DESIGN & THERMAL ANALYSIS OF CERAMIC LAYERED PISTON

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ABSTRACT

A piston is a disc which reciprocates within a cylinder. It is either moved by the fluid or it moves the fluid which enters the cylinder. The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod. The piston must also disperse a large amount of heat from the combustion chamber to the cylinder walls. Cast iron, Aluminium Alloy and Cast Steel etc. are the common materials used for piston of an Internal Combustion Engine. In this project here we were taken steel is an existing material and aluminium is another material.The material used is Aluminium Alloy and steel are used to determine the good material for manufacture of the piston here we analyze the two materials with the help of fem. In order to get better results here we are adding 0.4mm ceramic layer for both material and analysed with same boundary conditions. And calculating results like deformation, stress, safety factor. And total temperature and heat flux also.
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 boundary conditions and we determining total temperature on the body, total heat flux values.
Tools were used:
Cad tool: creo-2
Cae tool: Ansys Workbench.

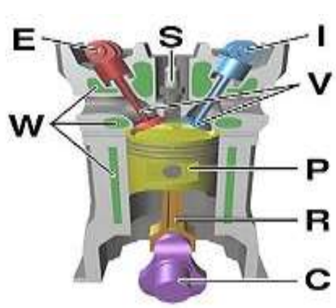
INTRODUCTION TO PISTON

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

Design of Piston

A piston does the dirty work of actually taking the brunt of the force of explosion arising of the combustion of the fuel and passes it onto the crankshaft (the big, heavy part of an engine that rotates due to the movement of the piston). It takes a tremendous amount of pressure (about 1000 Psi) notwithstanding the severe heat that it has to take.

Pistons move up and down in the cylinders which exerts a force on a fluid inside the cylinder. Pistons have rings which serve to keep the oil out of the combustion chamber and the fuel and air out of the oil. Most pistons fitted in a cylinder have piston rings. Usually there are two spring-compression rings that act as a seal between the piston and the cylinder wall, and one or more oil control ring s below the compression rings. The head of the piston can be flat, bulged or otherwise shaped. Pistons can be forged or cast. The shape of the piston is normally rounded but can be different. A special type of cast piston is the hypereutectic piston. The piston is an important component of a piston engine and of hydraulic pneumatic systems. Piston heads form one wall of an expansion chamber inside the cylinder. From there the power is conveyed through a connecting rod to a crankshaft, which transforms it into a rotary motion, which usually



Drives a gearbox through a clutch. Components of a typical, four stroke cycle, DOHC piston engine. (E) Exhaust camshaft, (I) Intake camshaft, (S) Spark plug, (V) Valves, **(P) Piston**, (R) Connecting rod, (C) Crankshaft, (W) Water jacket for coolant flow.

Introduction to CREO

CREO is a suite of programs that are used in the design, analysis, and manufacturing of a virtually unlimited range of product.

CREO is a parametric, feature-based solid modeling system, **"Feature based"** means that you can create part and assembly by defining feature like pad, rib, slots, holes, rounds, and so on, instead of specifying low-level geometry like lines, arcs, and circle& features are specifying by setting values and attributes of element such as reference planes or surfaces direction of creation, pattern parameters, shape, dimensions and others.

"Parametric" means that the physical shape of the part or assembly is driven by the values assigned to the attributes (primarily dimensions) of its features. Parametric may define or modify a feature's dimensions or other attributes at any time

For example, if your design intent is such that a hole is centered on a block, you can relate the dimensional location of the hole to the block dimensions using a numerical formula; if the block dimensions change, the centered whole position will be recomputed automatically.

"**Solid Modeling"** means that the computer model to create it able to contain all the information that a real solid object would have. The most useful thing about the solid modeling is that it is impossible to create a computer model that is ambiguous or physically non-realizable.

3D MODEL IS DEVELOPED USING CREO:-

Ceramic coated piston with 4mm

INTRODUCTION TO ANSYS

INTRODUCTION

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.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc

GENERIC STEPS TO SOLVING ANY PROBLEM IN ANSYS:

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

FLUID FLOW

The ANSYS/FLOTRAN CFD (Computational Fluid Dynamics) offers comprehensive tools for analyzing two-dimensional and three-dimensional fluid flow fields. ANSYS is capable of modeling a vast range of analysis types such as: airfoils for pressure analysis of airplane wings (lift and drag), flow in supersonic nozzles, and complex, three-

dimensional flow patterns in a pipe bend.
In addition, ANSYS/FLOTRAN could be used to perform tasks including:
Calculating the gas pressure and temperature distributions in an engine exhaust manifold
Studying the thermal stratification and breakup in piping systems
Using flow mixing studies to evaluate potential for thermal shock
Doing natural convection analyses to evaluate the thermal performance of chips in electronic enclosures
Conducting heat exchanger studies involving different fluids separated by solid regions

