DESIGN AND ANALYSIS OF I.C. ENGINE PISTON AND PISTON-RING ON COMPOSITE MATERIAL USING CREO AND ANSYS SOFTWARE

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Abstract - In this Paper the stress distribution is evaluated on the four stroke engine piston by using FEA. The finite element analysis is performed by using FEA software. The couple field analysis is carried out to calculate stresses and deflection due to thermal loads and gas pressure. These stresses will be calculated for three different materials. The results are compared for all the three materials and the best one is proposed. The materials used in this project are aluminium alloy, silumin and Gray cast iron composite material. In this project the natural frequency and Vibration mode of the piston and rings were also obtained and its vibration characteristics are analyzed. With using computer aided design (CAD), CREO software the structural model of a piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS.

Keywords - Stress distribution, four stroke engine piston, Finite element analysis, Aluminum alloy, Silumin, and Gray cast iron Natural frequency, Vibration mode, Computer aided design (CAD), Ansys.

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1 .INTRODUCTION

Automobile components are in great demand these days because of increased use of automobiles. The increased demand is due to improved performance and reduced cost of these components. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products. 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 and/or connecting rod. As an important part in an engine, 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/crown cracks and so on. The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure. This paper describes the stress distribution on piston of internal combustion engine by using FEA. The FEA is performed by CAD and CAE software. The main objectives are to investigate and analyze the thermal stress and mechanical stress distribution of piston at the real engine condition during combustion process. The paper describes the FEA technique to predict the higher developed. Using ANSYS V14.5 software, simulation and stress analysis is performed

2 LITERTURE REVIEW

An advanced piston which is lighter and more grounded is covered with zirconium for bio-fuel. In this [1], the covered piston experienced a Von miss's test by utilizing ANSYS for burden connected on the best. Examination of the pressure dissemination was done on different pieces of the covered piston for finding the worries because of the gas weight and warm varieties. Von misses pressure is expanded by 16% and redirection is expanded after streamlining. Be that as it may, every one of the parameters are well with in structure thought. Plan, Analysis and enhancement of piston [2] which is more grounded, lighter with least expense and with less time. Since the plan and weight of the piston impact the engine execution. Investigation of the pressure circulation in the different pieces of the piston to know the worries because of the gas weight and warm varieties utilizing with Ansys. With the distinct component examination programming, a three-dimensional unequivocal component investigation [3] has been done to the fuel engine piston.

Considering the warm limit condition, the pressure and the twisting dissemination states of the piston under the coupling impact of the warm burden and blast weight have been determined, hence giving reference to structure improvement. Results demonstrate that, the fundamental driver of the piston wellbeing, the piston disfigurement and the extraordinary pressure is the temperature, so it is achievable to additionally diminish the piston temperature with structure streamlining. This paper [4] includes recreation of a 2-stroke 6S35ME marine diesel engine piston to decide its temperature field, warm, mechanical and coupled warm mechanical pressure. The dispersion and

stress and critical region on the component. With using CREO 2.0 software the structural model of a piston will be

sizes of the up to referenced quality parameters are valuable in plan, disappointment investigation and streamlining of the engine piston. The piston display was created in strong works and brought into ANSYS for preprocessing, stacking and post preparing. Material model picked was 10-hub tetrahedral warm strong 87. The recreation parameters utilized in this piston material, burning weight, inertial impacts and temperature. This work [5] depicts the pressure conveyance of the piston by utilizing limited component strategy (FEM). FEM is performed by utilizing PC supported building (CAE) programming. The principle target of this work is to explore and examine the pressure circulation of piston at the genuine engine condition amid burning procedure.. The report portrays the work streamlining by utilizing FEM procedure to foresee the higher pressure and basic district on the segment. The effect of crown thickness, thickness of barrel and piston top land stature on stress dispersion and complete disfigurement is observed amid the study [6] of real four stroke engine piston. The whole streamlining is completed dependent on measurable investigation FEA examination is done utilizing ANSYS for ideal geometry. This portrays the pressure circulation and warm worries of three distinctive aluminum composites piston by utilizing limited component strategy (FEM). The parameters utilized for the reenactment are working gas weight, temperature and material properties of piston.

Temperature estimations in an inside ignition (IC) engine give fundamental data that can be utilized in the investigation and plan of engine segments. The investigation of piston surface temperatures is of specific significance because of the impact this variable has on both segment/engine life and burning amid an engine cycle. Because of the immediate connection among temperature and the productivity of an engine, the investigation of warmth exchange and warm stacking in engine segments is an essential region of center in sparkle start (SI) engine research as planners endeavor to accomplish higher engine temperatures while limiting the unfavorable impacts on parts. This information likewise assumes a job in investigation of the ignition procedure, since engine thump and the development of carbon stores and toxins as NOx, for instance, are affected by piston surface temperatures [7-9]. In this manner, the capacity to gauge piston surface temperatures is essential for the long haul advancement of better plans at it takes into account a clearer comprehension of engine behavior's.

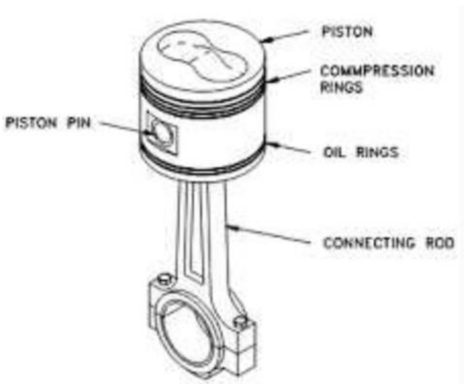


Fig 1:.labeled image of a piston.

3 PISTON MATERIALS AND MANUFACTURING PROCESS

Following materials are used for I.C. Engines pistons: Cast iron, Cast Aluminum, cast steel and forged aluminum. The material used for piston is mainly aluminum alloy. Aluminum pistons can be either cast of forged. In early years cast iron was almost universal material for pistons because it possess excellent wearing qualities, coefficient of expansion and genera suitability in manufacture. But due to reduction of weight in reciprocating parts, the use of aluminum for piston was essential. To obtain equal strength a greater thickness of metal is necessary. But some of the advantages of the light metal is lost. Aluminium is inferior to cast iron in strength and wearing qualities, and its greater coefficient of expansion necessities greater clearance in the cylinder to avoid the risk of seizure. The heat conductivity of aluminium is about thrice that of cast iron this combined with the greater thickness necessary for strength, enables and aluminum alloy piston to run at much lower temperature than a cast iron as a result carbonized oil doesn't form on the underside of the piston, and the crank case therefore keeps cleaner. This cool running property of aluminium is now recognized as being quite as valuable as its lightness. Indeed; piston are sometimes made thicker than necessary for strength in order to give improved cooling

4. Problem Definition and Methodology

In this paper the stress distribution is evaluated on the four stroke engine piston by using FEA. The finite element analysis is performed by using FEA software. The couple field analysis is carried out to calculate stresses and deflection due to thermal loads and gas pressure. The materials used in this project are aluminium alloy and silumin and gray cast iron composite material. In this project the natural frequency and Vibration mode of the piston were also obtained and its vibration characteristics are analyzed. With using computer aided design (CAD), UNI-GRAPHICS software the structural model of a piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS.

