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Structural and Thermal Analysis of IC Engine Connecting Rod Using Ansys

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ABSTRACT

The connecting rod is a greater link inside of combustion engine. It combine the plunger to the crankshaft and is answerable for transferring power from the piston to the crankshaft. It has to work on high r.p.m because of which it has to severe stressed which make its design living for internal combustion engine. In this paper, design of connecting rod for IC engine by analytical method. On the base of that mean a physical model is created in CATIA V5. Structrural analysis of connecting rod has been analyzed using FEA. With the use of FEA various stresses are adapted for a appropriate loading conditions FEA software ANSYS WORKBENCH 14.5. Structural and Thermal analysis done on different materials(C70 steel and ALSIC). The obtained results (Stresses, Shear Stress, Total deformation, Strain, Temperature distribution, Heat flux) based on results concluded the suitable material for connecting rod and more compared on the base of various performances.

Keywords:— *Catia, Ansys, Connecting rod, Thermal analysis, Structural analysis.*

I. INTRODUCTION

The internal combustion engine is essentially a crank-slider mechanism, wherever the slider is that piston in this case. The piston is affected up and down by the rotation of crankshaft. The piston is encapsulated inside a combustion chamber. The combustion of a fuel happen with associate oxidizing agent in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the growth of the high-temperature and high-hitting gases created by combustion applies direct force to piston. This force moves the part over a distance, named as connecting rod, crankshaft, which transforms chemical energy into useful mechanical energy. It acts as a linkage between piston and crank shaft. The small end of connecting rod attaches to the piston pin, gudgeon pin (the usual British term) or wrist pin, that is presently most frequently press fit into the connecting rod however swivel within the piston. The other end, the bigger end being connected to the crankshaft. The main function of connecting rod is to transmit the translational motion of piston to rotational motion of crank shaft. The function of the connecting rod also involves sending the thrust of the piston to the connecting rod. The connecting rods subjected to a fancy state of loading. It undergoes high cyclic load of eight nine order ten to10 cycles, that is why it comes underneath the influence of different types of loads in operation. Fatigue loading is one amongst the prime causes causative to its failure. The most stress occurs within the connecting rod close to the piston end due because of thrust of the piston. The tensile and compressive stresses are produced because of the gas pressure, and bending stresses are produced due to centrifugal result. Because of these factors, the connecting rod has been the subject of analysis for various aspects such as production technology, materials, performance simulation, fatigue parameter etc. The foremost common materials which are being used for Connecting rods are steel and aluminium. The foremost common types of manufacturing processes are casting, forging and powdered metallurgy from the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight. So the connecting rods are designed generally of I-section to provide most rigidity with minimum weight.

II. Literature Review

Vivek C. Pathade, Bhumeshwar Patle and Ajay N. Ingale,[1] the stress analysis of connecting rod by Finite Element Method using Pro/E Wildfire 4.0 and ANSYS WORKBENCH 11.0 Software. Bin Zheng Stress distribution and fatigue life of CR in light vehicle engine were analyzed using the commercial 3D finite element software, ANSYSTM. The results showed that the medial surface of small end will be the critical surface whereby damage will initiate at the maximum stretch condition. The most stress and deformation values are 190.23 MPa and 0.0507mm respectively. The critical location is at the transition region between the big end and connecting shank at maximum compression condition. The most stress and deformation values are 459.21 MPa and 0.0702283 mm respectively. Safety factor is 1.584. In order to increase the reliability of CR, some improvement is carried out. Safety factor of CR increases by 59%[2]. Ramesh N.G[3]A connecting rod for 2 wheeler is designed by analytical method. On the basis of that design a physical model is created in CATIA V5. Structural analysis of connecting rod has been analyzed using FEA. With the use of FEA various stresses are calculated for a particular loading conditions using FEA software ANSYS WORKBENCH 14.5. The similar work is carried out for dissimilar material. Also the thermal analysis of the connecting rod is performed.. Abhinav Gautam[4] Static stress analysis of connecting rod made up of SS 304 used in Cummins NTA 885 BC engine is conducted, using finite element method. After measuring the dimension of connecting rod, model is developed in CATIA V5 software and imported to ANSYS WORKBENCH 14.0 software. Static analysis is done by fixing the smaller end and load is applied at bigger end of connecting rod. Stress developed at four totally different sections is used for analysis. The most stress point and section prone to failure is finding out by this analysis. H. B. Ramani and P. M. Kasundra [5]Detailed load analysis was performed on connecting rod, followed by finite element method in Ansys-13 medium. In this regard, In order to estimate stress in Different part of connecting rod, the total forces exerted connecting rod were designed and then it was modeled, meshed and loaded in Ansys software. Shahrukh Shamim,[7] Finite element analysis of connecting rod used in single cylinder four stroke petrol engines is taken for the study. Static stress analysis is conducted on connecting rod made up of two dissimilar materials viz. E-glass/Epoxy and Aluminium composite reinforced with Carbon nanotubes. Modelling and comparative analysis of connecting rod is carried out in commercially used FEM software ANSYS fourteen. Static structural analysis was done by fixing the piston end and applying load at the crank end of the connecting rod. Output parameters in static stress analysis are von-Mises stress, Shear stress, total deformation and equivalent elastic strain for the given loading condition.

