DESIGN AND ANALYSIS OF PISTON AND CONNECTING ROD

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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.

In this Project we describe the stress distribution of the piston by using FEA. The finite element analysis is performed by using computer aided design (CAD) software.

The aim of our project is to design a piston for a two wheeler using Solid works software and analyses with Ansys, in this case we analyses our piston with existing material and different material and finally we conclude which material is more suitable for manufacturing of the piston. In this project we took steel as existing material and then analyzed model at high pressure values

The piston investigate and analyzes with modified dimensions at the real engine condition during combustion process. The optimization is carried out to reduce the stress concentration on the upper end of the piston. With using computer aided design (CAD), Solid works software the structural model of a steel and Aluminum piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS

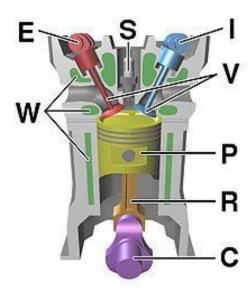
Connecting rodis replaced aluminium based composite material reinforced with silicon carbide and fly ash. And it also describes the modelling and analysis of connecting rod. Fea analysis was carried out by considering two materials. The parameters like von misses stress, safety factor and displacement were obtained from ansys software. Compared to the former material the new material found to have less weight and better stiffness. It resulted reduction reduction of weight, displacement.

1. INTRODUCTION

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

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systems. Piston heads form one wall of an expansion chamber inside the cylinder. The opposite wall, called the cylinder head, contains inlet and exhaust valves for gases. As the piston moves inside the cylinder, it transforms the energy from the expansion of a burning gas usually a mixture of petrol or diesel and air into mechanical power in the form of a reciprocating linear motion. 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.

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.

2. CONSTRUCTION OF PISTON

Its top known by many names such as crown, head or ceiling and thicker than bottom portion. Bottom portion is known as skirt. There grooves made are accommodate the compression rings and oil rings. The groove, made for oil ring, is wider and deeper than the grooves made for compression ring. The oil ring scraps the excess oil which flows into the piston interior through the oil return holes and thus avoiding reaching the combustion chamber but helps to lubricate the gudgeon pin to some extent. In some designs the oil ring is provided below the gudgeon pin boss

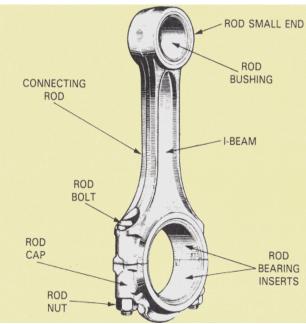
The diameter of piston always kept smaller than that of cylinder because the piston

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reaches a temperature higher than cylinder wall and expands during engine operation. The space between the cylinder wall and piston is known as piston clearance. The diameter of the piston at crown is slightly less than at the skirt due to variation in the operating temperatures. Again the skirt itself is also slightly tapered to allow for unequal expansion due to temperature difference as we move vertically along the skirt the working temperature is not uniform but slightly decrease.

Connecting rod description

Connecting rod is the intermediate link between the piston and the crankshaft. And is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crankshaft. Connecting rod, automotives should be lighter and lighter, should consume less fuel and at the same time they should provide comfort and safety to passengers, unfortunately leads to increase in weight of the vehicle. This tendency in vehicle construction led the invention and implementation of quite new materials which are light and meet design requirements. Lighter connecting rods help to decrease lead caused by forces of inertia in engine as it does not require big balancing weight on crankshaft. Application of metal matrix composite enables safety increase and advances that leads to effective use of fuel and to obtain high engine power. Honda Company had already started the manufacturing of aluminium connecting rods reinforced with steel continuous fibers. By carrying out these modifications to engine elements will result in effective reduction of weight, increase of durability of particular part, will lead to decrease of overall engine weight, improvement in its traction parameters, economy and ecological conditions such as reduction in fuel consumption and emission of harmful substances atmosphere. In his project carbon steel connecting rod is replaced by aluminium boron carbide connecting rod. Aluminium boron carbide is found to have working factory of safety is nearer to theoretical factory of safety, to increase the stiffness by 48.55% and to reduce stress by 10.35%. Connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end. Optimization was performed to reduce weight. Weight can be reduced by changing the material of the current forged steel connecting rod to crack able forged steel (C70). And the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage, using FEA. In this analysis of connecting rod were performed under dynamic load for stress analysis and optimization. Dynamic load analysis was performed to determine the in service loading of the connecting rod and FEA was conducted to find the stress at critical locations.



