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Design And Analysis Of Piston and Piston rings with Cast iron, Aluminium alloy And Cast steel materials

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Abstract

The goal of this project is to determine both temperature and thermal stress distributions in piston and piston rings crown to improve the Thermal efficiency of a diesel engine thickness on temperature and thermal stress distributions are investigated piston and and piston rings by means of both static and thermal analysis., designing with Creo software.The main objective piston is investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process, in this process We applied temperature and convection as and we determining total temperature on the body, total heat flux, heat flux in x,y,z directions respectively And this piston also having less stress(173.82 MPa) and good safety factor 1.6102. and the thermal heat flux also less other material cast iron and cast steel.piston and piston rings using thermal analysis and static analysis applied the temperature, pressure difference material like al alloy,cast iron and cast steel

Keywords: Temperature, stress, FEA Analysis, Piston and piston rings crown temperature etc

1.Introduction

The demand for energy is increasing day by day. The world is depending mostly on fossil fuels to face this energy needs. The increase in standard of living demands better mode of transport, hence a large number of automobile companies has been introduced. Automobiles provide better transport but the combustion of fuel in automobile engine creates harmful effluents, which has an adverse effect on water and air.Combustion generated pollution is by far the largest man made contribution to atmospheric pollution. The principal pollutants emitted by the automobile engines are CO, NOX, HC and particulates. The modern day automobiles is a result of several technological improvements that have happened over the years and would continue to do so to meet the performance demands of Exhaust-Gas Emissions, Fuel Consumption, Power Output, Convenience and Safety.In order to reduce emissions and increasing engine performance, modern car engines carefully designed to control the amount.

1.1Piston:

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. 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. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall. A piston ring is a split ring that fits into a groove on the outer diameter of a piston in a reciprocating engine such as an internal combustion engine or steam engine

2. Literature Survey

Ravinder Reddy P., Ramamurthy G., "Computer Aided Analysis of Thermally Air Gap Insulated Pistons made of Composites", National Conference on Machines and Mechanisms (NACOMM-95), pp. 177-180, Jan 20-21, 1995, CMERI, Durgapur Ravinder Reddy Pinninti [1] has investigated to determine both temperature and thermal stress distributions in a plasmasprayed magnesia-stabilized

Ekrem Buyukkaya [7], Muhammet Cerit [6] et al (2007) has investigated a conventional (uncoated) diesel piston, made of aluminum silicon alloy and steel. He has performed thermal analyses on pistons, coated with MgO–ZrO2 material by means of using a commercial code, namely ANSYS. Finally, the results of four different pistons are compared with each other. The effects of coatings on the thermal behaviors of the pistons are investigated.

Bala Showry A.V.S[2] et al, 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.the definite-element analysis software, a three-dimensional definiteelement analysis 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 it is feasible to further decrease the piston temperature withtructure optimization.

U.I Siodin[18] et al,study for wear interaction between piston and piston ringgroove in radial piston ringThis paper [] 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

Design of piston:

The piston and piston rings are designed according to procedures and specifications given in machine design and design data book. Dimensions are calculated and these are used for modeling the piston and piston ring in CATIA V5R20 as shown in Fig 1and Fig 2 Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

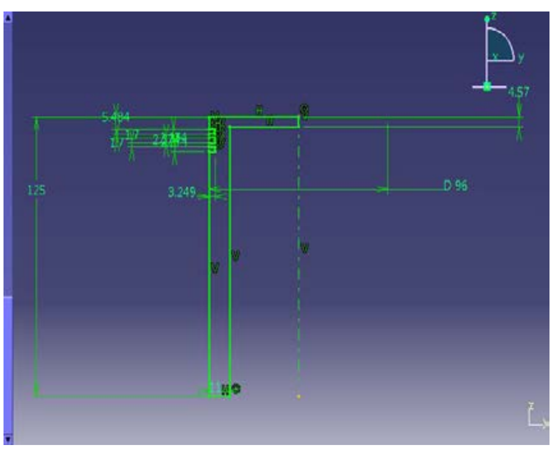

Fig.2.1Piston Drawing and Dimension

These were then imported to ANSYS 14.5 for structural and thermal analysis. Structural analysis of piston is performed on ANSYS 14.5 mechanical APDL and thermal analysis is performed on ANSYS 14.5 workbench. at pin hole. So whatever the load is applying on piston due to gas explosion that force causes to failure of piston pin.

