IJERST

International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 3 (2026)

ijerst.editor@gmail.com

editor@ijerst.com

ISSN 2319-5991 www.ijerst.com

Peer Reviewed, Referred & Indexed Journal

Research Paper

ANALYSIS OF PISTON AND CONNECTING ROD WITH DIFFERENT MATERIALS SUBJECTED TO STATIC AND DYNAMIC ANALYSIS

K. Sarangapani[1] B.Teja[2]

[1]M. Tech Student, Department of Mechanical Engineering, Kakinada Institute of Technological sciences. Ramachandrapuram, East Godavari District, AP, 533255

[2]Assistant professor, Department of Mechanical Engineering, Kakinada Institute of Technological sciences. Ramachandrapuram, East Godavari District, AP, 533255

AbstractA 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 rod is replaced by 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 in reduction of weight, reduction in displacement.

1. INTRODUCTION

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.

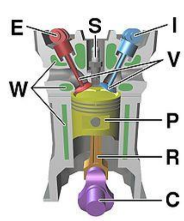
The piston is the single, most active and very critical component of the automotive engine. The Piston is one of the most crucial, but very much behind-the-stage parts of the engine which does the critical work of passing on the energy derived from the combustion within the combustion chamber to the 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.

Construction of piston rod

Its top known by many names such as crown, head or ceiling and thicker than bottom portion. Bottom portion is known as skirt. There are grooves made to 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

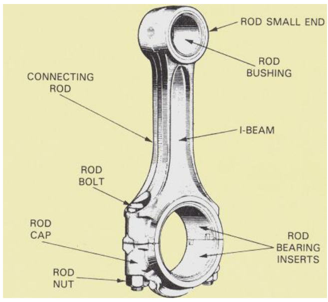
The diameter of piston always kept smaller than that of cylinder because the piston reaches a temperature higher than cylinder wall and expands during engine operation. The space between the cylinder wall and piston is known as piston clearance. The diameter of the piston at crown is slightly less than 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.



Components of a typical, four stroke cycle, DOHC piston engine

Connecting rod

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, that 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 into 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

2. LITERATURE REVIEWS

Durrant G. et al (1996) [2] explained about the aluminum alloy reinforced with mild steel insert by squeeze cast technique. The bonding of aluminum silicon alloy with the reinforced insert plays a vital role in improving the service life of the component. The importance on the suitable registry between these reinforced insert and alloy is restricted by the surface contaminants and surface oxides (Stefaniay et al 1987).

Zone Ching Lin and Din yanchen (1995) [3] studied on Cubic Boron Nitride (CBN) a sintered product, which can be used as a cutting tool material for hard turning and for higher productivity. CBN tool has various characteristics like excellent wear durability, high hardness and good thermal resistance. The cost of the tool is extremely high and it is 10-20 times more than carbide tools (Steven Y Liang 2003).

WuyiChen (2006) [4] explained that radial thrust cutting force was the largest among three cutting force components and the most sensitive to the changes of cutting edge geometry and tool wear while machining medium hardness steel with CBN tool. Mustafa Gunay et al (2006) 19 identified the influence of rake angle on cutting force. It has been proved that the mean cutting force decreases, as rake angle increases.

3. DESIGN CALCULATIONS

Pressure calculations

Piston Rod

Suzuki GS 150 R specifications

Engine type: air cooled 4-stroke SOHC

Bore $\times\ stroke(mm) = 57 \times 58.6$

Displacement =149.5CC

Maximum power = 13.8bhp @8500rpm

Maximum torque = 13.4Nm @ 6000 rpm

Compression ratio =9.35 : 1

Density of petrol $C_8H_{18} = 737.22\frac{kg}{m^3}\ at\ 60F$

= 0.00073722 kg/cm^3

= 0.00000073722 kg/mm^3

T = 60F =288.855K =15.55^{0}C

Mass = density $\times\ volume$

m = 0.00000073722$\times$ 149500

m = 0.11kg

Molecular cut for petrol 144.2285 g/mole

PV = mRT

P = $\frac{mRT}{V} = \frac{0.11\times8.3143\times288.555}{0.11422\times0.0001495} = \frac{263.9}{0.00001707}$