The methodology used for doing the analysis is as follows:

- Develop a 3D model from the available 2D drawings of the Piston.
- The 3D model is created using CREO 2.0 software
- The 3D model is converted into Para solid and imported into ANSYS to do couple field analysis.
- The thermal analysis is performed on the piston model with the heat of (160°C-200°C) for Aluminum alloy material.
- Temperature distribution is plotted from the thermal analysis for Aluminum alloy material.
- Structural analysis is performed by applying temperature distribution from the thermal analysis as body loads and working pressure of 3.3Mpa to find the stress distribution due to thermal and structural loads for Aluminum alloy material.

- Plot deflections and stresses for the piston from the above analysis.
- The above analysis is repeated for Silumin composite material.
- Perform modal analysis for all the 2 materials.
- Compare the results for all the 2 materials.

5. MODELING AND ANALYSIS PISTON DESING

The piston is designed according to the procedure and specification which are given in machine design and data hand books. The dimensions are calculated in terms of SI Units. The pressure applied on piston head, temperatures of various areas of the piston, heat flow, stresses, strains, length, diameter of piston and hole, thicknesses, etc., parameters are taken into consideration .

A. DESIGN CONSIDERATIONS FOR A PISTON

- In designing a piston for an engine, the following points should be taken into consideration:
- It should have enormous strength to withstand the high pressure.
- It should have minimum weight to withstand the inertia forces.
- It should form effective oil sealing in the cylinder.
- It should provide sufficient bearing area to prevent undue wear.
- It should have high speed reciprocation without noise.
- It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
- It should have sufficient support for the piston pin.

B. ASSUMPTIONS MADE

It is very difficult to exactly model the piston, in which there are still researches are going on to find out transient thermo elastic behavior of piston during combustion process. There is always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling.

1. The assumptions which are made while modeling the process are given below:-
2. The piston material is considered as homogeneous and isotropic.
3. Inertia and body force effects are negligible during the analysis.
4. The piston is stress free before the application of analysis.
5. The analysis is based on pure thermal loading and thus only stress level due to the above said is done the analysis does not determine the life of the piston.
6. Only ambient air-cooling is taken into account and no forced Convection is taken.
7. The thermal conductivity of the material used for the analysis is uniform throughout.
8. The specific heat of the material used is constant throughout and does not change with temperature.

C. THE PISTON MODEL

The following are the sequence of steps in which the piston is modeled.

- Drawing a half portion of piston.
- Exiting the sketcher.
- Developing the model.
- Creating a hole.

6. PROPERTIES OF MATERIAL

The materials chosen for this work are Aluminum alloy, Sliumin and Gray cast iron. Testing processes that are done on the piston as well as on piston rings by using three different materials for both piston as well as ring. Two types of analysis have been discussed one static analysis and thermal analysis. The mechanical properties of materials are listed in the following table 6.1.

6.1: MATERIAL PROPERTIES

PROPERTIES	ALUMINIUM	SILUMIN	GRAY CAST IRON
DENSITY (Kg/m^{-3})	**2770**	**2659**	**7200**
POISSION RATIO	**0.33**	**0.27**	**0.28**
YOUNGS MODULUS(Pa)	**7.1E+10**	**3.17E+11**	**1.1E+11**

Table 6. 1: Material properties.

6.2 STATIC ANALYSIS ON PISTON

The static analysis for the piston was done by finite elements method using ANSYS software. For ANSYS simulation the solid works geometry is separated into elements. In this elements are interlinked to one another at a point called as Node. In present examination work we have used FEA for the Thermal and Structural analysis of piston solid works Software is used to prepare the piston. After completing solid works modeling, the model is saved in IGES file then IGES file is imported to ANSYS software for the finite element analysis.

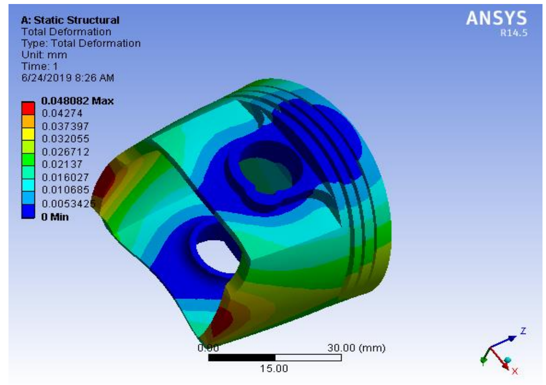


Fig 6.2.1: Total Deformation on piston AL alloy.

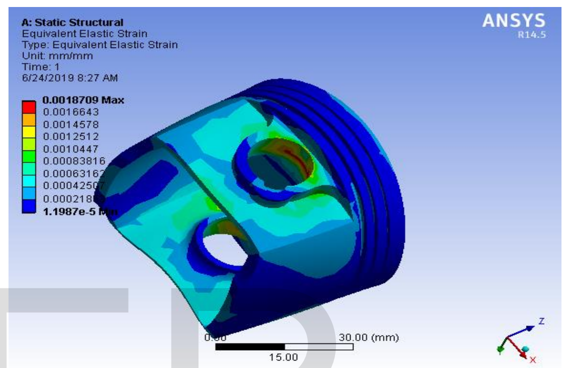


Fig 6.2.2: Equivalent strain on piston AL alloy.

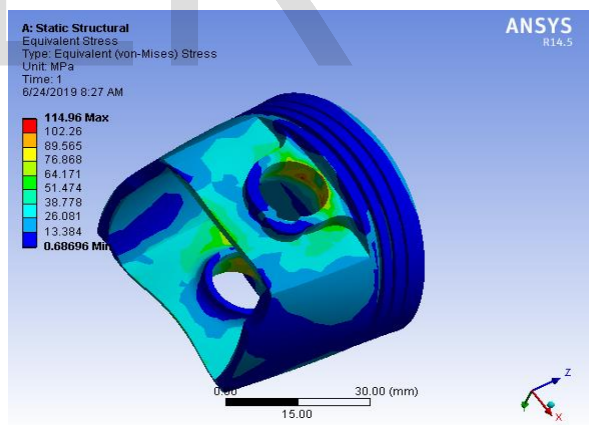


Fig 6.2.3: Equivalent stress on piston AL alloy.

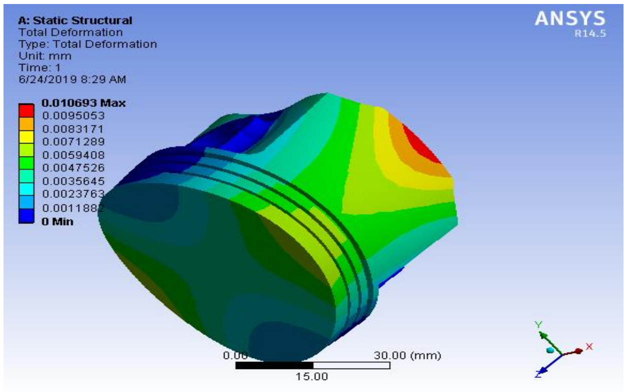


Fig 6.2.4: Total Deformation on piston Silumin alloy.