Design of piston rings:

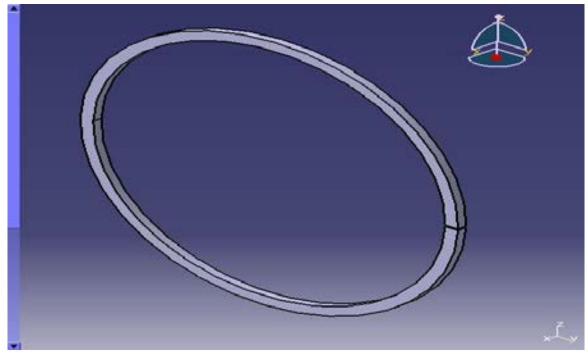

Fig. 2.2Three D piston ring

These were then imported to ANSYS 14.5 for structural and thermal analysis. Structural analysis of piston is performed on ANSYS 14.5 mechanical APDL and thermal analysis is performed on ANSYS 14.5 workbench. Static and thermal analysis piston ring performed on ANSYS 14.5 workbench.at pin hole. So whatever the load is applying on piston ring due to gas explosion that force causeto failure of piston ring pi

3. Methods for Design & Analysis to Develop the Work

3.1CREO:

Computer aided design (cad) is defined as any activity that involves the effective use of the computer to create, modify, analyze, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as cad system. The term CAD/CAM system is also used if it supports manufacturing as well as design applications.

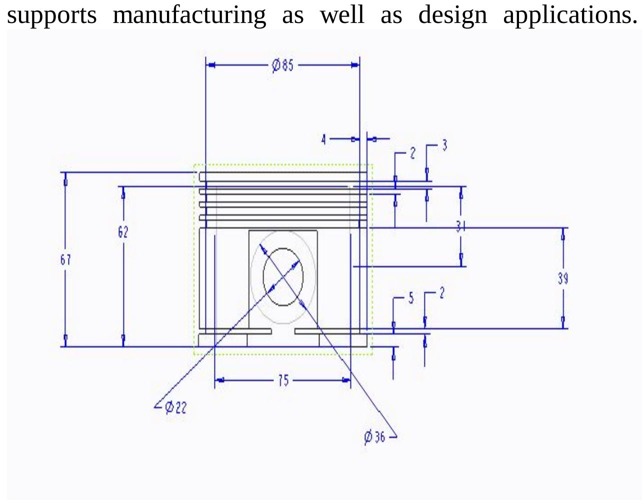

Fig: 3.1 Design Parameters of Piston

3.2 ANSYS:

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them. all creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

4.ANALYSIS

The goal of this project is to determine both temperature and thermal stress distributions of different materials like al alloy,cast iron,cast steel piston and piston rings crown to improve the Thermal efficiency of a diesel engine.Comparisons with results from piston and piston ring by means of both Static and Thermal analysis Using CREO and ANSYS.

Piston

Static analysis: Al alloy

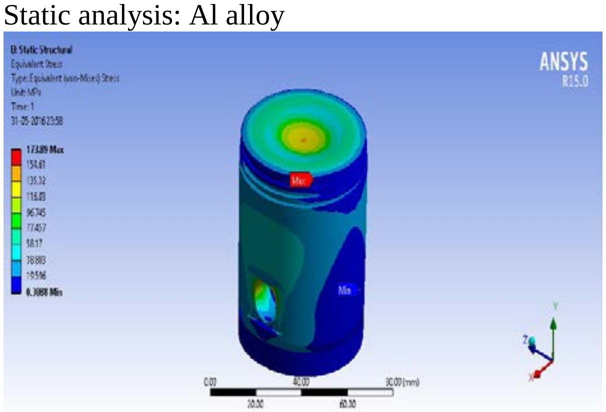

Fig4.11: static analys for Al alloy material for stress

Above fig shows we applied pressure 15mpa top of the surface then exciting the material al alloy piston crown, it produced 173.89 of stress

