MODEL AND THERMAL FE ANALYSIS OF FOUR STROKE GASOLINE ENGINE PISTON FOR DIFFERENT MATERIALS BY USING ABAQUS SOFTWARE

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ABSTRACT: Piston in the Internal Combustion (IC) Engine is robust, dynamically loaded tribo-pair that reciprocates continuously at varying temperature. Study has been made by various researchers on piston design, dynamics, fatigue and wear at the interface with other element in contact along with their effects on IC engines.

An attempt is made in this paper to carry-out Model and Thermal Analysis of Four Stroke Gasoline Engine piston by using different materials such as Aluminum Alloy (AA2618), Steel Alloy (AISI4340) and Titanium Alloy (Ti-6Al-4V). The dimensions of the piston are 80mm in diameter, 80mm in length, Top land width of 8mm, two compression rings of thickness 2.5mm and 2.5mm and Oil ring thickness of 5mm. First the piston is modeled by using CATIA V5 software, then meshing and analysis is done by ABAQUS CAE Software by using FE Analysis.

The Model and Thermal Analysis is done by applying boundary conditions for different materials. The results are drawn for the different materials of piston contour of maximum displacements, maximum heat flux distribution and Temperatures such as Aluminum Alloy AA2618, Steel Alloy AISI 4340 and Titanium Alloy Ti-6M-4V.It is observed that Aluminum Alloy AA2618 for the Model Analysis, maximum frequency of that material is 2883.9 Hz and maximum displacement is 1.008 mm, Steel Alloy AISI 4340 material is the maximum frequency of that material is 2761.6 Hz and maximum displacement is 1.008 mm and Ti-6Al-4V material for the maximum frequency of that material is 2698.4 Hz and maximum displacement is 1.008mm, Then Aluminum Alloy AA2618 for the Thermal Analysis, the maximum heat flux distribution 6201.951 and the maximum temperature of 650k, AISI4340 material is the maximum heat flux distribution 141774.078, maximum temperature of 650k and Titanium Alloy Ti-6Al-4V material for the maximum heat flux distribution 301.602, maximum temperature of 650k. From the above results Titanium Alloy Ti-6Al-4V material is best material.

Keywords: Piston, FE Analysis**,** Aluminum Alloy, Steel Alloy, Titanium Alloy

1. INTRODUCTION

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. So there is a need to optimize the design of piston by considering various parameters in this project the parameters selected are analysis of piston by applying pressure force acting at the top of the piston and thermal analysis of piston at various temperatures in various stroke. This analysis could be useful for design engineer for modification of piston at the time of design. In this project we determine the various stress calculation by using pressure analysis, thermal analysis and thermo-mechanical analysis form that we can find out the various zones or region where chances of damage of piston are possible. From analysis it is very easy to optimize the design of piston. The main requirement of piston design is to measure the prediction of temperature distribution on the surface of piston which enables us to optimize the thermal aspects for design of piston at lower cost. Most of the pistons are made of an aluminum alloy which has thermal expansion coefficient, 85% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behavior is extremely crucial in designing more efficient compressor. Good sealing of the piston with the cylinder is the basic criteria to design of the piston. Also to improve the mechanical efficiency and reduce the inertia force in high speed machines the weight of the piston also plays major role. To allow for thermal expansion, the diameter of the piston must be smaller than that of the cylinder. The necessary clearance is calculated by estimating the temperature difference between piston and cylinder and considering the coefficient of thermal expansion of piston.

Fig 1. Basic Components of A Piston

Piston materials	AA 2618	AISI4340	Ti – 6AL – 4V
Density (kg/m³)	2.8	8.03	4.512
Elastic modulus (MPa)	80000	210000	113000
Poisson ratio	0.33	0.30	0.37
Thermal conductivity(W/m-K)	146	44.5	7.1

Table 1: Different Material Alloys of the of Piston

1.1. MATERIALS FOR PISTON:

The material used for piston is mainly aluminum alloy. Aluminum pistons can be either cast or forged. Cast iron is also used for piston. In early years cast iron was almost universal material for pistons because it possesses excellent wearing, qualities, coefficient of expansion and general suitability in manufacture. Aluminum is inferior to cast iron in strength and wearing qualities and its greater coefficient of expansion necessitates greater clearance in the cylinder to avoid the risk of seizure. The heat conductivity of aluminum is about three times that of cast iron and this combined with the greater thickness necessary for strength, enables and aluminum alloy piston to run at much lower temperature than a cast iron one (200°C to 250°C as compared with 400°C to 450°C). As a result carbonized oil does not form on the underside of the piston and the crankcase therefore keeps cleaner.