P = 15454538.533 j/m^3 = n/m^2

P =15.454 N/mm^2

Mean effective pressure $P_m = \frac{T_{nc}}{V_d} \times 2\pi$

$= \frac{13.4\times2\times2\times3.14}{149.5}$

= 1.12

Indicated power IP = $\frac{P_m\times l\times A\times n}{60} = \frac{P_m\times l\times\pi\times D^2\times n}{60} = \frac{1.12\times58.6\times3.14\times57^2\times4}{4\times60} = 11217.05\ kw$

Brake power BP = $\frac{2\pi NT}{60} = \frac{2\pi\times6000\times13.4}{60} = 8415.2$

Mechanical efficiency $\eta_{mech} = \frac{BP}{IP} = \frac{8415.2}{11217.05} = 0.75 = 75\%$

Connecting rod

Consider a 150cc engine

Engine type : Air cooled, 4-stroke

Bore × 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

R specific = 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

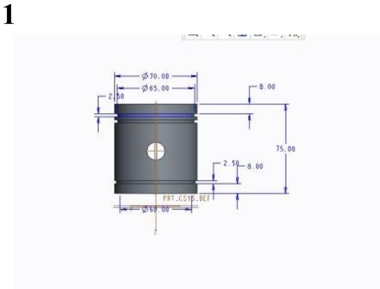
P = 0.11*72.786*288.85/150E3

P = 15.4177 MPa

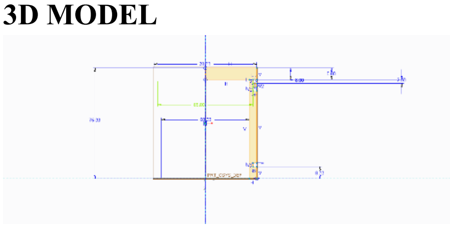
P ~ 16 MPA.