Cast iron

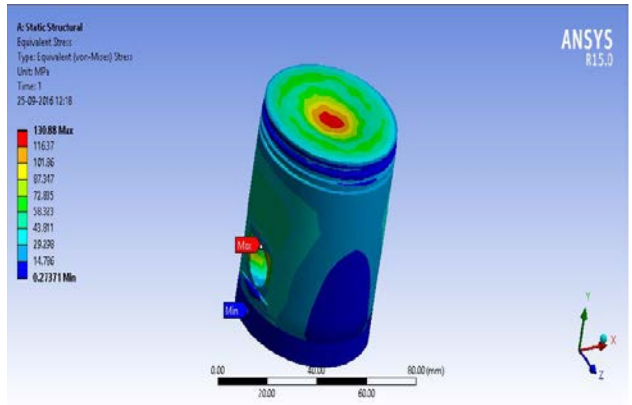

Fig 4.15:static analysis for cast iron

Above fig shows we applied pressure 6mpa on top of the surface of the exciting the material cast steel crown ,it produce130.88 of stress

Cast steel

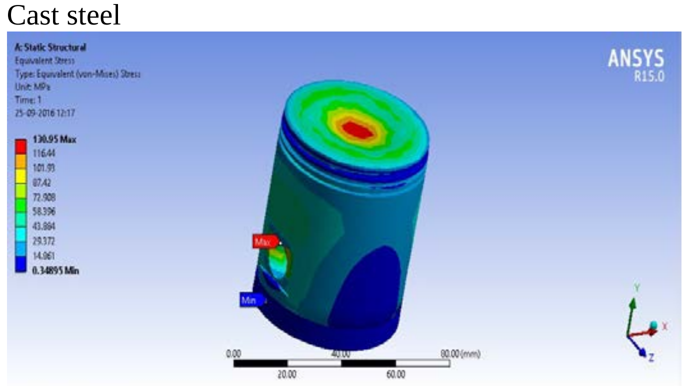

Fig 4.18: static analysis for cast steel stress

Above fig we shows applied pressure 6mpa on the surface of the exciting the material cast steel crown, it produce 130.96 of stress

Piston ring

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Static analys:al alloy

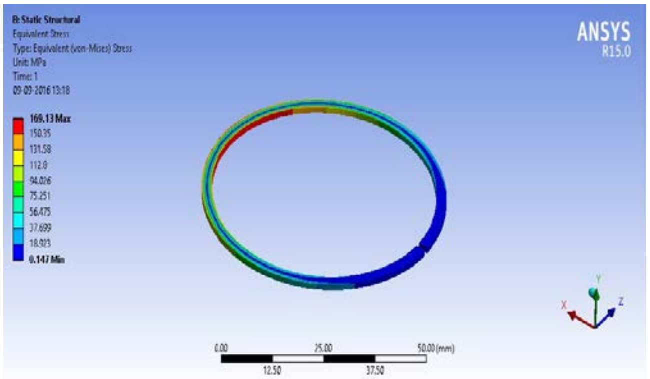


Fig4.31: static analysis for Al alloy for stress

Above fig shows we applied force 3.567N surface of the exciting the material al alloy piston ring crown it produce 169.13 of stress

Cast steel

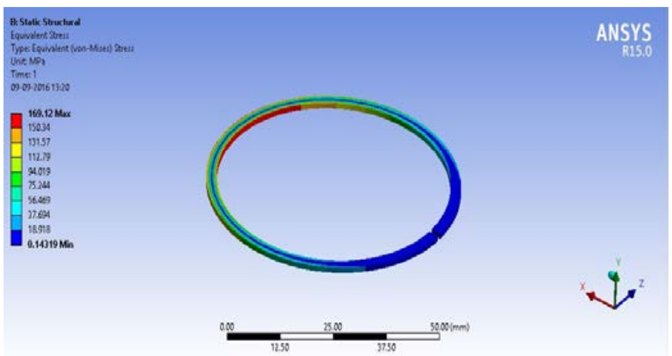
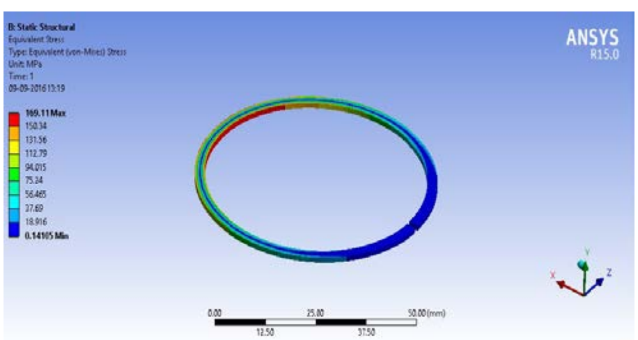


