casting. It can also be forged and clad, but that is not common practice with this alloy. It cannot be work hardened, but is commonly heat treated to produce tempers with a higher strength but lower ductility.

3.3.3 AL7075:

Aluminum alloy 7075 is an aluminum alloy, with zinc as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability. It has lower resistance to corrosion than many other Al alloys, but has significantly better corrosion resistance than the 2000 alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable. 7075 aluminum alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper,

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and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651.

S.NO	Parameters	Al-sic graphite	A7075	A6082	A4032	AL-ghy 1250
1	Density(Kg/m^3)	2711.4	2761.9	2700	2684.95	2880
2	Poisons ratio(μ)	0.34	0.33	0.33	0.33	0.3
3	Young's modulus(Gpa)	74	73	71	82	83
4	Ultimate Tensile strength(Mpa)	193.38	512	330	380	1250
5	Thermal conductivity (k)(W/m°C)	147	130	180	154	130
6	Specific heat (J/Kg°c)	826	860	890`	870	880

Table 2 Material Properties

3.3.4 AL-SIC graphite material:

Preparation of AL-SICGRAPHITES SPECIMEN Stir Casting technique is a method of producing composite materials, in which a scattered stage (fired particles, short filaments) is blended with a liquid metal by method for mechanical mixing with the help of stirrer. The liquid state composite material is cast by permanent die casting method. In this Stir casting technique has been used to prepare the work-piece samples of Al-Sic-Graphite hybrid metal matrix Composite material and accomplish the required properties of that composite material. The vortex stir casting is best approach to create an accurate mixing of the silicon carbide and graphite material in the matrix, the aluminium material was stacked in a crucible and it was placed into a resistance furnace at various temperature levels.

Figure 0.1 AL-SIC graphite

3.3.5 AL-GHY1250:

It is an ultra high strength Aluminum alloy processed via mechanically alloying route. The high strength and temperature stability comes from the Yttrium and Oxides. This alloy even outperforms most of the new amorphous Aluminum alloys. Due to the very stable and small Oxides it shows outstanding strength at elevated temperatures. It is the Excellent temperature stability.

3.3 Problem Identification :

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. Piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head cracks and so on working condition of the piston of an internal combustion engine is so worst are high chances of failure of piston due to wear and tear. So there is necessary to analyze area of maximum stress concentration, strain, deformation and temperature distribution and heat flux on piston. The objective of the present work is to design and analysis of piston made UP of A4032, Al-GHY1250,AL6082,AL7075,ALSIC GRAPHITE

3.4 Designing of the Model :

Create the half piston profile in sketcher workbench next go to exist work bench (part design) now go to the sketched based features and go to shaft option apply angle 360 after create the planes offset to xy planes create the circles and apply pocket around the up to surface now go to mirror option apply mirror finally as shown the figure below:

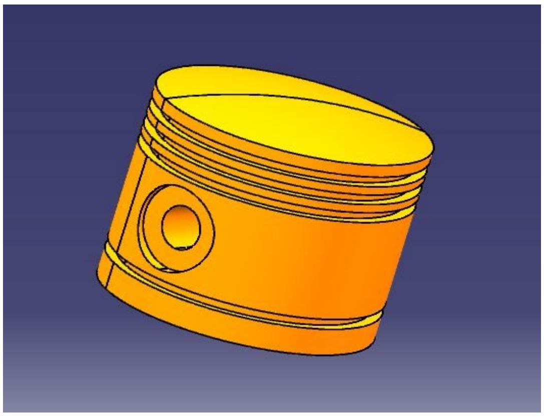

Figure :3.3 Piston in catia work bench

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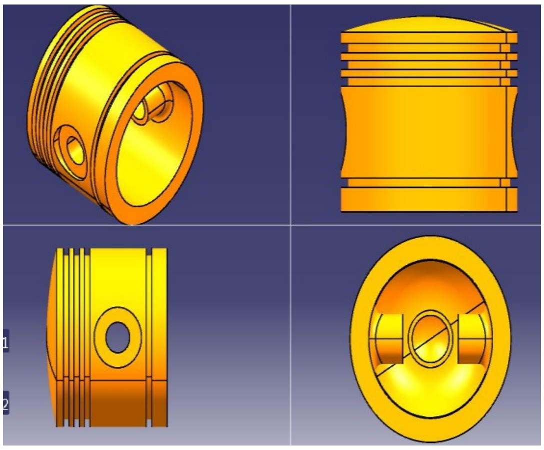


Figure 3.4 different views of piston in catia work bench

4. Expermentation:

4.1 Structural Static Analysis:

A static analysis calculates the effects of study loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can however include steady inertia loads and time varying loads that can be approximated as static equivalent loads. 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. Steady loading and response conditions are assumed, i.e. the loads and the structure's responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis include:

4.2 Procedure of Static Analysis and Thermal Analysis:

Create the geometry in catia workbench and save the file in igs format and open ansys workbench apply engineering data (material properties), create or import the geometry, apply model (meshing), apply boundary conditions(setup) shown the results(stress,deformation,heat flux).