III. Problem Statement

The objective of the present work is to determine the stresses in critical areas, the spots in the connecting rod where there are more chances of failure. The different dimensions of the connecting rod for Structural Steel is calculated through analytical method. Calculated loads are applied at one end and the other end kept fixed. Same process is carried out for Aluminium alloy. Finally both results are compared for performance, various Stress, Strain, Shear stress, Total deformation, Temperature distribution, Total heat flux.etc. and best alternative is defined. Connecting rod model was created in CATIA V5. After that the model is imported in ANSYS 14.5 (Workbench) for analysis.

Design for Pressure Calculation:

Consider 150cc Engine

Specifications

Engine type = air cooled 4-stroke

Bore x Stroke (mm) = 57 x 58.6

Displacement = 149.5CC

Maximum Power = 13.8 bhp@8500 rpm

Maximum Torque = 13.4 Nm @ 6000 rpm

Compression ratio = 9.35:1

Density of Petrol (C_8H_{18}) = 737.22 kg/m^3

737.22 x 10 $^{-9}$ kg/ mm^3

Auto ignition temp = 60^{0}F = 288.85^0 K

Mass = Density x Volume

737.22 x 10^{-9} x 149.5 x 10^3 = 0.110214 kg

Molecular weight of petrol = 114.228 g/ mole

=0.11423 kg/mole

From gas equation

$PV = m \times R_{specific} \times T$

Where

P= Gas Pressure, Mpa

V= Volume

M= Mass kg

T = Temperature

$R_{specific}$ = Specific gas constant = R/M

$R_{specific}$ = 8.3144/0.114228

$R_{specific}$ = 72.788 Nm/kg-K

$PV = m \times R_{specific} \times T$

P = 0.110214 x 72.788 x (288.85/149.5)= 15.49 Mpa

Calculation is done for maximum Pressure of 16 Mpa.

Properties of Material (Al360 material):

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion and deformation, and their ability to hold a cutting edge at elevated temperatures. As a result, tool steels are suited for use in the shaping of other materials. With a carbon content between 0.5% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality. The presence of carbides in their matrix plays the dominant role in the qualities of tool steel. The four major alloying elements that form carbides in tool steel are: tungsten, chromium, vanadium and molybdenum. The rate of dissolution of the different carbides into the austenite form of the iron determines the high-temperature performance of steel (slower is better, making for a heat-resistant steel). Proper heat treatment of these steels is important for adequate performance.