Fig 4.23: static analysis for cast steel stress

Above fig shows we applied the force 3.567surface of the exciting the material cast steel piston ring crown it produce 169.12 of stress

Cast iron



4.27:static analysis for cast iron stress

Above fig shows we applied force3.567N surface of the cast iron piston ring crown, it produce 169.11 of stress

Piston

Thermal Analysis :cast steel

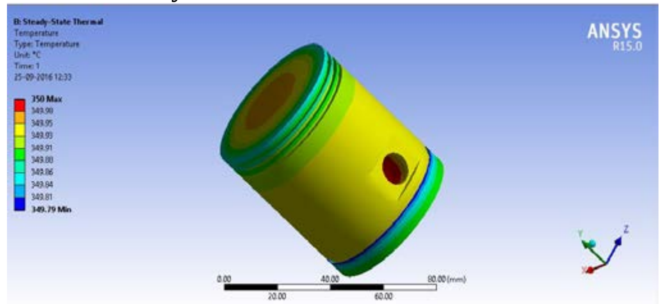


Fig 4.46 thermal analysis for cast steel total temperature

Above fig shows we applied bulk temperature 22^0c and film coefficient 1.24w/m^2* surface of the material cast steel piston crown, it produce 350^0c total temperature

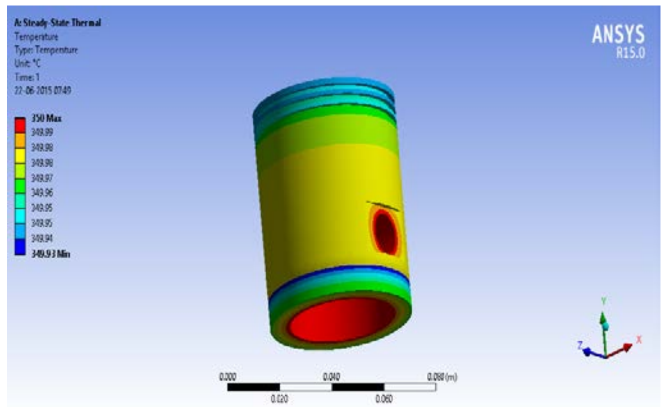


Fig4.36: thermal analysis for al alloy applied temperature

Above fig shows we applied temperature surface of the material al alloy 22^0c then produce 350 of total tempertature

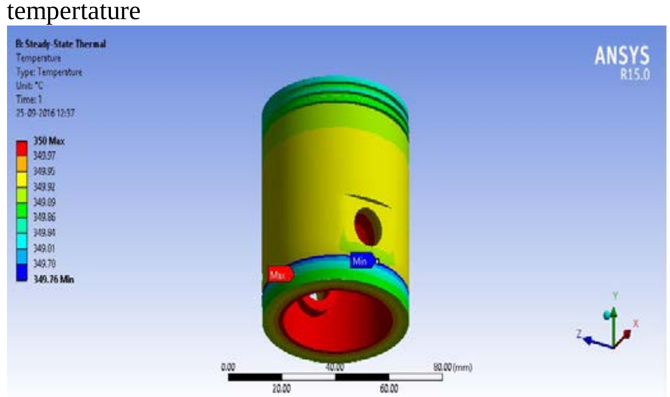


Fig 4.41:thermal analysis for cast iron for cast iron

Above fig shows we applied 22^0c bulk temperature of the surface cast iron

Piston ring:cast iron

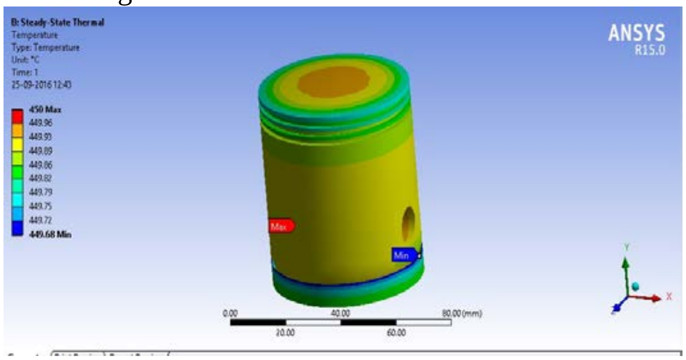


Fig4.57:thermal analysis for cast iron fo temperature

Above fig shows we applied temperature surface of the exciting material cast iron piston ring crown it produce temperature