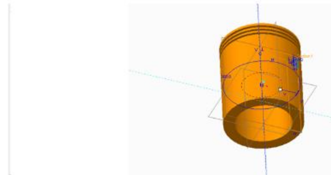
4. 3D MODEL IS DEVELOPED USING CREO

Design 1

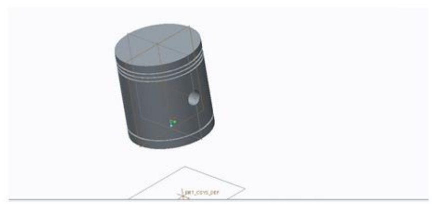


3D MODEL

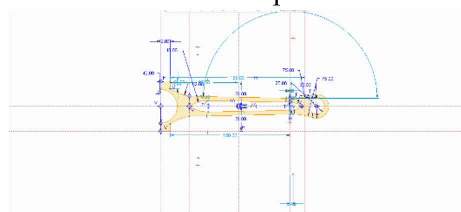




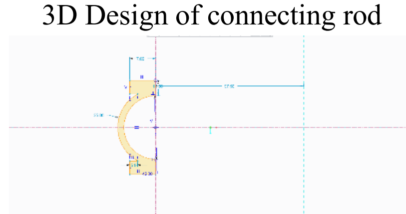
3D Design of piston

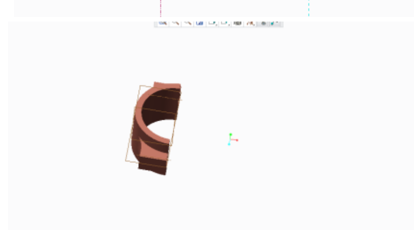


3D view of piston

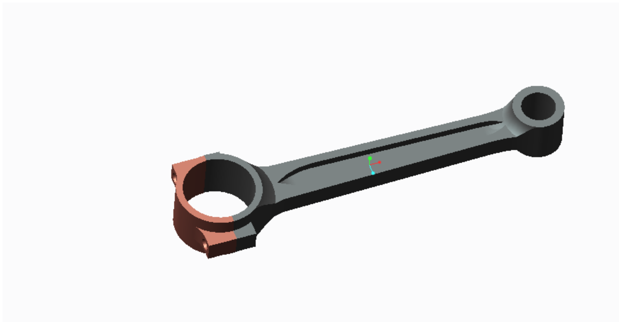


3D Design of connecting rod





3D Design of connecting rod big end bearing cup

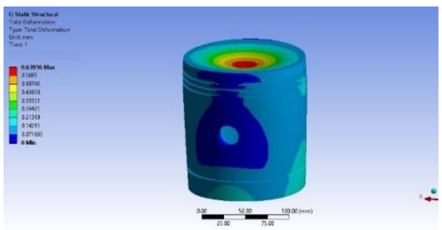


3D view of connecting rod

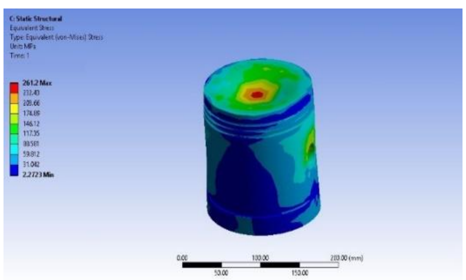
5. RESULTS AND ANALYSIS

For Steel (Excising Material)

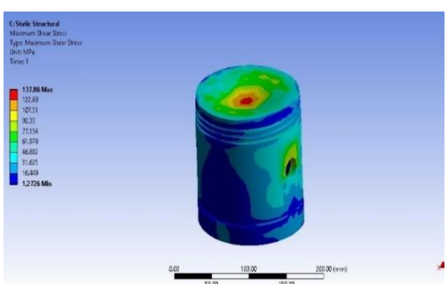
Deformation



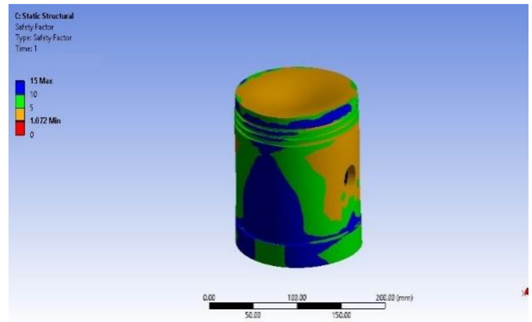
Stress



Shear stress



Factor of safety



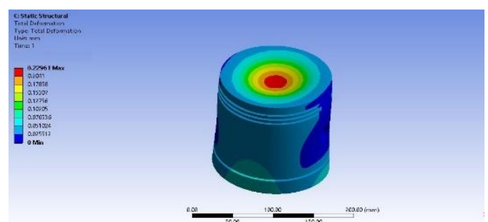
From above results we have maximum stress 261.2 MPa , and our project intension is reduce stress values , and basically we cannot eliminate total stress on the body but we can decrease the stress values by following 3 methods

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

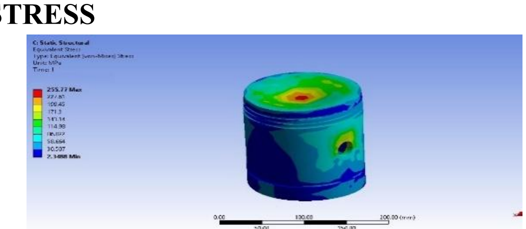
By following above methods, we can reduce the stresses on the body

For Al-Alloy (CHANGE MATERIAL)