1.2. COMPOSITION OF AA2618 MATERIAL

Element	**Al**	**Mg**	**Fe**	**Si**	**Cu**	**Ni**	**Ti**
Weight %	**93.7**	**1.60**	**1.1**	**0.18**	**2.30**	**1.0**	**0.07**

1.3. COMPOSITION OF AISI 4340 MATERIAL

Element	**C**	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**

Weight %	**0.38-0.43**	**0.6.0.8**	**0.15-0.30**	**0.035Max**	**0.04Max**	**0.70-0.90**	**1.65-2.0**	**0.20-0.30**

1.4. COMPOSITION OF Ti-6Al-4V MATERIAL

Element	**Al**	**V**	**C**	**Fe**	**O**	**N**
Weight %	**5.5 – 6.75**	**3.5-4.5**	**0.10Max**	**0.30 Max**	**0.02 Max**	**0.05 Max**

2. LITERATURE SURVEY

In modern trend automobile components are in great demand because of increase in usage of automobiles due to the improved performance & cost reduction of components. The purpose of literature survey of past research effort such as journals or articles related to static analysis of the Gasoline piston and use of FEM/ABAQUS for analysis move over, review of other relevant research studies are made to provide more information in order to understand more on this research. **B.A Devan et al** [1], have done by thermal distribution on different piston materials used. From the analysis results of different materials on piston on observed that heat flux reduces in AlSiC composite compared to Al – Si, Al – Mg – Si, alloys. **Ramesh.B.R and KishanNaik** [2] have done the thermal-stress analyses are investigated on a diesel engine piston made of Aluminium-Alloy and Carbon Steel. The maximum temperature is found in Carbon-Steel piston than Aluminium-Alloy piston. Due to increase in thermal conductivity, leads to reduction in temperature at piston crown surface and increase in temperature of piston skirt.

Hitesh Pandey et al [3] has done the thermal analysis of a Speculative IC engine piston using CAE (Computer Aided Engineering) tools for different materials of a cast iron, structural steel, A2618 Al alloys. Aluminum alloy should provide good mechanical, minimum thermal stress and high heat conductivity. The results is comparison between theoretical and analysis simulated done and found approximately same. **Neethu Sharma et al** [4], have done by thermal analysis we concluded that maximum temperature on the piston is 2000oc and minimum temperature is 22^0c. Also the maximum heat flux is 35.277 w/mm^2 and minimum value of total heat flux is 1.0309e-009. The corresponding graphs and provides us further details. In this analysis is performed on Ansys 14.5 analysis software. These results are based on FEM. **K.Anusha et al** [6] has done by the thermal analysis of 4 – stroke Direct Injection diesel engine piston by using NASA398 as a piston material. The model is done in CATIA V5 Software. This model is meshed in hypermesh Software it can be analyzed by using FEA analysis ABAQUS SOFTWARE and applying the boundary conditions. **M.Nageswari et al** [7] have done by design and analysis of both static and steady state thermal on piston head,they have designed piston using CAD software namely CATIA V5 and analysis is done using ANSYS 14.5 and the thermal and static analysis. It was analyzed piston with aluminum alloy material immersed with material namely zirconium and MgSi in place of silicon for better thermal conditions and deformation factors.

OBJECTIVE OF THE PAPER : In this paper the model and thermal analysis of piston by using different material such as Aluminum Alloy AA2618 ,Titanium Alloy (Ti-6Al-4V) and Steel Alloy (AISI 4340) is carried out. The piston model is done in CATIA V5 Software and then analysis carried-= out using ABAQUS CAE software.