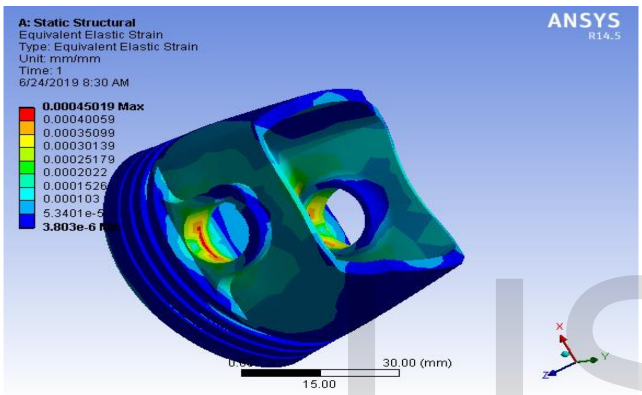


Fig 6.2.5: Equivalent strain on piston silumin alloy.

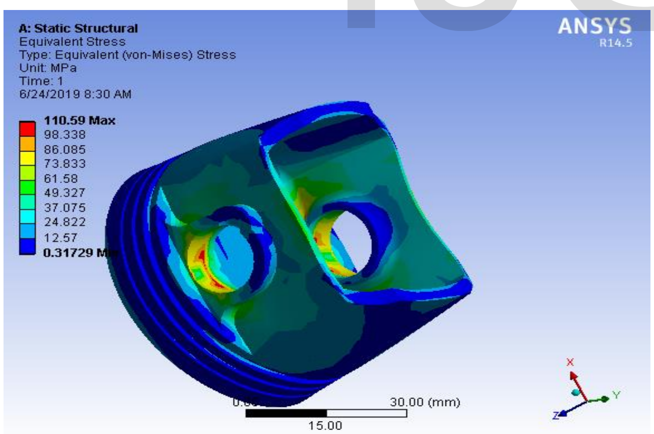


Fig 6.2.6: Equivalent stress on piston silumin alloy.

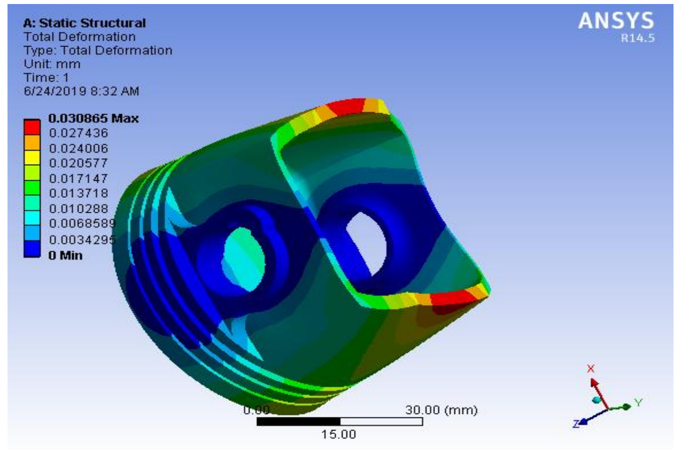


Fig 6.2.7: Total Deformation on piston Gray Cast Iron.

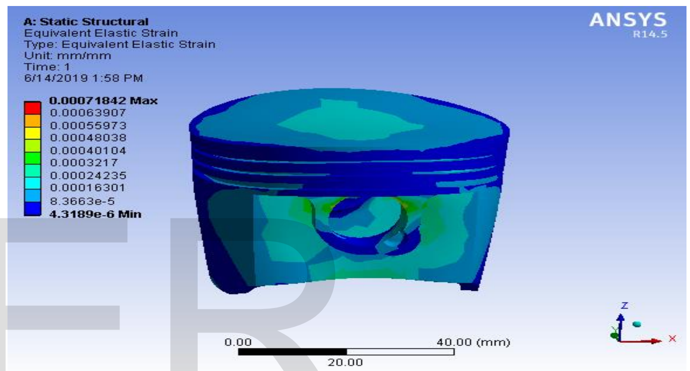


Fig 6.2.8: Equivalent strain on piston gray cast iron.

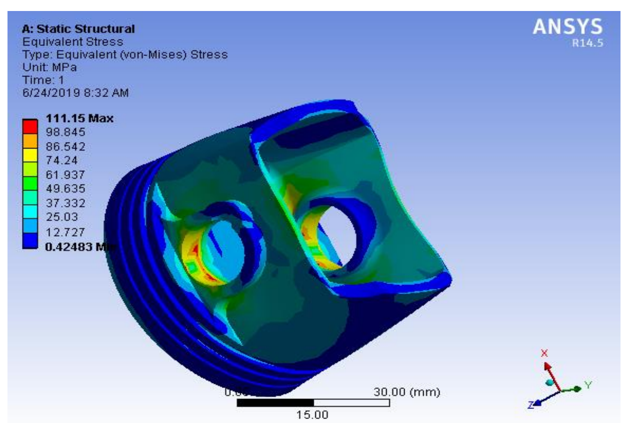
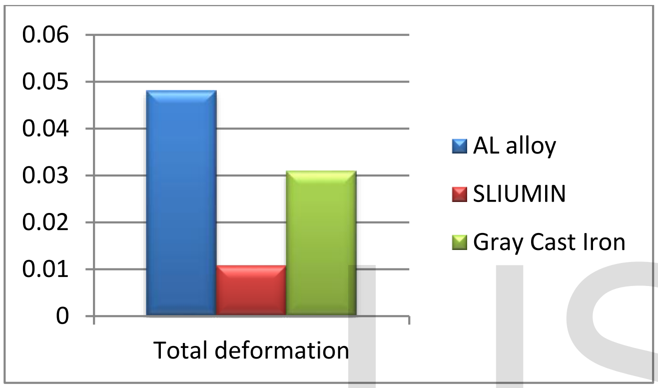


Fig 6.2.9: Equivalent stress on piston Gray Cast Iron.

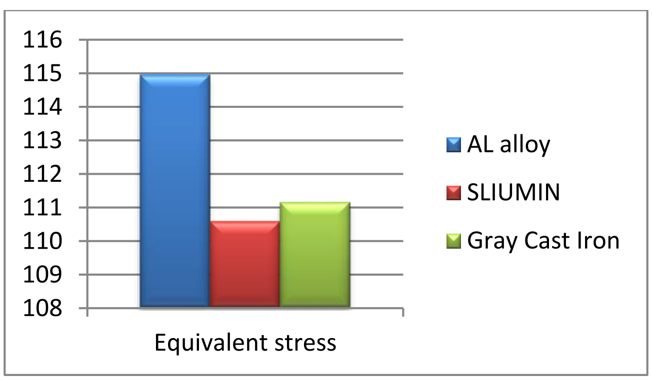
Table 6.2.1: Results of static analysis on piston.