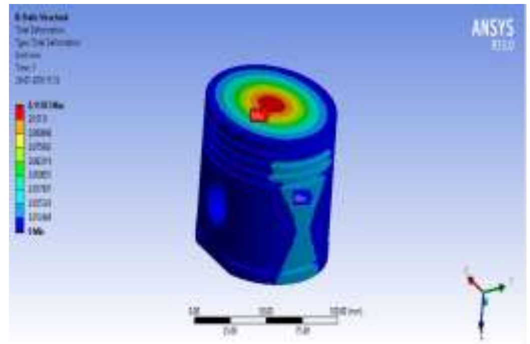
COUPLED FIELDS

A coupled-field analysis is an analysis that takes into account the interaction (coupling) between two or more disciplines (fields) of engineering. A piezoelectric analysis, for example, handles the interaction between the structural and electric fields: it solves for the voltage distribution due to applied displacements, or vice versa. Other examples of coupled-field analysis are thermal-stress analysis, thermal-electric analysis, and fluid-structure analysis.

Some of the applications in which coupled-field analysis may be required are pressure vessels (thermal-stress analysis), fluid flow constrictions (fluid-structure analysis), induction heating (magnetic-thermal analysis), ultrasonic transducers (piezoelectric analysis), magnetic forming (magneto-structural analysis), and micro-electro mechanical systems (MEMS).

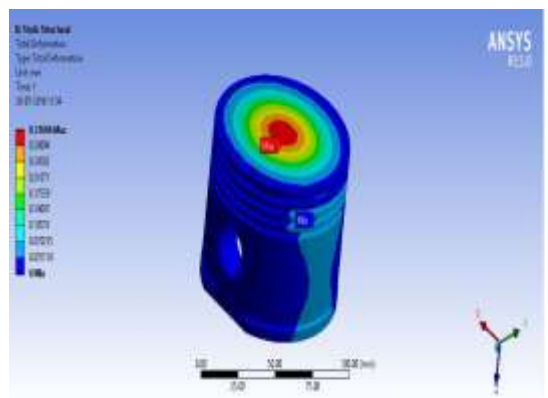
ANSYS PROCESS

esults for (STEEL-Exciting Material) Deformation



In this model when we applied 6Mpa pressure on the top surface it produces 180Mpa of stress and its safety factor is 1.38,in this we cannot eliminate total stress on the body but we can reduce it with suitable material

Results for (Al-Alloy-Exciting Material) Deformation



From the above graphs we can say the strength and energy of existing model has been increased by material change but by changing material from steel to al-alloy we may not reduces the stress and it has been increased from 180Mpa to 184Mpa but the strength is increased from 1.3 to 1.5. by this we can say this material is good.

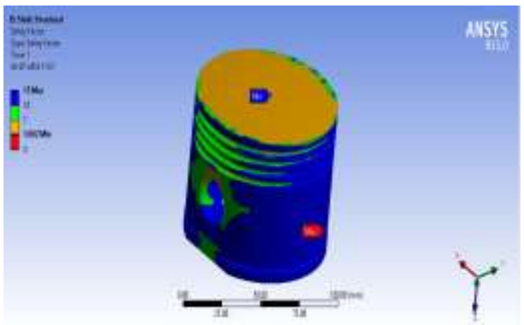
Here we have taken ceramic materials as zirconium and silicon dioxide, now we analysing once steel with zirconium and once steel with silicon dioxide, then for al-

alloy also analyses with ones zirconium and silicon dioxide. From all these results we can say which most suitable material is and which more efficiency is.

ANSYS PROCESS FOR CERAMIC COATED MATERIAL

Results for (Al-Alloy-silicon dioxide)

Deformation

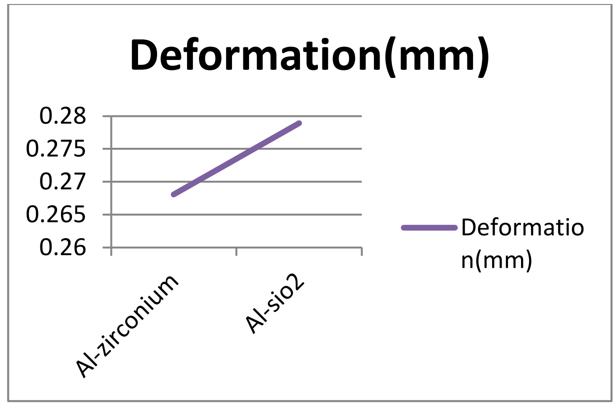


Tables

Material	Deformation(mm)	Safety factor	Strain energy(mJ)	Strain	Stress(Mp)
Al-zirconium	**0.26805**	**1.0261**	**16.346**	**0.0023794**	**224.16**
Al-sio2	**0.27892**	**1.002**	**16.98**	**0.00208333**	**154.69**