3. DATA COLLECTION

Table :2 Geometrical entities of the piston

S.NO	**DESCRIPTION**	**UNIT**	**VALUE**
1.	Length of the Piston	mm	80
2.	Bore (Dia)	mm	80
3.	Thickness of the piston head(t_H)	mm	4
4.	Radial thickness of the ring(t_1)	mm	5.24

5.	Axial thickness of the ring(t_2)	mm	5
6.	Width of the top land (b_1)	mm	8
7.	Width of other ring lands(b_2)	mm	4

4. MODELING AND FINITE ELEMENT ANALYSIS

Increase in computational power of modern computers, CATIA V5 has found more and more applications in the Gasoline engine design and development. In this chapter mainly discussed detailed view of CATIA SOFTWARE introduction, applications, and its design data and also piston model is developed in CATIA V5 and then imported to Abacus CAE Software.

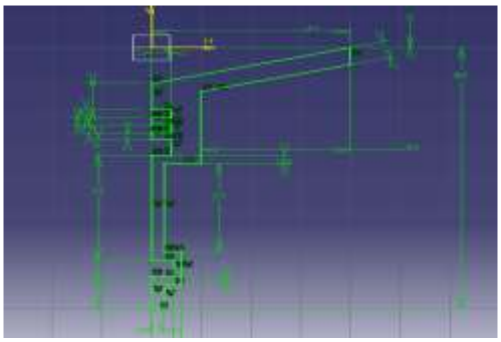

Fig. 2: 2D Piston Design Model

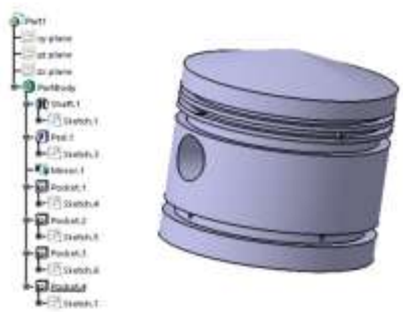

Fig.3: Isometric view of Piston Model in CATIA

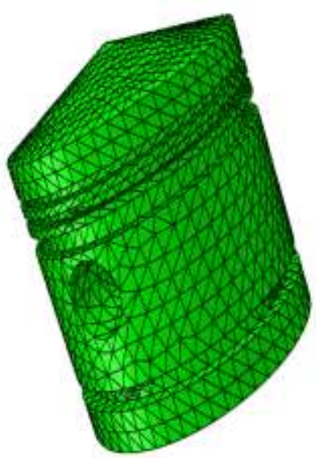

Fig.4 Meshed model of the Gasoline Piston

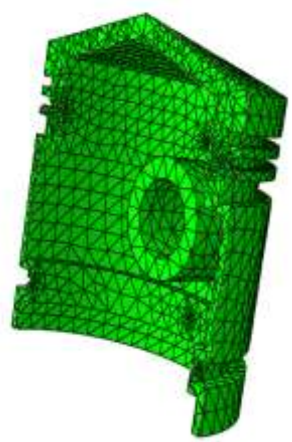

Fig.:5 Meshed cut section model of the Gasoline Piston

Once the model is built, then it has to be meshed to perform analysis. Meshing is done using HYPERMESH 14 or using the ABAQUS meshing tool itself.ABAQUS offers a variety of meshing techniques to mesh models of different topologies. The different meshing techniques provide varying levels of automation and user control. The Gasoline piston was meshed by using TET mesh (tetrahedral) consisting of 14944 elements using free technique and an aspect ratio of 5.0, skew angle 60^0.

5. RESULTS & DISCUSSIONS

In model analysis apply the all mechanical properties on the piston such as density, young's modulus and Poisson's ratio. No load is applied on piston. Wrist pin hole is fixed

5.1 AA2618 ALLOY

The result of AA2618 material for Modelanalysis is given below. The maximum frequency of that material is 2883.9 Hz and maximum displacement is 1.008 mm is attained