Typical view of Connecting rod

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Theoretical calculation of connecting rod Pressure calculation:

Consider a 150cc engine

Engine type: Air cooled, 4-stroke

Bore \times Stroke (mm) = 57×58.6

Displacement = 149.5CC

Maximum Power = 13.8bhp at 8500rpm

Maximum Torque = 13.4Nm at 6000rpm

Compression Ratio = 9.35/1

Density of petrol at 288.855 K - 737.22*10-

9 kg/mm3

Molecular weight M - 114.228 g/mole

Ideal gas constant R – 8.3143 J/mol.k

From gas equation,

PV=m.Rspecific.T

Where, P = Pressure

V = Volume

m = Mass

Rspecific = Specific gas constant

T = Temperature

But,

mass = density * volume

m = 737.22E - 9*150E3

m = 0.11 kg

Rspecific = R/M

Rspecific = 8.3143/0.114228

Rspecific = 72.76

P = m.Rspecific.T/V

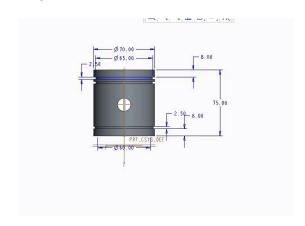
P = 0.11*72.786*288.85/150E3

P = 15.4177 MPa

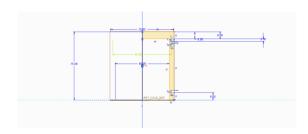
 $P \sim 16 \text{ MPA}.$

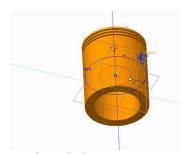
3D MODEL IS DEVELOPED USING CREO

Design 1



3D MODEL



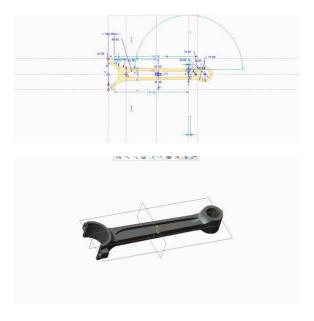


3D Design of piston

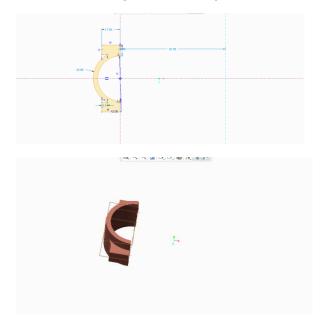


3D view of piston

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3D Design of connecting rod



3D Design of connecting rod big end bearing cup



3D view of connecting rod

3. SOFTWARE USED

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.

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.

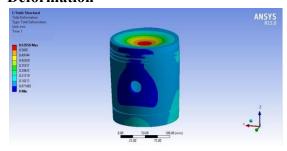
With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users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

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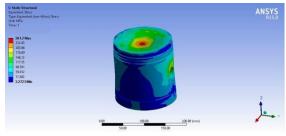


4. RESULTS AND ANALYSIS

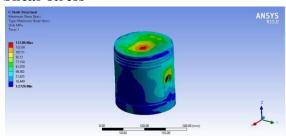
Design 1 Results For Steel (Excising Material) Deformation