Cast steel

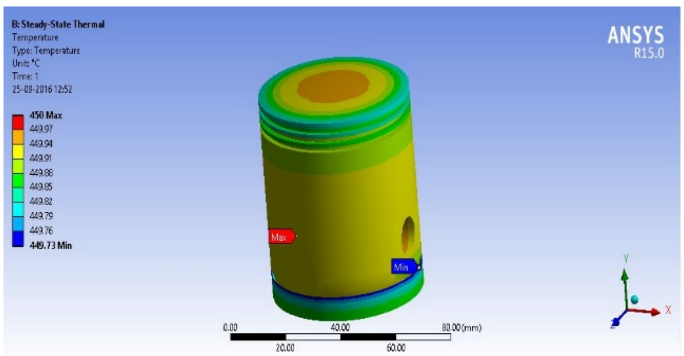


Fig 4.62 thermal analysis for cast steel temperature

Above fig shows we applied bulk temperature 22 ^{0} and film coefficient 1.24w/m^2* surface of the material exciting cast steel material piston ring, it produce 450^{0} c temperature

Al alloy

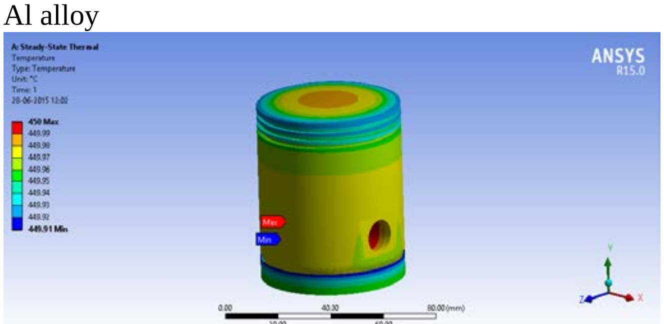


Fig4.52 thermal analysis for al alloy applied temperature

Above fig. shows we applied temperature 22^{0}c bulk temperature and film coefficient 1.24 w/m^2*c surface of the exciting material al alloy piston ring crown ,it produce 450of total temperature

5. Results and Discussion

Piston

Static analysis

Table5.1static analysis b/w al alloy,cast steel&cast iron

Materials	Al-alloy	Cast steel	Cast iron
Deformation (mm)	0.105969	0.036373	0.066456
Stress (Mpa)	173.82	130.95	130.88
Safety factor	1.6102	1.9091	1.8337

Above table shows the variation between the materials cast steel,cast iron and aluminium when we applied 15MPa pressure on piston.

Static analysis between cast steel, 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 steel to cast iron we may reduces the stress and it has been decrease from 173Mpa to 130.9Mpa to130.9 but the safety factor is increased from 1.6 to 1.9. From this we can say this material is good

Piston ring

Table 5.2 static analysis between al alloy, cast iron and cast steel

Materials	Al alloy	Cast steel	Cast iron
Deformation (mm)	7.3984	2.62	4.77
stress	169.13	169.12	169.11
strain	0.0023823	0.000845	0.00153

Above table shows the variation between the materials cast steel,cast iron and aluminium when we applied 15M Pa pressure on piston ring

Static analysis between al alloy to cast steel 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 al alloy to cast steel to cast iron we may reduces the stress and it has been decrease from 169.13Mpa to 169.12 to 169.11Mpa From this we can say this material is good.

piston

Thermal analysis

Table 5.3 thermal analysis b/w al alloy,cast steel&castiron

Materials	Al-alloy	Cast steel	Cast iron
Total temperature (*c)	350(max) -349.93 (min)	350(max)-349.7(min)	350(max) - 349.76(min)

Heat flux (w/m^2)	2316.8	1858.1	1857.9
Heat flux in x (w/m^2)	1684.5	1213.1	1213
Heat flux in y (w/m^2)	1660.1	1853.8	1853.7
Heat flux in z (w/m^2)	1693.1	1212.4	1212.3

A bove table shows the variation between the material al alloy to cast steel to cast ironwhen we applied22^{0}c ambient temperature and 1.43w/m^2*c film coefficient on the top surface of the Piston crown.