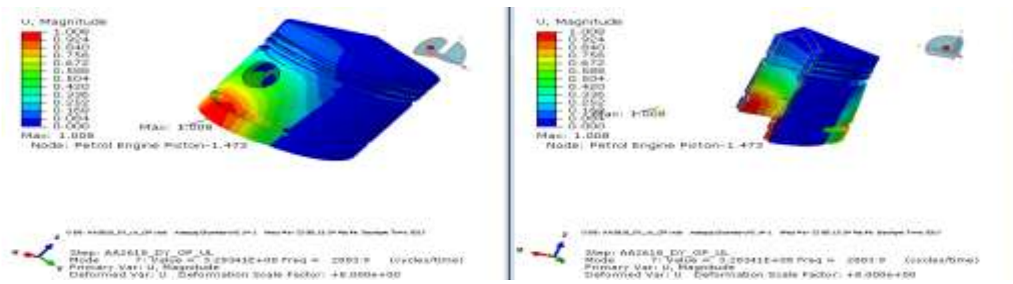

Fig 6: Displacement distribution contours for AA2618 material

5.2 AISI4340 ALLOY

The result of AISI4340 material for Modelanalysis is given below. The maximum frequency of that material is 2761.6 Hz and maximum displacement is 1.008 mm is attained.

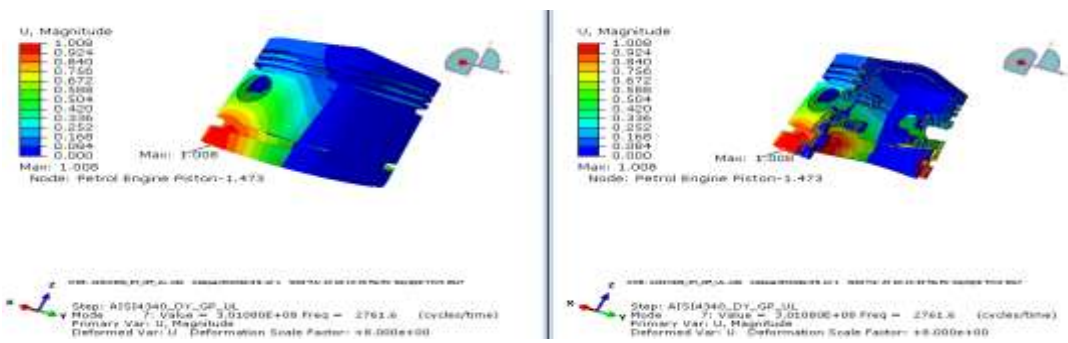

Fig7: Displacement distribution contours for AISI4340 material

5.3 Ti – 6Al – 4V ALLOY

The result of Ti – 6Al – 4Vmaterial for Modelanalysis is given below. The maximum frequency of that material is 2698.4 Hz and maximum displacement is 1.008 mm is attained

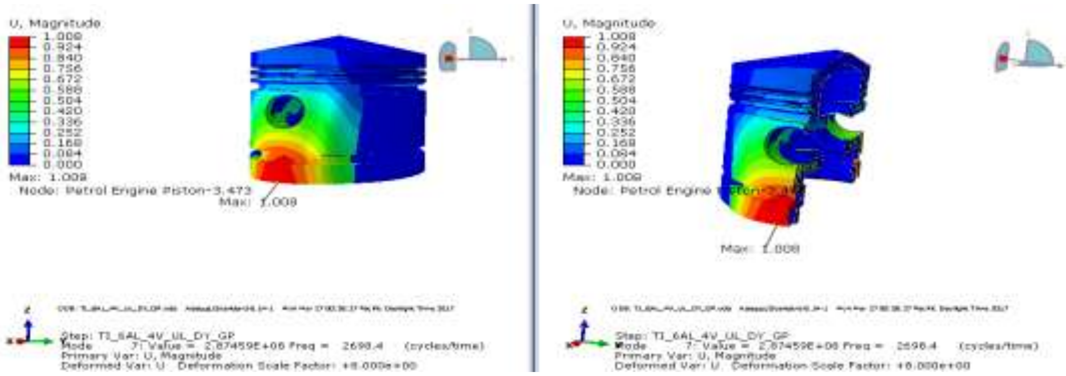

Fig 8: Displacement distribution contours for Ti – 6Al – 4Vmaterial

The frequency indicates the average life of the Gasoline Piston and the frequency of Ti – 6Al – 4Vmaterial is lower than the other materials

5.4 THERMAL ANALYSIS:

In thermal analysis apply the all mechanical properties on the piston such as density, young's modulus, Poisson's ratio and thermal conductivity. The applied minimum temperature 350k and maximum temperature 650k.