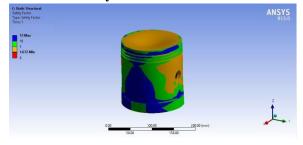
Stress



Shear stress



Factor of safety



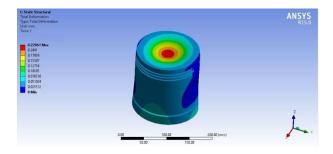
From above results we have maximum stress 261.2 MPa, and our project intension is reduce stress values, and basically we cannot eliminate total stress on the body but we can decrease the stress values by following 3 methods

- 1. Material change design same
- 2. Design change material constant
- 3. Both design and material change

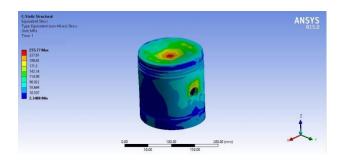
By following above methods we can reduce the stresses on the body

For Al-Alloy (CHANGE MATERIAL) RESULTS

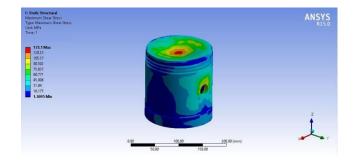
Deformation



Stress

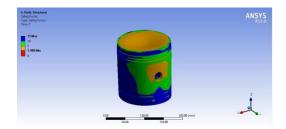


Shear stress



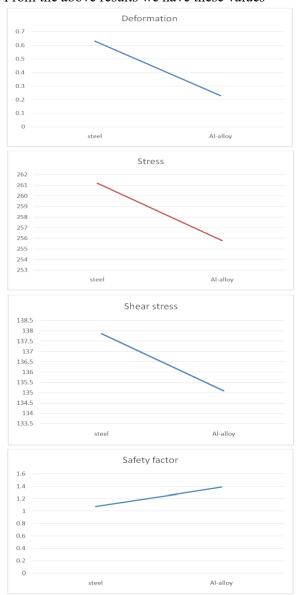
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Safety factor



And to get better results and now we are changing dimensions of the model, i.e. we changing design

From the above results we have these values

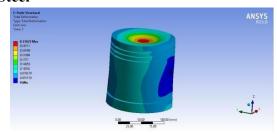


Design 2 Results

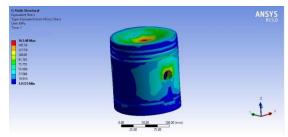
The modifications are done now we are checking results for this model with same materials and same boundary conditions

Results Deformation

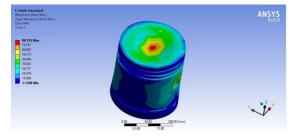
Steel



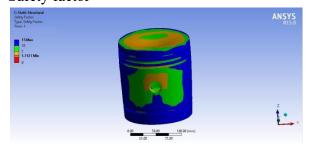
Stress



Shear stress

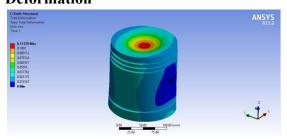


Safety factor

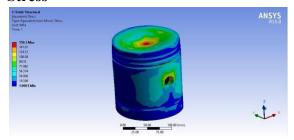


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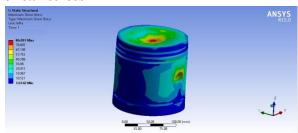
Results for Al-alloy (change material) Deformation



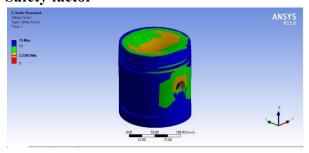
Stress



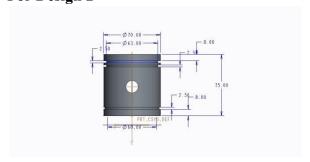
Shear stress



Safety factor

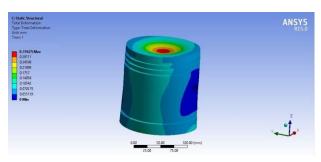


For Design 2

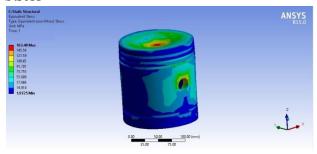


The modifications are done now we are checking results for this model with same materials and same boundary conditions