Analysis of Piston:

Frictionless support at pin bore areas and fixed all degree of freedom. Downward pressure (18.66 MPa) due to gas load acting on piston head. The piston is analyzed by giving the constraints they are Pressure or structural analysis and Thermal analysis.

Structural Analysis of Piston: Combustion of gases in the combustion chamber exerts pressure on the head of the piston during power stroke. The pressure force will be taken as boundary condition in structural analysis. Fixed support has given at surface of pin hole. Due to the piston will move from TDC to BDC with the help of fixed support at pin hole. So whatever the load is applying on piston due to gas explosion that force causes to material.

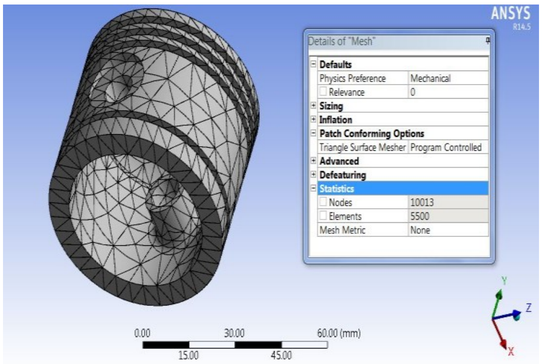


Figure 4.1 Mesh body

4.3 Boundary conditions and in static analysis :

1. Maximum pressure load at the top surface of the piston crown 18.66 Mpa
2. Temperature at the top surface of the piston crown 1400 K
3. Piston pin holes are fixed DX = DY = DZ = 0

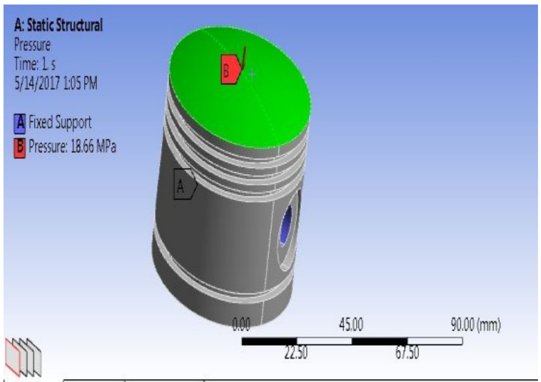


Figure 4.2 Boundry conditions of static analysis

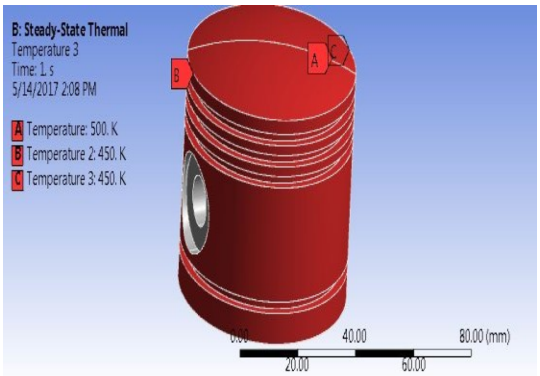


Figure 4.3 Boundry conditions of thermal analysis

5. Results and Discussion:

The constructed piston in catia is analyzed using ANSYS V15.0 and the results are depicted below. Combustion of gases in the combustion chamber exerts pressure on the head of the piston during power stroke. Fixed support has given at surface of pinhole. Because the piston will move from top dead center to bottom dead centre with the help of fixed support at pinhole.

AL-Sic Graphite Static analysis :