5.5 AA2618 ALLOY

The result of AA2618 material for Thermal analysis is given below. The maximum heat flux distribution 6201.951 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 615.034k, 462.879k were obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

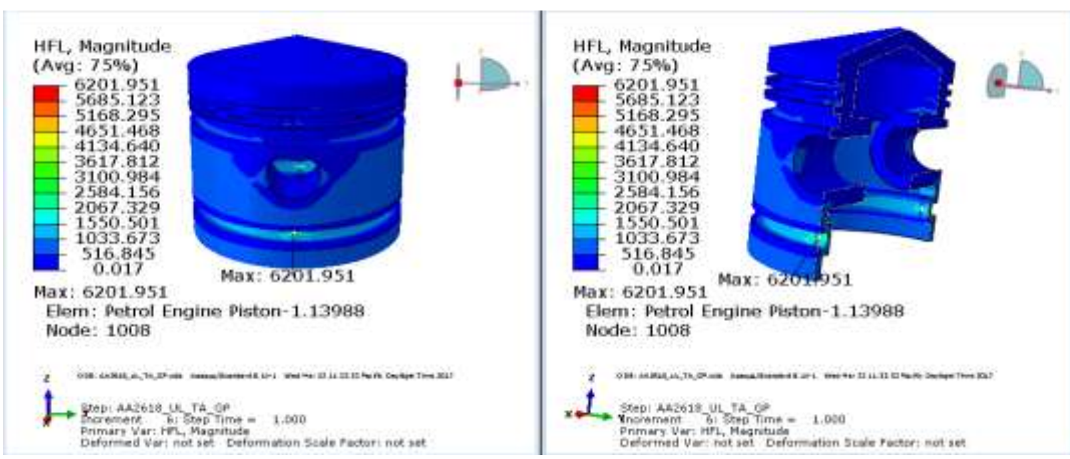

Fig 9: Heat flux distribution contours for AA2618 material

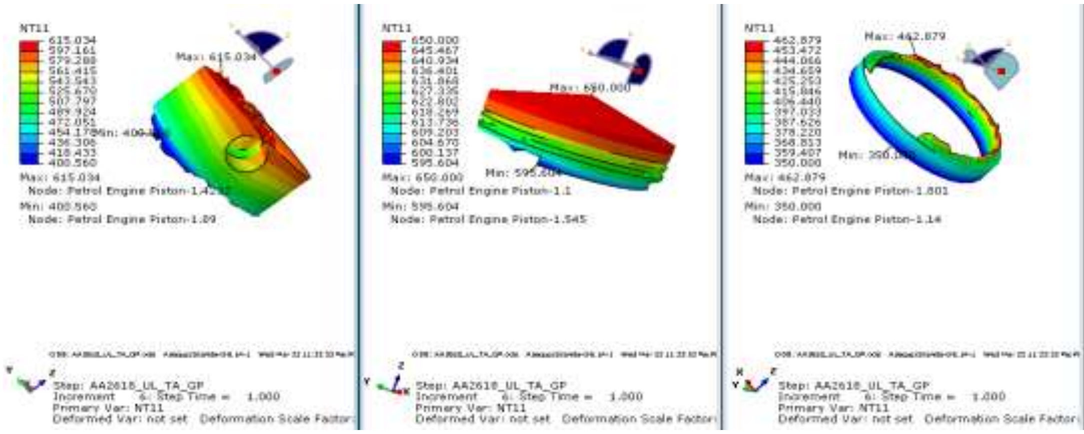

Fig 10: Temperature distribution contours for AA2618 material

5.6 AISI 4340 ALLOY

The result of AISI4340 material for Thermal analysis is given below. The maximum heat flux distribution 141774.078 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 619.045k, 485.860k were obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