STATIC ANALYSIS	AL alloy	SLIUMIN	Gray Cast

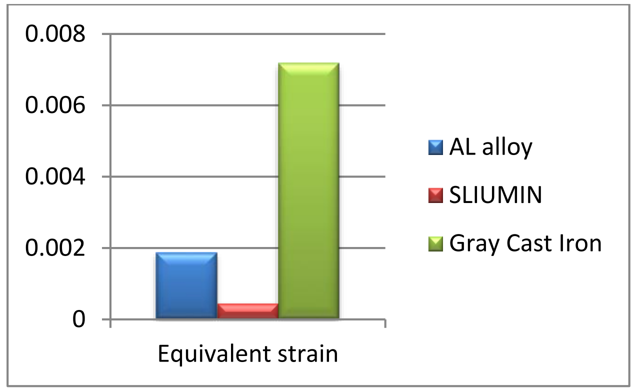
				Iron
Total deformation		0.048082	0.010693	0.030865
Equivalent stress	**Max**	114.96	110.59	111.15
Equivalent strain	**Max**	0.001870	0.0004501	0.0071842



Graph 6.2 (a): Total Deformation values of three different materials.



Graph 6.2 (b): Maximum stress values of three different materials.



Graph 6.2 (c): Maximum Equivalent Strain of three different materials.

6.3 PISTON RINGS

Piston rings are utilized on pistons to keep up gastight seals between the pistons and pistons, to help in cooling the piston and to control piston divider oil Piston rings are of two unmistakable characterizations: pressure rings and oil control rings.

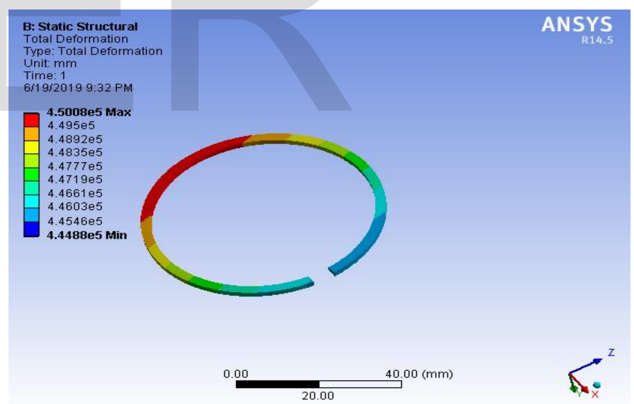


Fig 6.3.1: Total Deformation on AL alloy.

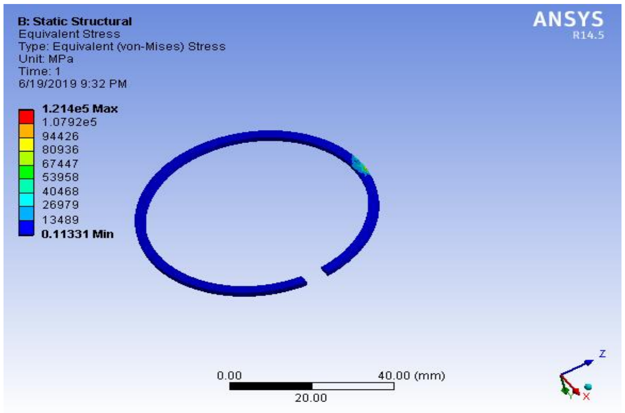


Fig 6.3.2: Equivalent stress on AL alloy.

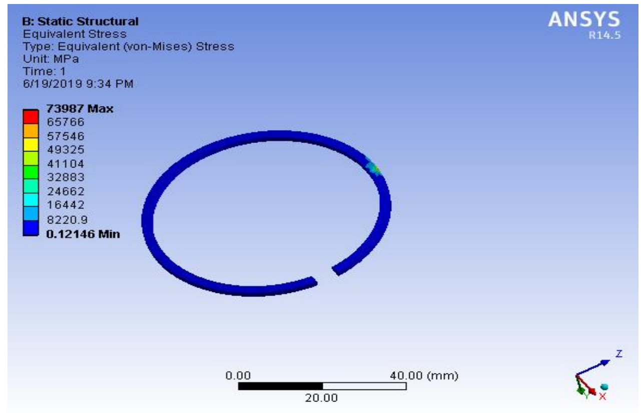


Fig 6.3.5: Equivalent stress on silumin.

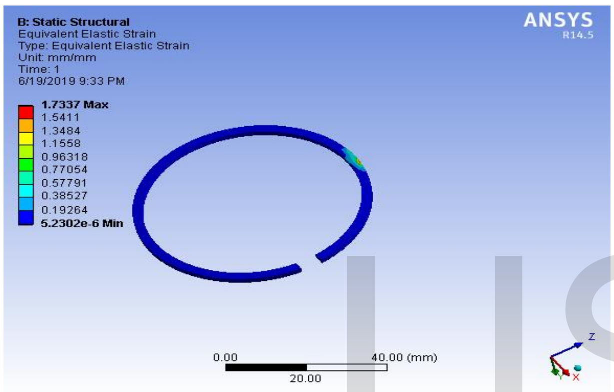


Fig 6.3.3: Equivalent strain on AL alloy.

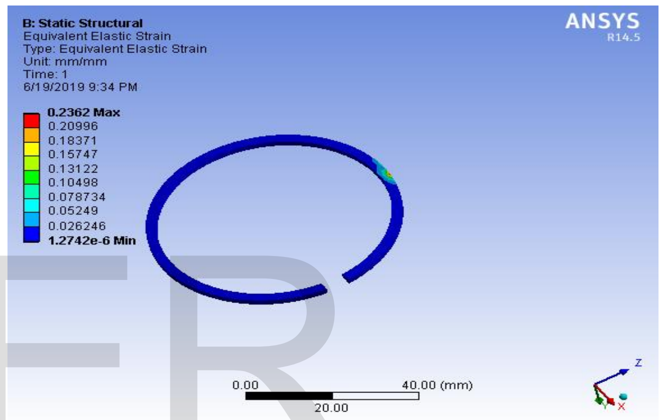


Fig 6.3.6: Equivalent strain on silumin.

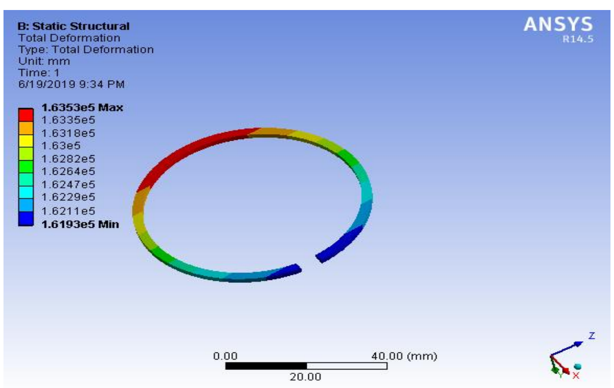


Fig 6.3.4: Total Deformation on Silumin.