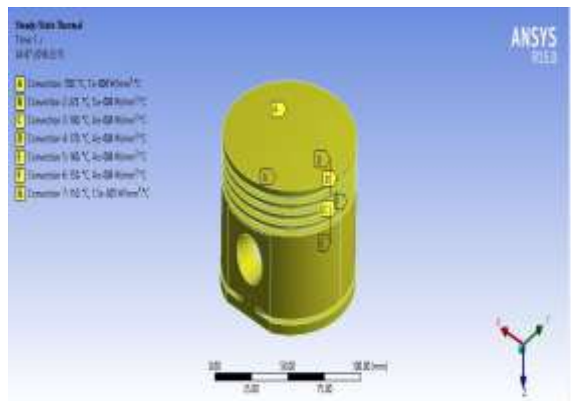
Graphs

Deformation



THERMAL ANALYSIS

Model imported from pro-e tool in IGES format.

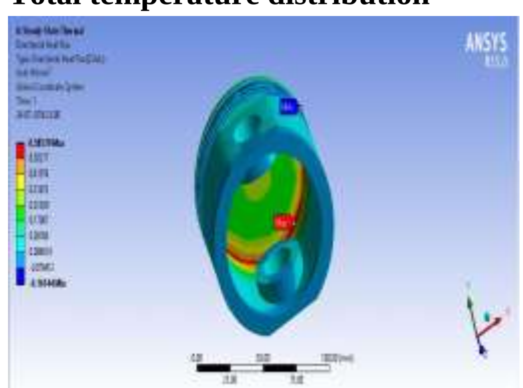


Select geometry assign material properties

Results for (existing model)

Material (steel)

Total temperature distribution

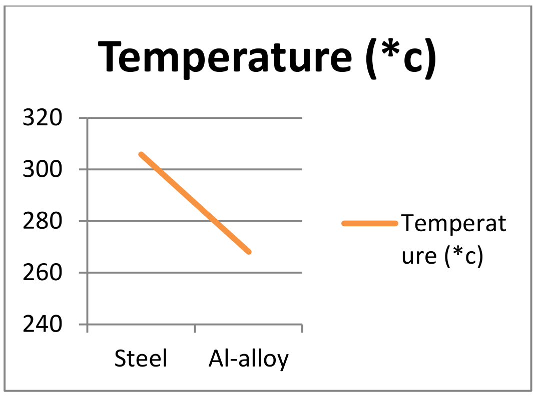


Tables

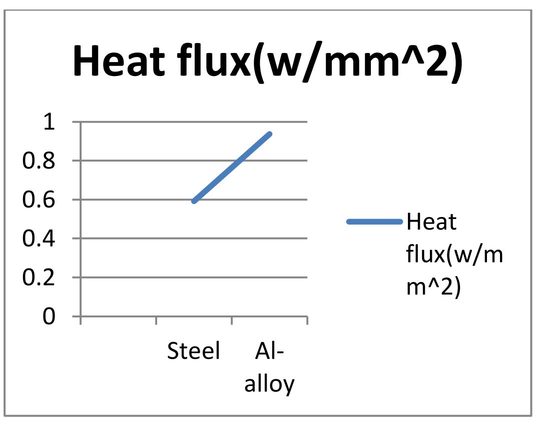
Materia	Heat flux(w	Hf_x-	Hf_y-	Hf_z -	Temperatur

l	/mm^2)	direc tion (w/ mm^ 2)	direc tion (w/ mm^ 2)	direc tion (w/ mm^ 2)	e (*c)
Ste el	**0.5912 1**	**0.28 18**	**0.26 056**	**0.58 579**	**305.8 2**
Al-allo y	**0.9372 9**	**0.37 787**	**0.37 213**	**0.89 472**	**268.0 7**