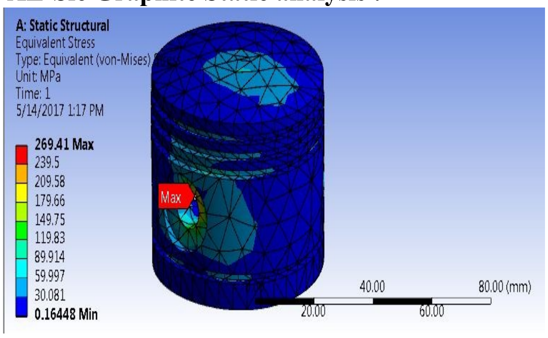


Figure 5.1 Stress

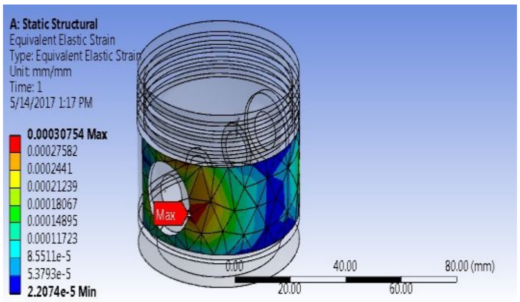


Figure 5.2 Strain

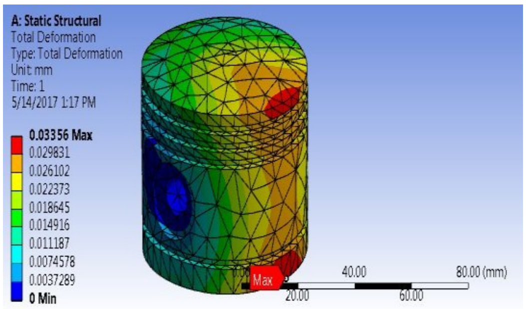


Figure 5.3 Deformation

AL-Sic Graphite Thermal analysis :

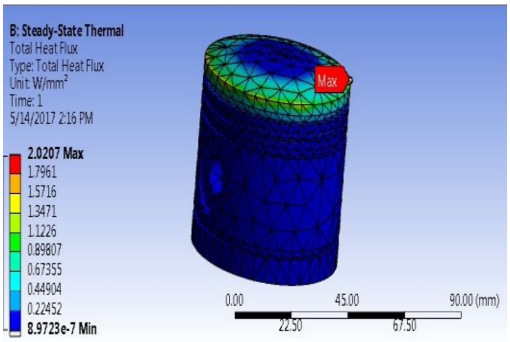


Figure 5.4 Heat flux

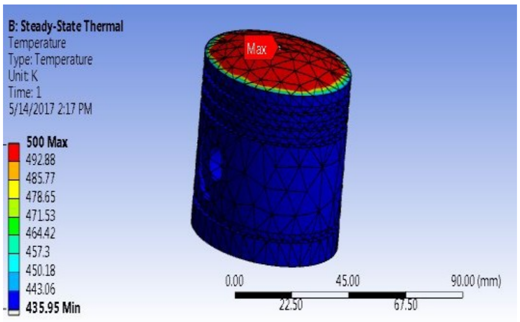


Figure 5.5 Temperature Distribution

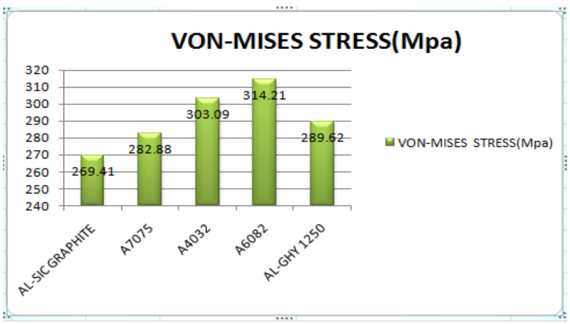
5.1 Graphs:

5.2.1 Static Structural Analysis:

The static structural analysis of Al-sic graphite, A7075, A6082, A4032, AL-ghy 1250are done and results are obtained for Equivalent (Von-Mises) stress, equivalent elastic strain, total deformation, heat flux, and temperature . These results are plotted graphically and a comparison is made between these results.

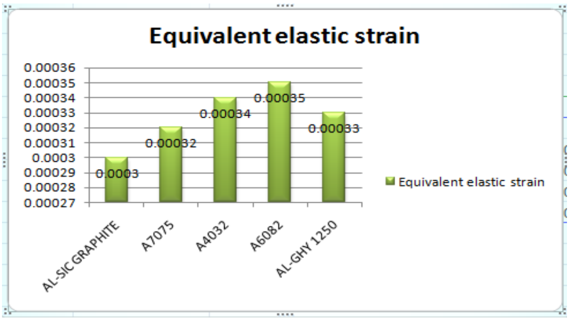
5.2.2 Von mises stresses (Mpa):

we can observe that in case of equivalent (von-mises) stress, piston made of Al-sic graphite is found to have least stress of 269.41MPa in comparison with remaining materials including the present material. Highest stress of 314.21MPa is observed in piston made of A6082. Maximum equivalent stress on A4032 was found to be 303.09 Mpa, that of AL-ghy 1250 was found to be 289.62Mpa and A7075 was found to be282.88 Mpa



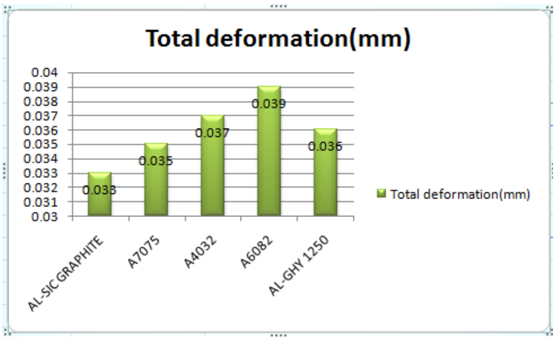
5.2.3 Equivalent Strain:

we can observe that in case of equivalent strain , piston made of Al-sic graphite is found to have least strain of 0.0003MPa in comparison with remaining materials including the present material. Highest strain of 0.00035MPa is observed in piston made of A6082. Maximum equivalent strain on A4032 was found to be 0.0034 Mpa, that of AL-ghy 1250 was found to be 0.00033 Mpa and A7075 was found to be0.00032 Mpa.