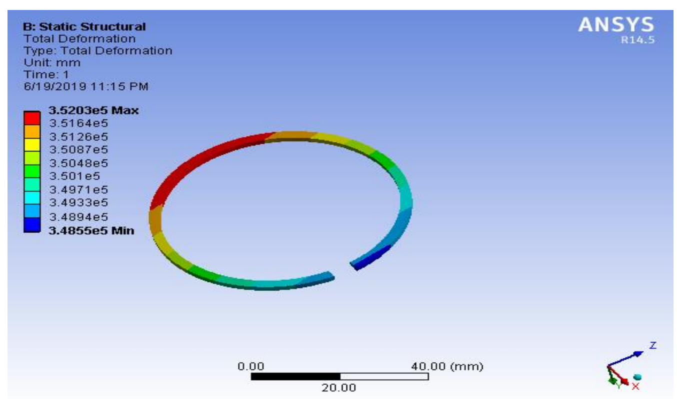


Fig 6.3.7: Total deformation on Gray Cast iron.

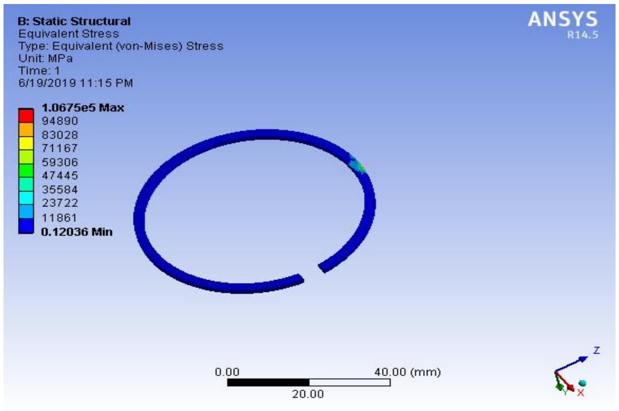


Fig 6.3.8: Equivalent stress on Gray Cast Iron.

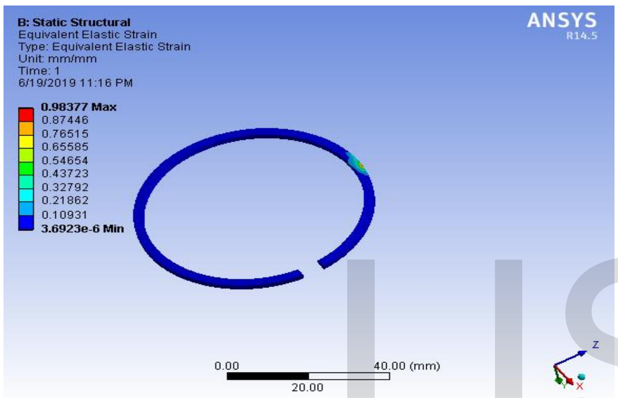
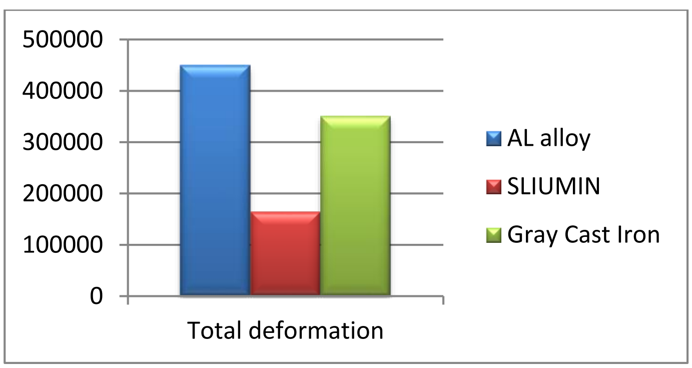


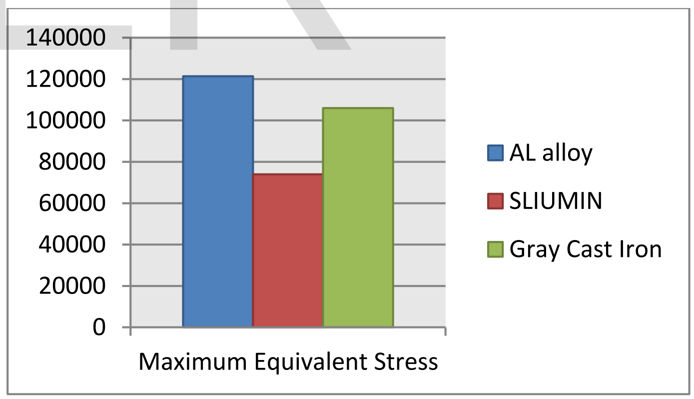
Fig 6.3.9: Equivalent strain on Gray Cast Iron.

Table 6.3.1: Results of Static Analysis on piston rings

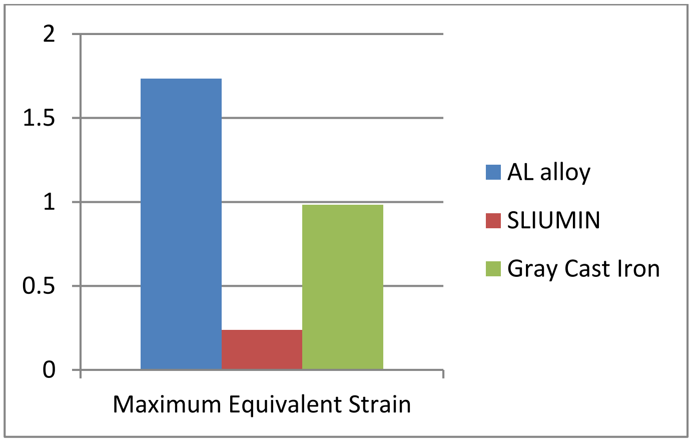
STATIC ANALYSIS		AL alloy	SLIUMIN	Gray Cast Iron
Total deformation		$4.5x10^5$	$1.6353x10^5$	$3.5x10^5$
Equivalent stress	Min	0.11331	0.12146	0.12036
	Max	$1.214x10^5$	$7.3987x10^4$	$1.06x10^5$
Equivalent strain	Min	$5.23x10^{-6}$	$1.2742x10^{-6}$	$3.69x10^{-6}$
	Max	1.7337	0.2362	0.98377



Graph 6.3.1: Total deformation of Piston rings on three different materials.



Graph 6.3.2: Maximum Equivalent Stress of Piston rings on three different materials.



Graph 6.3.3: Maximum Equivalent Strain of Piston rings on three different.