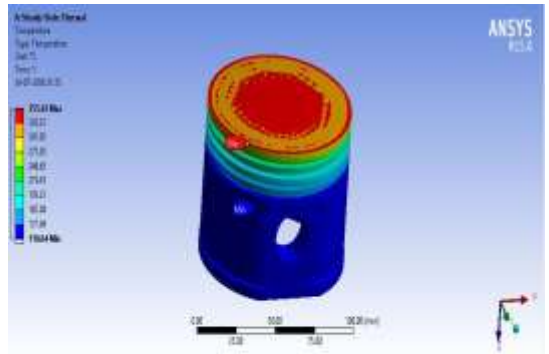
Temperature



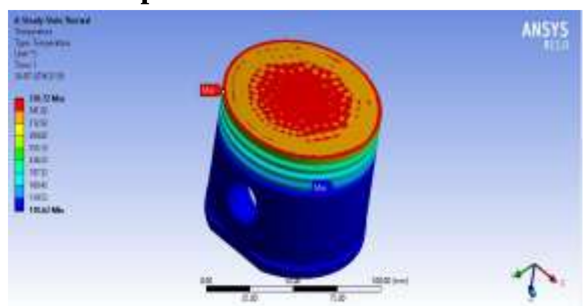
Total Heat Flux



Results for (ceramic coated Model)
Material (steel-zirconium)
Total temperature distribution



Results for (ceramic coated Model)
Material (steel-sio2)
Total temperature distribution



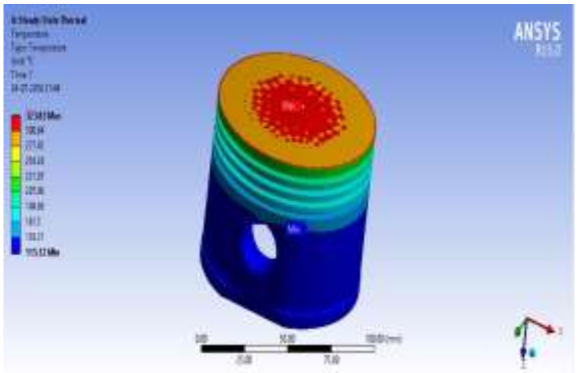
Tables

Material	Heat flux(w /mm^ 2)	Hf_ x-direction (w/ mm ^2)	Hf_ y-direction (w/ mm ^2)	Hf_ z-direction (w/ mm ^2)	Temperature (*c)
Steel-zirconium	0.543 36	0.28 132	0.27 099	0.54 095	355.4 3
Steel-sio2	0.527 25	0.27 489	0.26 747 4	0.52 502	370.7 2

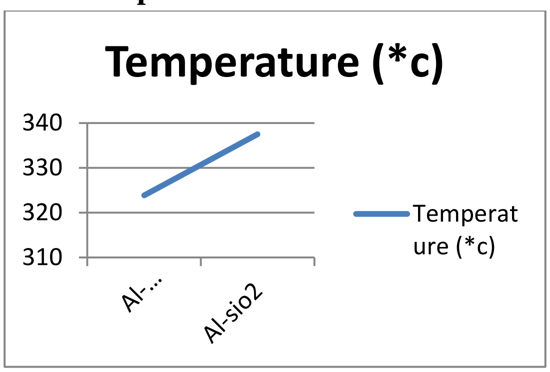
Total temperature

Results for (Ceramic Coated Model) Material (Aluminium-Zirconium)

Total temperature distribution



Total temperature



In static conditions when we applied 6Mpa pressure on existing piston (steel) produced 180.73Mpa by changing design and adding zirconium coating we reduced it to 158.72Mpa nearly 22Mpa 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 thermal analysis the existing model with existing material gained temperature 305.82*c only by changing design **steel-zirconium** gained 355.43*c and **steel–sio2** gained 370.72*c. Ceramic coating increased exhaust gases temperatures at every operational condition. Exhaust gases temperatures were increased 50 to 70 0C according to standard engine configuration. This increase corresponds to 15 to 25 percent of standard engine exhaust gases temperatures. When a turbine is combined to the system, aforementioned excess of exhaust energy can be converted to useful mechanical energy.

From the above we can say in thermal conditions **steel-sio2** combination produces better results compare with other. And it also has good static results.

Finally we conclude steel with sio2 ceramic coated piston will satisfy both static and thermal conditions. And it increases the piston efficiency

CONCLUSION

In this project we have done one piston model by using CAD tool (creo-2) and then imported into CAE tool (Ansys). For 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 got good results for existing material only. So we decide to change the design

For changing design here we added 0.4mm thickness material on the top surface which is called ceramic coating and we used two materials for this one is zirconium and silicon dioxide, we analyses for both steel and al-alloy pistons with these coatings.

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