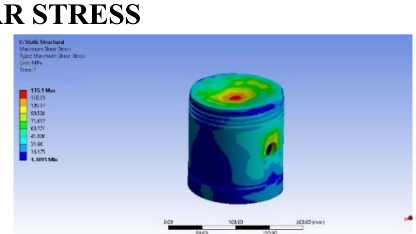
DEFORMATION



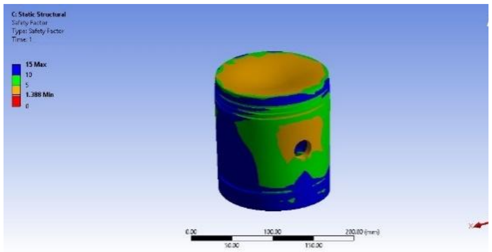
STRESS



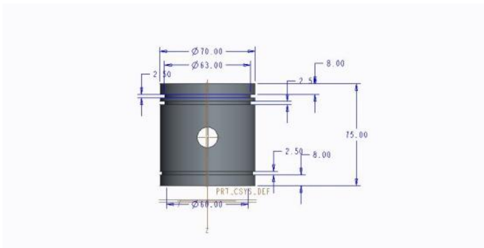
SHEAR STRESS



SAFETY FACTOR



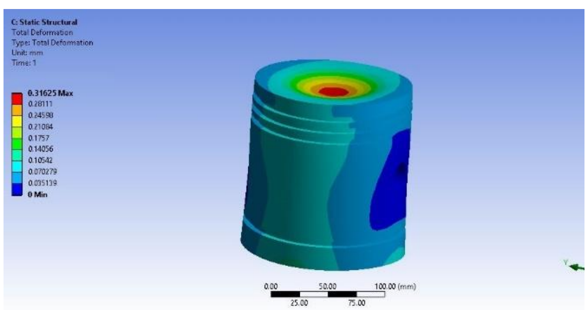
Design 2 Results



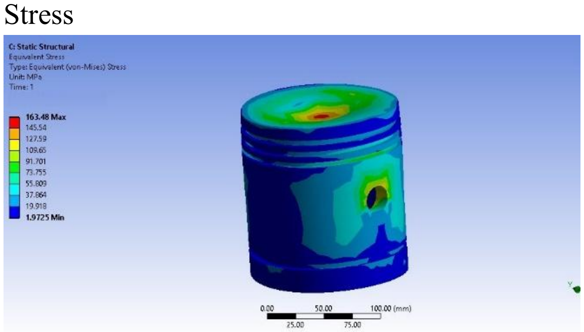
The modifications are done now we are checking results for this model with same materials and same boundary conditions

Deformation

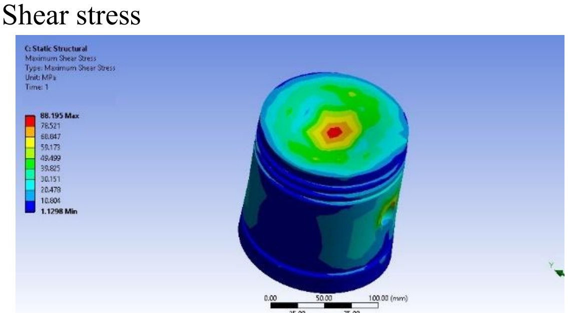
Steel



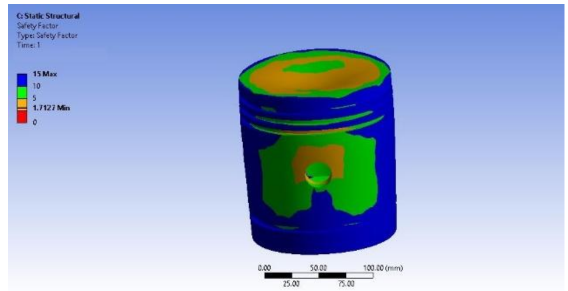
Stress



Shear stress

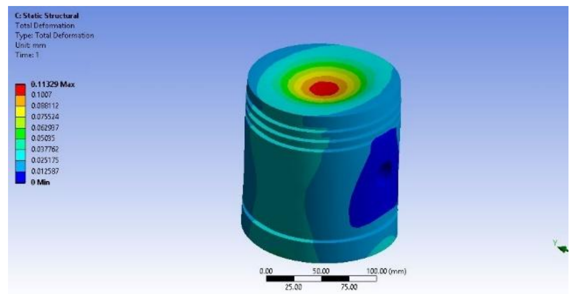


Safety factor

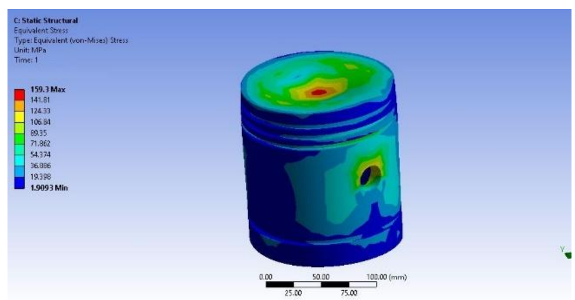


Al-alloy (change material)