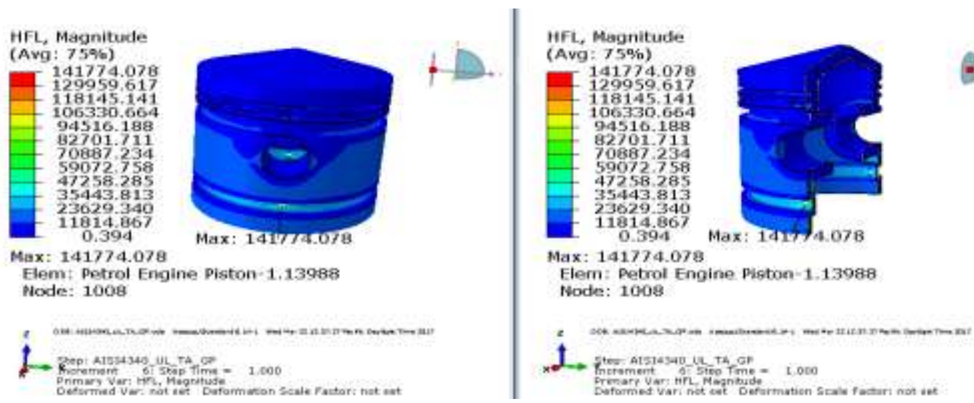

Fig 11 : Heat flux distribution contours for AISI4340 material

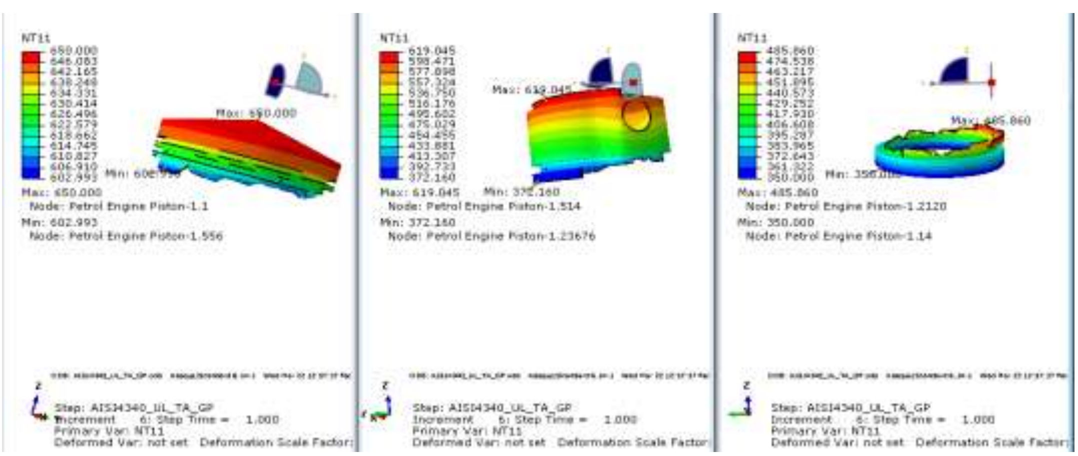

Fig 12: Temperature distribution contours for AISI4340 material

5.7 Ti – 6Al – 4V ALLOY

The result of Ti – 6Al – 4V material for Thermal analysis is given below. The maximum heat flux distribution 301.602 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 623.156k, 462.879k were obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