5.4 THERMAL ANALYSIS ON PISTON

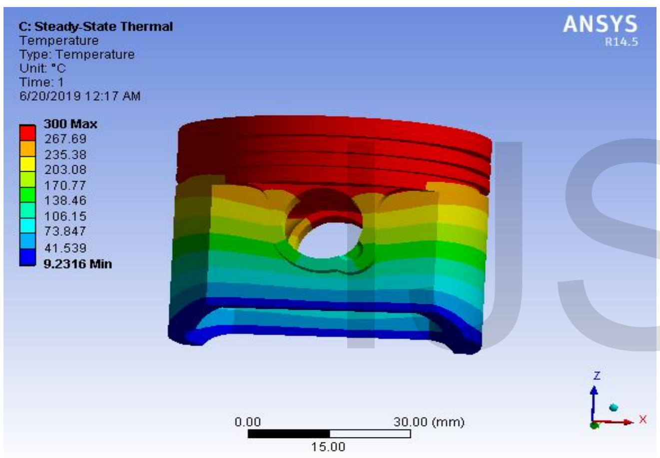


Fig 5.4.1: Temperature on AL alloy.

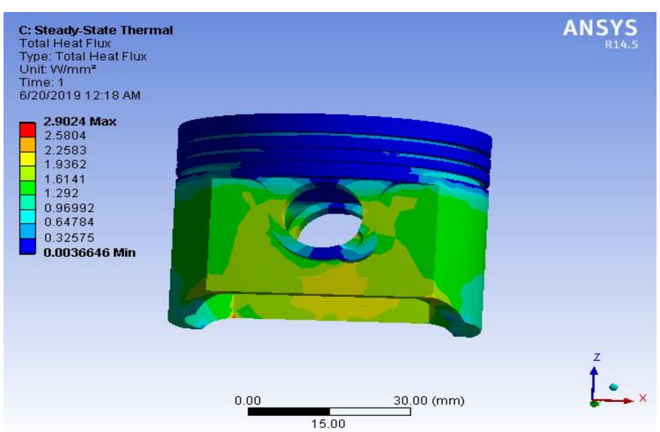


Fig 6.4.2: Total Heat flux on AL alloy.

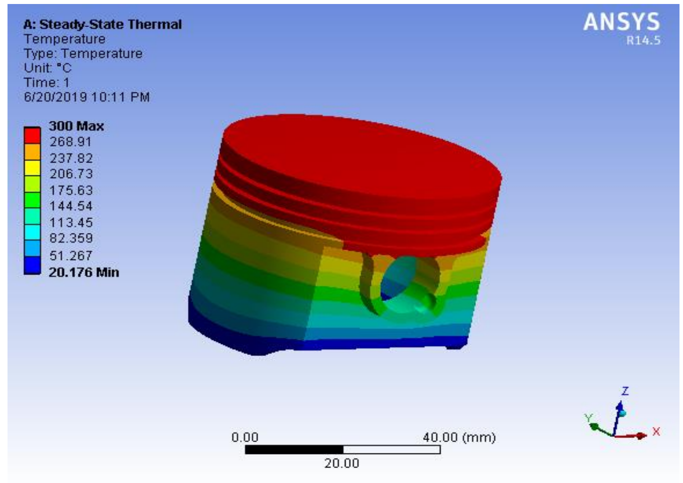


Fig 6.4.3: Temperature on Sliumin alloy.

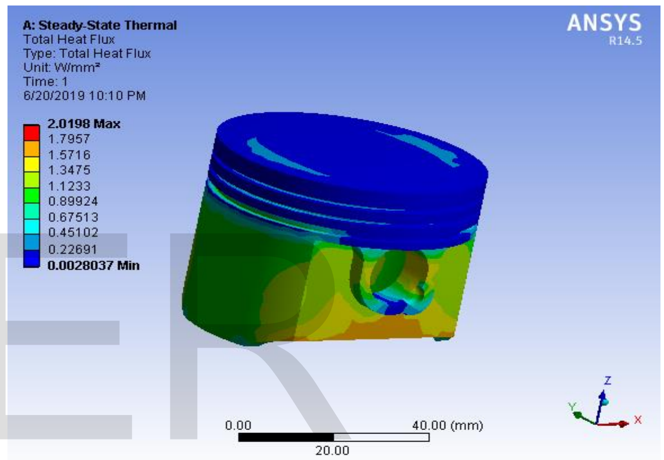


Fig 6.4.4: Total Heat flux on Silumin.

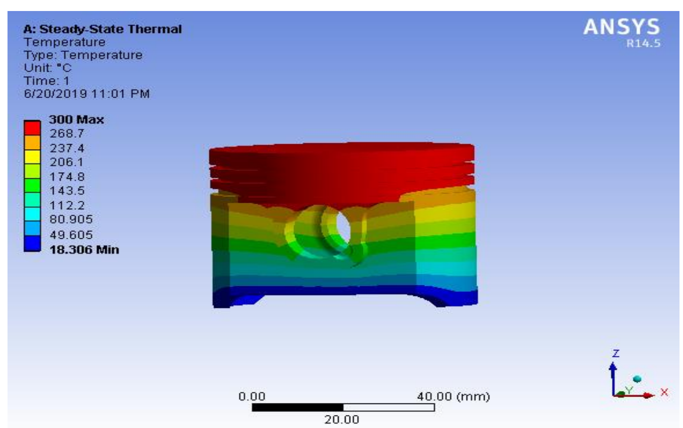


Fig 6.4.5: Temperature on Gray Cast Iron.

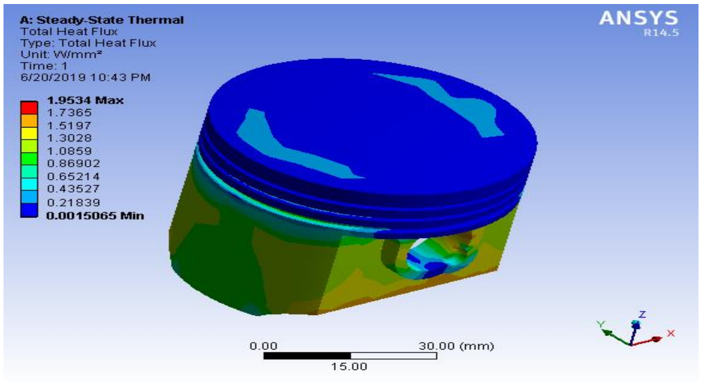
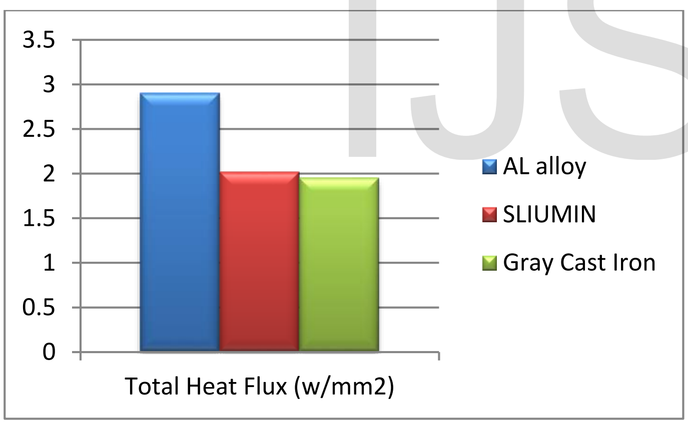


Fig 6.4.6: Total Heat flux on Gray Cast iron.