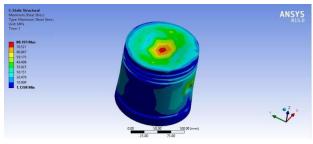
Results Deformation Steel



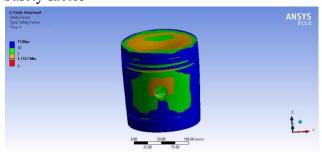
Stress



Shear stress

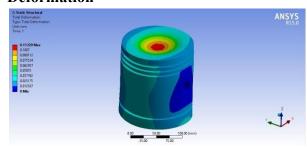


Safety factor

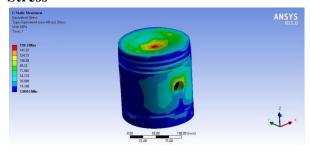


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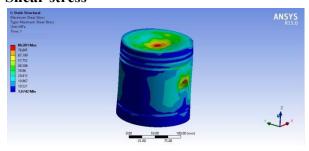
Results for Al-alloy (change material) Deformation



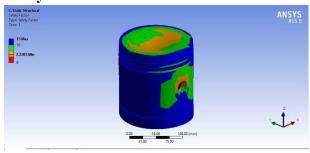
Stress



Shear stress



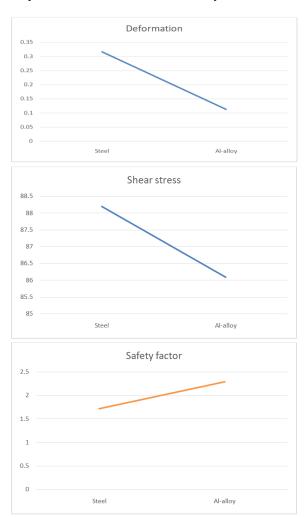
Safety factor



From the above values we can conclude that Design 2 with changing material has produce less stress and high safety factor values

From the above tables we can say the **Al-Alloy**material have less deformation values less deformation means high strength.

But when we designing one piston we should consider thermal conditions also so that now am applying both static and thermal loads on the body and then checking the results of heat flux and total temperature and total stress on the body.



Comparison between two piston results

For Design 1

	steel	Al-alloy
Deformation	0.63	0.22961
Stress	261.2	255.77
Shear stress	137.86	135.1
Safety factor	1.072	1.388

For Design 2

	Steel	Al-alloy
Deformation	0.31625	0.11324
Stress	163.48	159.3
Shear stress	88.195	86.091
Safety factor	1.7127	2.288

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Connecting rod analysis Connecting rod material properties

> Al-3600

Ex:- 60*10^9 pa

Poison ratio: 0.33

Density: 2800 kg/m³

Yield strength: 170*10^6 pa

> Al-silicon-fly-ash

Ex:- 70*10^9 pa

Poison ratio: 0.33

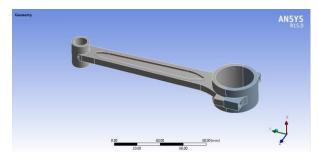
Density: 2611 kg/m³

Yield strength: 363*10^6 mpa

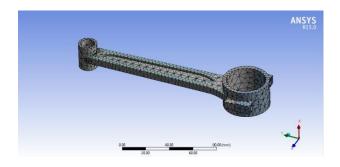
Geometry→ right click→ import

geometry→ import iges format model

Model imported from pro-e tool in IGES format.

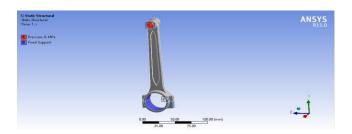


Imported Model connecting rod View In Ansys.