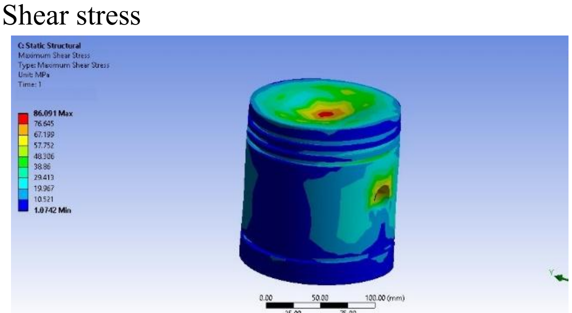
Deformation



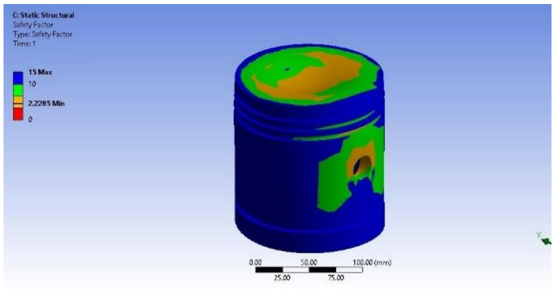
Stress



Shear stress



Safety factor



Comparison between two piston

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

From the above results by optimizing our piston design we can reduce nearly 28-35%Mpa stress over the body for both materials. And this indicates that high strength of the model.

Connecting Rod Results

MATERIAL PROPERIES

Al-3600

Ex: - 60*10^9 pa

Poison ratio: 0.33

Density: 2800 kg/m^3

Yield strength: 170*10^6 pa

Al-silicon-fly-ash

Ex: - 70*10^9 pa

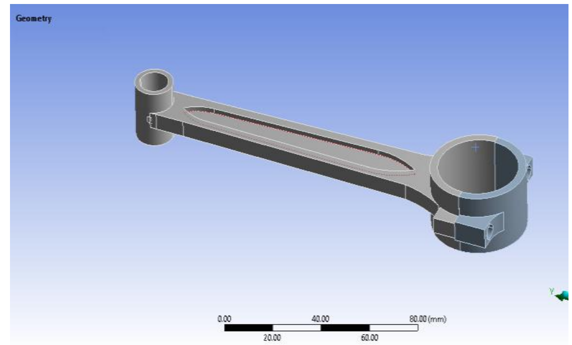
Poison ratio: 0.33

Density: 2611 kg/m^3

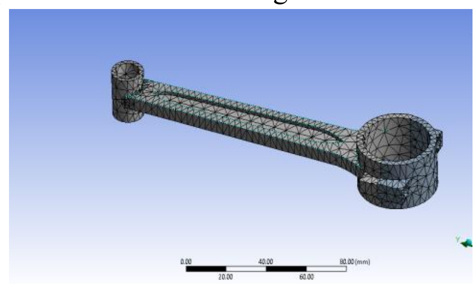
Yield strength: 363*10^6 mpa

Geometry→ right click→ import geometry→ import iges format model

Model imported from pro-e tool in IGES format.

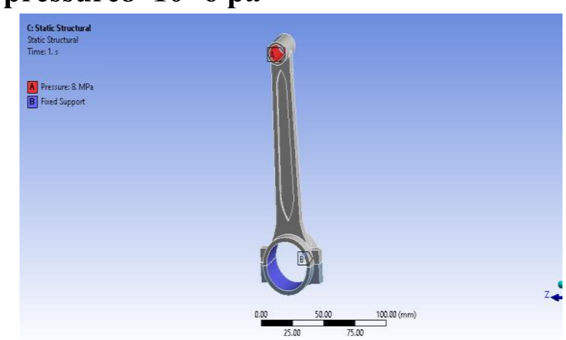


Imported Model connecting rod View InAnsys.