6.4.1: Results of thermal analysis on piston.

THERMAL ANALYSIS	AL alloy	SLIUMIN	Gray Cast Iron
Total Heat Flux (w/mm^2)	2.9024	2.0198	1.9534



Graph 6.4.1: Total heat flux of three materials.

6.5 THERMAL ANALYSIS PISTON RINGS

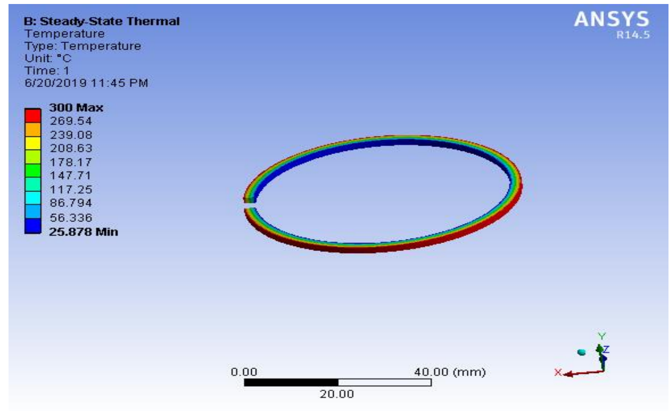


Fig 6.5.1: Temperature on AL alloy.

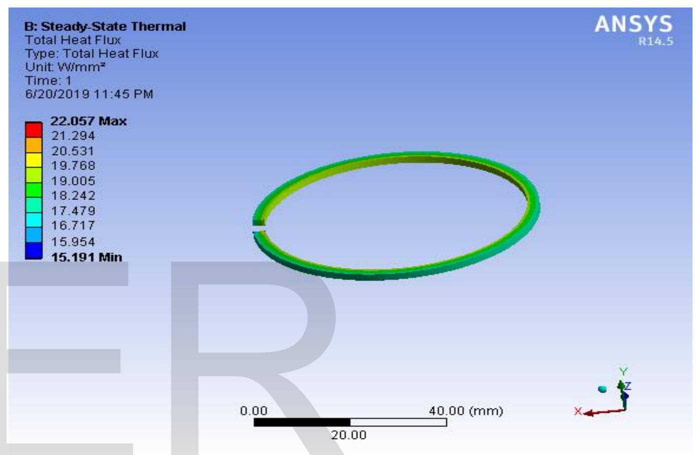


Fig 6.5.2: Heat flux on AL alloy.

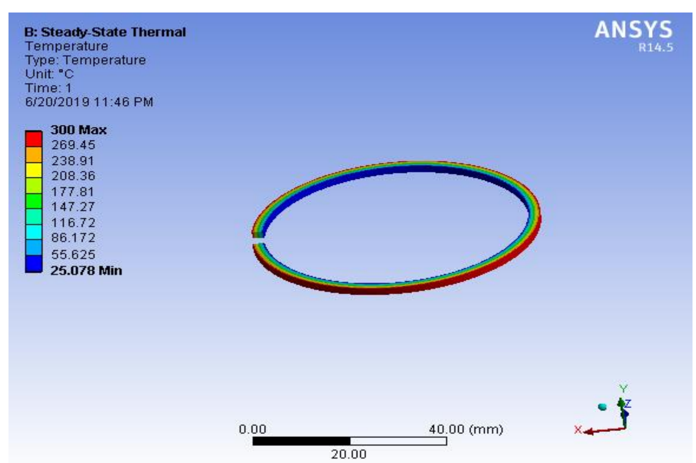


Fig 6.5.3: Temperature on Silumin.

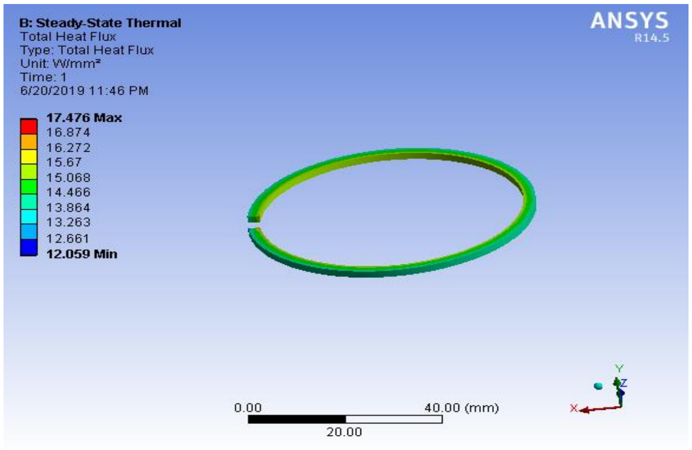


Fig 6.5.4: Heat flux on Silumin.

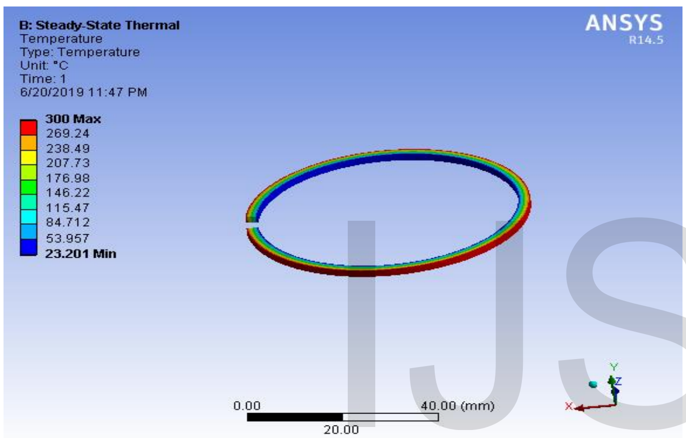


Fig 6.5.5: Temperature on Gray Cast Iron.