5.2.3 Total Deformation:

we can observe that in case of total deformation , piston made of Al-sic graphite is found to have least total deformation of 0.033MPa in comparison with remaining materials including the present material. Highest total deformation of 0.039MPa is observed in piston made of A6082. Maximum total deformation on A4032 was found to be 0.037 Mpa, that of AL-ghy 1250 was found to be 0.036 Mpa and A7075 was found to be0.035 Mpa.



6. Conclusion :

Pistons made of different aluminium alloys like Al-sic graphite, A7075, A6082, A4032, AL-GHY 1250 were designed and analyzed successfully. In structural analysis, and in thermal analysis the pistons were analyzed to find out the equivalent (von-mises) stress, equivalent elastic strain, total deformation heat flux and temperature distribution. The results show that in case of equivalent (von-misses) stress, piston of Al-sic graphite is found to have least stress of 269.41Mpa in comparison with remaining materials. Highest stress of 314.21MPa is observed in material of A6082, followed by A4032, AL-ghy 1250 and A7075.From the strain analysis figures, it can be observed that maximum strain is near piston pin area in all the materials. The results show that in case of equivalent (von-misses) strain, piston of Al-sic graphite is found to have least strain of 0.00030 in comparison with remaining materials. Highest strain s of 0.00035 is observed in material of A6082, followed by A4032, AL-ghy 1250 and A7075. The results show that in case of Total deformation, piston of Al-sic graphite is found to have least strain of 0.033 in comparison with remaining materials. Highest strain s of 0.039 is observed in material of A6082, followed by A4032, AL-ghy 1250 and A7075. The results show that in case of temperature distribution , piston of Al-sic graphite is found to have minimum temperature 435.95 .The results show that in case of heat flux , piston of Al-sic graphite is found to have highest heat flux of 2.0207 in comparison with remaining materials. Least heat flux of 1.5719 is observed in material of A6082, followed by A7075, A4032, and Al-ghy 1250.finally suitable material for piston is al-sic graphite material.

7. References:

[1]. Ajay Raj Singh, “Design, Analysis and Optimization of Three Aluminium Piston Alloys Using FEA” Int. Journal of Engineering Research and Applications, Vol. 4, Issue 1 Version 3, January 2014, pp.94-102.

[2]. IsamJasimJaber and Ajeet Kumar Rai, “Design and analysis of i.c. engine piston and piston-ring using catia and ansys software” International Journal of Mechanical Engineering and Technology (IJMET),Volume 5, Issue 2, February 2014.

[3]. Vinod Yadav, Dr. N. D. Mittal, “Design and Analysis of Piston Design for 4 Stroke Hero Bike Engine” International Journal of Engineering Innovation & Research Volume 2, Issue 2, 2013FERENCES.

[4]. Ch.Venkata Rajam, P.V.K. Murthy, M.V.S. Murali Krishna, G.M .PrasadaRao, “Design Analysis and Optimization of Piston using CATIA and ANSYS ”, International Journal of Innovative Research in Engineering & Science , issue 2 volume 1, January 2013.

[5]. S.Srikanth Reddy, Dr. B.Sudheer Prem Kumar, “Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method” International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 12, December 2013

[6].Hidehiko Kajiwara, at.al An analytical approach for prediction of piston temperature distribution in diesel engines

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 07
March 2018

[7].V. Esfahanian, A. Javaheri, M. Ghaffarpour- Thermal analysis of an SI engine piston using different combustion boundary condition treatments

[8]. B. Bhandari, "Design of Machine Elements", 3rd Edition, McGraw Hill.

[9]. Ajay Raj Singh, Dr. Pushpendra Kumar SharmaDesign, Analysis and Optimization of Three Aluminum Piston Alloys Using FEA International Journal of Material and Mechanical Engineering, Jan 2014.

[10].Vaishali R. Nimbarte, Prof. S.D. Khamankar-STRESS ANALYSIS OF PISTON USINGPRESSURE LOAD AND THERMAL LOAD IPASJ International Journal of Mechanical Engineering (IIJME)