Tet Volume Mesh

StaticAnalysis on Connecting rod at pressure8*10^6 pa



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

Select geometry assign material properties

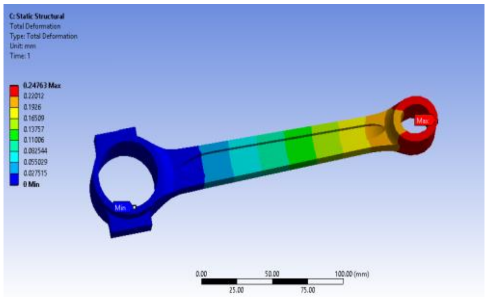
Click on static structural → supports→ fixed supports→select areas

→ loads→pressure→ 8*10^6 pa→ apply

RESULTS

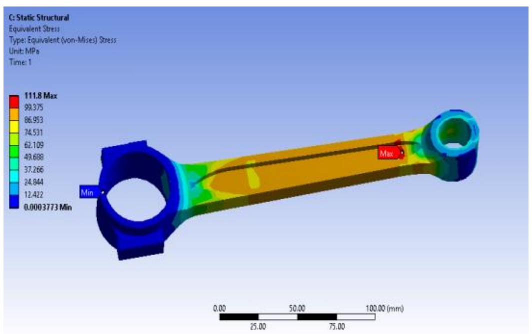
a. MATERIAL: Al-3600

- **Deformation**



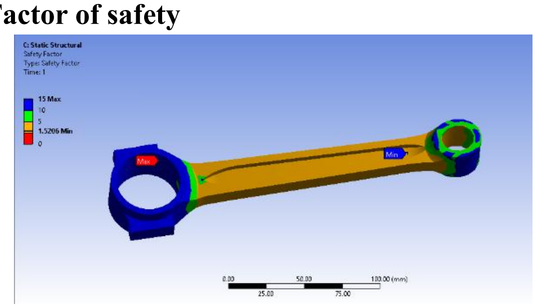
Deformation Analysis of Connecting rod on Al-3600 at pressure 8*10^6 pa

Stress



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

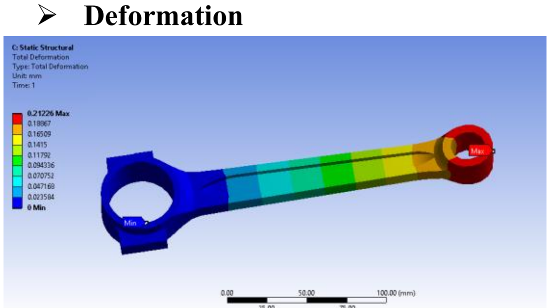
Factor of safety



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

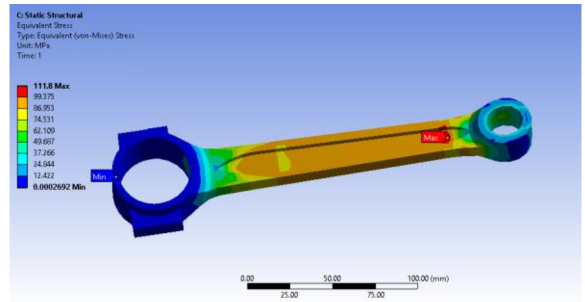
MATERIAL: AL-SILICON-FLY-ASH

- **Deformation**



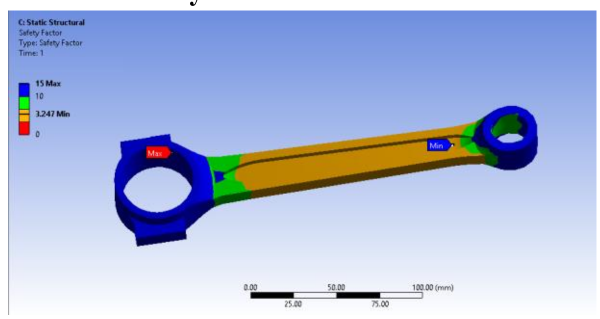
Deformation Analysis of Connecting rod on Al-Silicon-Fly-Ash at pressure 8*10^6 pa

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 pa

6. CONCLUSIONS

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 Mpa**and 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 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 senergy 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.

REFERENCES

1. A Textbook of Machine Design by R.S.KHURMI AND J.K.GUPTA
2. Engineering_fundamentals_of_the_internal_combustion_engine by Willard W. Pulkrabek
3. Mechanical Engineering Design by Budynas−Nisbet
4. Manufacturing Process For Engineering Materials, 5th Edition by j.mater
5. Automotive Engineering by Patric GRANT.
6. Handbook of mechanical engineering - modern manufacturing by Ed. Frank Kreith
7. Automotive.Production.Systems.and.Standardisation by WERNER.
8. Engineering Fundamentals of the Internal Combustion Engine by Willard W. Pulkrabek