Tet Volume Mesh

Static Analysis on Connecting rod at pressure8*10^6 pa



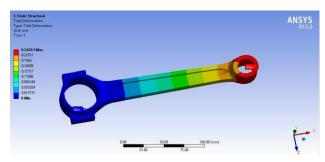
Static Analysis on Connecting rod at pressure 8*10^6 pa

Select geometry assign material properties
Click on static structural → supports → fixed supports → select areas
→loads → pressure → 8*10^6 pa → apply

RESULTS

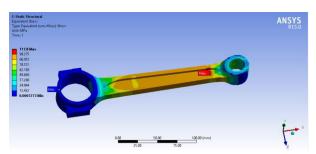
a. MATERIAL: Al-3600

Deformation



Deformation Analysis of Connecting rod on Al-3600 at pressure 8*10^6 pa

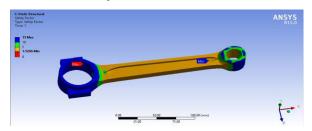
Stress



Stress Analysis of Connecting rod on Al-3600 at pressure 8*10^6 pa

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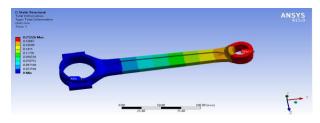
Factor of safety



Factor of safety Analysis of Connecting rod on Al-3600 at pressure 8*10^6 pa

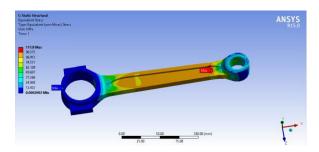
MATERIAL: AL-SILICON-FLY-ASH

Deformation



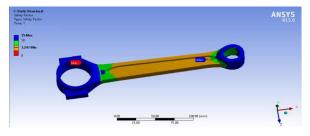
Deformation Analysis of Connecting rod on Al-Silicon-Fly-Ash at pressure 8*10^6 pa

Stress

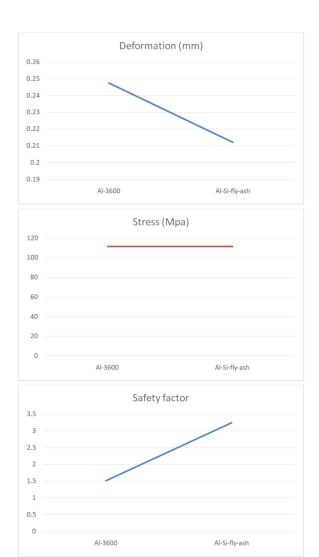


Stress Analysis of Connecting rod on Al-Silicon-Fly-Ash at pressure 8*10^6 pa

Factor of safety



Factor of safety Analysis of Connecting rod on Al-Silicon-Fly-Ash at pressure 8*10^6



5. CONCLUSION

In this project we designed piston and connecting rod by using cad tool (solid works)here piston's existing material is steel and checking maximum limits for that object in static structural condition from this we got maximum von-misses stress values 261.22 Mpaand this is very high stress and we don't have chance to eliminate stress but we have choice to reduce the stress values, to reduce the stress values over the body we are not changing piston bore and stroke dimensions, we modified piston ring values here, and here we reduced piston ring thickness 2mm only, and analyzed with same boundary conditions, by this

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optimization we nearly reduces 28-35% Mpa stress for both materials.

In this process we got very less stress values and high strength values for al-alloy only, but we cannot decide our material is good by single analysis, here we applied thermal boundary conditions on it From the theoretical calculations we know the temperature distribution on piston head is in between 260*c to 290*c only. Here steel material is observes our required amount of energy by modifying our design the amount of energy is increases for both material and their heat transfer rate values also. We know that if our model observe more energy then we can convert that more energy into mechanical energy. From the results al-alloy is good at only static load conditions only but steel is satisfying both static and thermal results, finally we can conclude we can use our optimization piston with steel material to increase efficiency.

For connecting rod weight can be reduced by changing the material of the current al360 connecting rod to Al-Sic-Fly-Ash composites. The optimised connecting rod is 46.42% lighter than the current connecting rod. The new optimised connecting rod is comparatively much stiffer than the former.

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