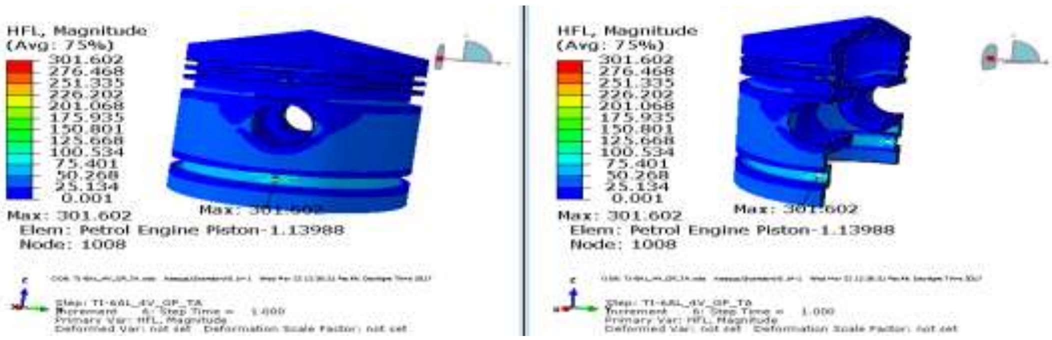

Fig 13: Heat flux distribution contours for Ti – 6Al – 4V material

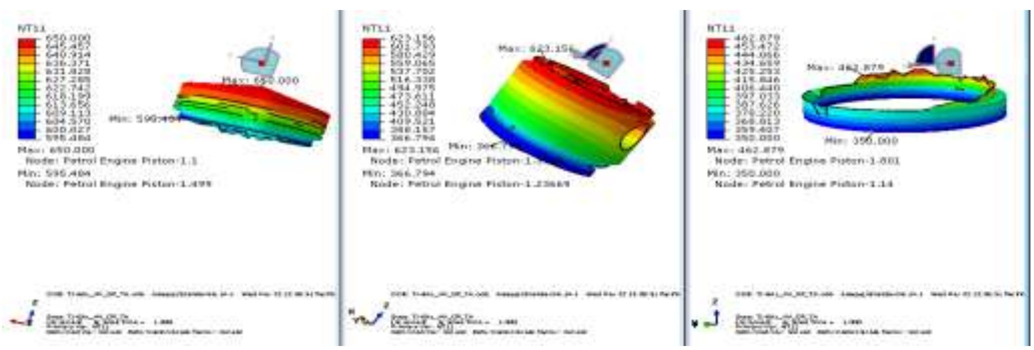

Fig 14: Temperature distribution contours for Ti – 6Al – 4V material

5.8 Model analysis:

Table 2: Model analysis results of gasoline piston

Model Analysis		Gasoline Piston	
S.No	**Material name**	**Displacement (mm)**	**Frequencies (Hz)**
1	AA2618	1.008	2883.9
2	AISI4340	1.008	2761.6
3	Ti – 6Al – 4V	1.008	2698.4

5.9 Thermal analysis:

Table 3: Thermal analysis results of Gasoline Piston

Thermal analysis			Gasoline piston			
S.No	Material Name	Heat flux (350 - 650)	Temperature distribution			
			piston head (Temp)	Oil ring (Temp)	Skirt (Temp)	Below point of piston (Temp)
1	AA 2618	10950	650K	615.034k	462.879k	350k
2	AISI 4340	3337	650K	619.045k	485.86k	350k
3	Ti-6Al-4V	532	650K	623.156k	462.86k	350k

6.0 CONCLUSION

Investigate Thermal and Model Analysis of 4-stoke gasoline Engine Piston by using different Piston materials such as Aluminum Alloy (AA2618 and AA4032), Titanium Alloy (Ti-6Al-4V) and Steel Alloy (AISI 4340) are successfully analyzed.

6.1 Model Analysis:

The result of AA2618 material for Model analysis is given below. The maximum frequency of that material is 2883.9 Hz and maximum displacement is 1.008 mm is attained.

The result of AISI4340 material for Model analysis is given below. The maximum frequency of that material is 2761.6 Hz and maximum displacement is 1.008 mm is attained.

The result of Ti – 6Al – 4Vmaterial for Model analysis is given below. The maximum frequency of that material is 2698.4 Hz and maximum displacement is 1.008 mm is attained.

6.2 Thermal Analysis:

The result of AA2618 material for Thermal analysis is given below. The maximum heat flux distribution 6201.951 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 615.034k, 462.879k are obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

The result of AISI4340 material for Thermal analysis is given below. The maximum heat flux distribution 141774.078 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 619.045k, 485.860k are obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

The result of Ti – 6Al – 4Vmaterial for Thermal analysis is given below. The maximum heat flux distribution 301.602 is obtained. The maximum temperature of 650k is attained at piston head surface and temperature of 623.156k, 462.879k are obtained at oil ring and skirt respectively. The temperature at below piston surface region was 350k.

From observed above three analyzed values of different materials, the Ti -6Al -4V material is best material. In Model Analysis the maximum displacement (1.008), frequencies (2698.4Hz).The Heat Flux Distribution (301.602) and temperature Distributions (350k – 650k) in thermal Analysis is less as compared to other materials.

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