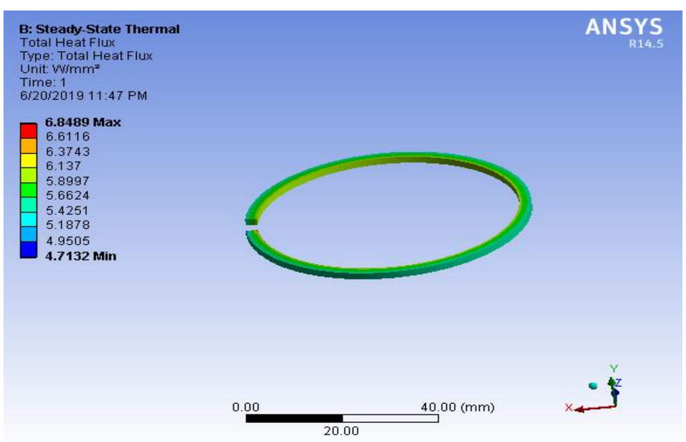
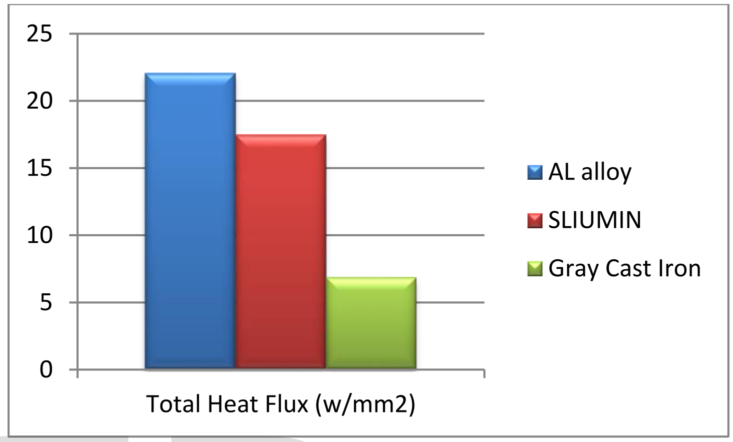


Fig 6.5.6: Heat flux on Gray Cast Iron.

6.5: Results of thermal analysis on piston rings

THERMAL ANALYSIS	AL alloy	SLIUMIN	Gray Cast Iron
Total Heat Flux (w/mm^2)	22.057	17.476	6.8489



Graph 5.5: Total heat flux of three different materials.

6.6. COMPRASION WITH THE EXISTING WORK

1. The comparison is between the proposed and existing work on the basis of thermal analysis (heat flux) of materials AL alloy and Gray cast iron of piston

S .NO	MATERIALS	Existing work (heat flux)	Proposed work (heat flux)
1	AL ALLOY	0.55471	2.9024
2	Gray Cast Iron	1.8145	2.0198

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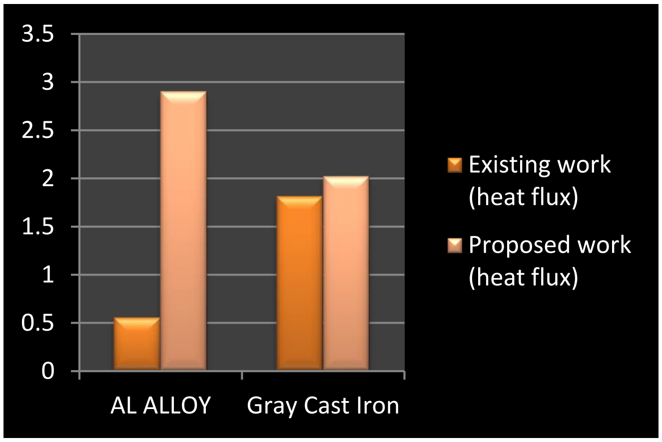
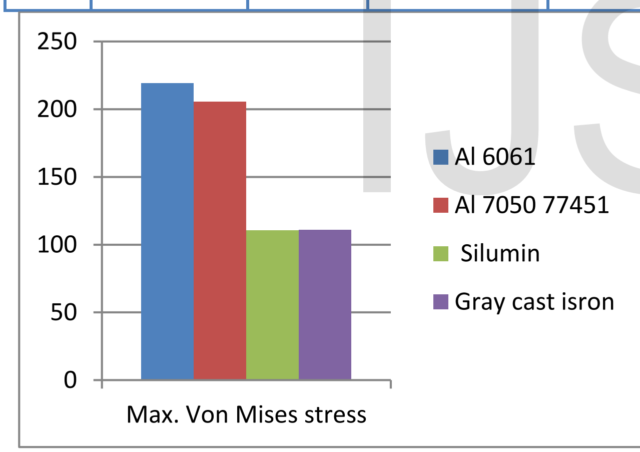
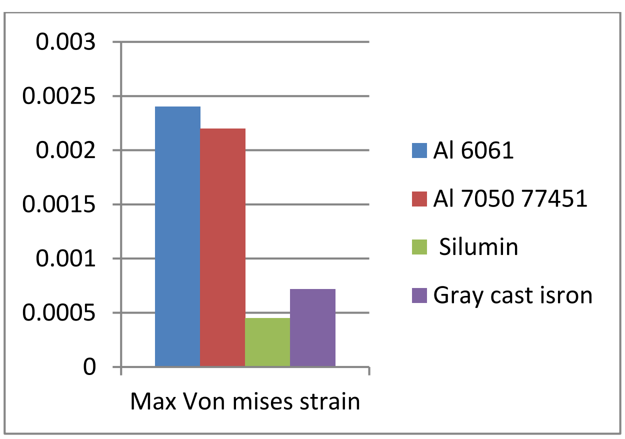


2. COMPARISION WITH THE EXISTING WOERK ON THE BASIS OF STATIC STRUCTURAL ANALYSIS

S.NO	Parameter	Al 6061	Silumin	Gray cast iron
1	Max. Von Mises stress	219.2	110.59	111.15
2	Max Von mises strain	0.0024	0.00045019	0.000718
3	Max Deformation	0.1557	0.010693	0.030865



Graph 6.6.1: Max stress comparison with existing work.



Graph 6.6.2: Max strain comparison with existing work.

7. Results and Discussion

Piston:

Static analysis

Above table 6.2.1 shows the variation between the materials aluminium, Silumin, cast iron and aluminium when we applied 8MPa pressure on piston. Static analysis between, Silumin, cast iron and Al alloy piston we can say the strength and energy of existing model has been decreased by material change but by changing material from al alloy to cast iron to Silumin we may reduce the stress and it has been decrease from 114.96Mpa to 111.15Mpa to 110.59Mpa . From this we can say this material is good.

Piston ring:

Above table6.3.1 shows the variation between the materials Silumin, cast iron and aluminium when we applied 8MPa pressure on piston ring

Static analysis between al alloy to Silumin to cast iron piston ring we can say the strength and energy of existing model has been decreased by material change but by changing material from Silumin to al alloy to cast iron we may reduce the stress and it has been decrease from $7.3987x10^4$ to $1.214x10^5$ to $1.06x10^5$ From this we can say this material is good.

8. CONCLUSION

Based on the above testing results the design of piston and piston rings is done in Solid works and for static analysis and thermal analysis is done in ANSYS software 14.5. The design file is converted into IGS format and thus imported into ANSYS. For static structural the pressure on the piston top is applied as a magnitude of 8MPa with three different materials in ansys workbench.

From the above tests the results of total deformation, stress and strain are tabulated and thus compared graphically. The thermal analysis is carried at a temperature of 300 deg on both piston as well as rings

For the above three materials. The temperature and total heat flux of three different materials are tabulated and compared. The results are also compared with the existing system on the basis of thermal analysis. In future for the betterment of results, the design and materials properties can change. For the further work, the constraint condition of the piston pin can be improved much more better, hoped that it can be closer to the real situation of piston. And in the conditions allow, the experimental approach can be used to determine the convection coefficient of the piston to get the realistic temperature field

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