Thermal analysis between al alloy,cast steel and steel cast ironpiston we can say the heat flux of existing model has been decreased by material change but by changing material al alloy to cast steel to cast iron we may increase the temperature distribution and it has been not chane from 350C to 350 to 350 but the heat flux is decreased from 2316.8to 1858.1 to 1857.9w/mm^2.

Piston ring

Table 5.4 thermal analysis between al alloy,cast steelandcast iron

Materials	Al-alloy	Cast steel	Cast iron
Total temperature (*c)	450(max) -449.91 (min)	450(max)-449.73(min)	450(max)-449.68(min)
Heat flux (w/m^2)	3023.3	2424.6	2424.3
Heat flux in x (w/m^2)	2198.4	1583	1582.9
Heat flux in y (w/m^2)	2166.4	2419	2418.8
Heat flux in z (w/m^2)	2209.3	1582.1	1582

Above table shows the variation between the material al alloy to cast steel to cast ironwhen we applied22^0 c ambient temperature and 1.43w/m^2*c film coefficient on the top surface of the Piston ring crown.

Thermal analysis between al alloy,cast steel and steel cast ironpiston ring we can say the heat flux of existing model has been decreased by material change but by changing material al alloy to cast steel to cast iron we may increase the temperature distribution and it has been not chane from 450C to 450 to 450 but the heat flux is decreased from 3023.3to 2424.6 to 2424.3w/mm^2.

Conclusion

- In this project we have done one piston model by using CAD tool (creo-2) and then imported into CAE tool (ANSYS). To improve results here we selected another material Al-Alloy and existing material is steel only. And applied real time boundary conditions on it but in this case we get good results for existing material only. So we decide to change the design.
- In our project we have designed a piston used in two wheeler and modeled in 3D modelling, software CREO-2.and the we analyze the piston with different materials like Aluminum And cast steel and cast iron with help of fem
- In static conditions when we applied 15Mpa pressure on existing piston (steel) and piston ring produced 173.73MPa by changing design and adding zirconium coating we reduced it al alloy,cast iron and cast steel 158.72Mpa nearly 160MPa stress have been reduced but in real time conditions these results are not enough so we have analyse these models with thermal loads also
- In this project we replace piston material cast iron to al-alloy to cast steel to cast iron by this change we are getting same results for both reduce our piston and piston ring weight nearly 35% of original piston And this piston also having less stress(173.82 MPa) and good safety factor 1.6102. and the thermal heat flux also less (2316.8 w/m^2) compare
- the above we can say in thermal conditions cast steel,cast iron and al alloycombination produces better results compare with other. And it also has good static results
- Finally we conclude caste steel, al alloy and cast iron piston and piston ring will satisfy both static and thermal conditions. And it increases the piston and piston ring efficiency

Scope of Future Work

- In this work simulation is carried out for three types of material al alloy,cast iron,and cast steel piston and piston ring materials. This work can be extended to study for various materials and for different compositions.
- The functions of a piston ring are to seal off the combustion pressure, to distribute and control the oil, to transfer heat, and to stabilise the piston. The piston is designed for thermal expansion, with a desired gap between the piston surface and liner wall. The efficiency of diesel engine can be increased by using of TBC method but it is difficult to perform it experimentally. In future try to develop new material or select proper material to avoid the above problem and reduce NOx emission also.
- Piston and piston ring Design models are simulated on iteration based and it requires more number of iterations to check whether design is safe or not and to validate the models with the allowable. Instead of the above process, DOE – Design of Experiments concept can be used to optimize the design within short time and to get better optimized parameters. DOE should

be carried in ANSYS workbench. In ANSYS workbench modeling can be done from CATIA or Design Modeler using parametric model options. DP stands for design points, optimization can be done in workbench based on the required outputs namely deformations and stress with in prescribed limits.

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