Table 1: Material Properties of C70 Steel

Material Properties	C70 Steel
Young Modulus(E)	210 Gpa
Passion's ratio	0.33
Tensile Ultimate Strength	480Mpa
Tensile Yield Strength	380Mpa
Density	7.8g/cc
Specific heat capacity	450 J/kg-K

ALSIC:

It is one of the powerful parts of a modern racing engine. The fault can come from any number of places, but the failure often occurs at the connecting rod because of the stresses involved and change over the linear motion of the piston to the rotary motion of the crankshaft. The each stroke, the connecting rod is stretched and pressed. In this pressure, plus another elements, can make the connecting rod to terminate. The broken rod is move through the engine block completely and run the engine, a condition known as "throwing a rod." The connecting rod often fails due to either of Over Reviving, Pin Failure, Stress Failure, Fatigue Failure or Hydro-lock. Manufacture of Al/SiC by Stir Casting methods shown in Figure 1. The liquid Infiltration Process involved in infiltration of a fibrous reinforcement, it's preformed using a liquid metal. Liquid-phase infiltration of MMCs is not straight forward; it's mainly trouble with wetting, ceramic reinforcement used as the molten metal. The percolation of a fiber material to perform come about readily, reactions among the fiber and the molten metal may fall out which implication degrade the main properties of the fiber materials. The fiber coating is used to apply prior the implication, it is developing the leak and allows the control of interface reactions, which is improved and also generating some promotive results. This study even if, the weakness is that the fiber coating essential mot be unprotected the air prior to infiltration because surface oxidation of the coating fall out. One liquid infiltration process is involving particulate reinforcement, known as Dural can process it has been quite powerful and efficient. Ceramic particles and ingot-grade Al is blended and melted. The melt is agitated slightly above the liquids temperature around (600-700°C). The solidified is also under the secondary processing by rolling. The Duralcan process of producing the particulate composites by a liquid metal casting route involved and were 8-12 µm particles is used. For particles that are very small size (2 -3 µm), result shows the very high interface region and a varying the viscous melt. In foundry -grade Metal Matrix Composite, high Si aluminum alloys (e.g., A356) is used to prevent the formation of the brittle compound Al4C3, which is formed from the interfacial reaction between Al and SiC, Al4C3 is particularly damaging to mechanical properties, toughness and corrosion resistance.

Table 2: Material Properties of ALSIC

Material Properties	ALSIC
Young Modulus(E)	280
Passion's ratio	0.34
Tensile Ultimate Strength	490
Tensile Yield Strength	385
Density	2.8g/cc
Specific heat capacity	490 J/kg-K

Design Calculation for the Connecting Rod

Thickness of the flange & web of the section = t

Width of the section B= 4t

Height of the section H= 5t

Area of the section A = $11t^2$

Moment of Inertia about x- axis, I_{xx} = $34.91\ t^2$

Moment of Inertia about y-axis,I_{yy} = $1091\ t^4$

Therefore I_{xx}, I_{yy} = 3.2

Length of the connecting rod (L) = 2 times stroke

L = 117.2

Total Force acting F = $F_p - F_1$

Where

Fp = force acting on the piston

F_1 = force of inertia

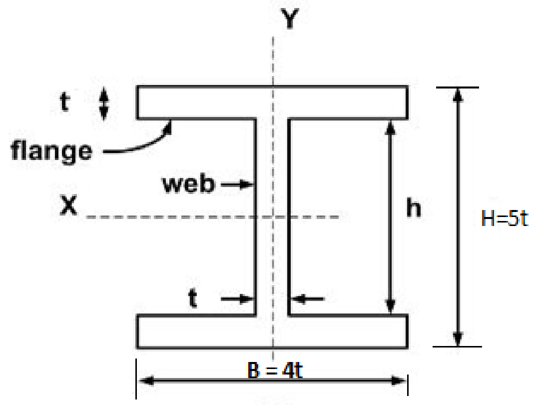

Figure 1 : I-Shape Section

F_p = Πx D^2/4 X Gas pressure

Where

D = Bore Diameter

Fp = Πx57^2/4 X 15.49 = 38275N

F1 = n x $ώ^2$ x r (cosϕ + $\frac{\cos 2\phi}{N}$)

Where

M = Mass = $\frac{2\Pi\ 8500}{60}$ = 890.118 rad sec

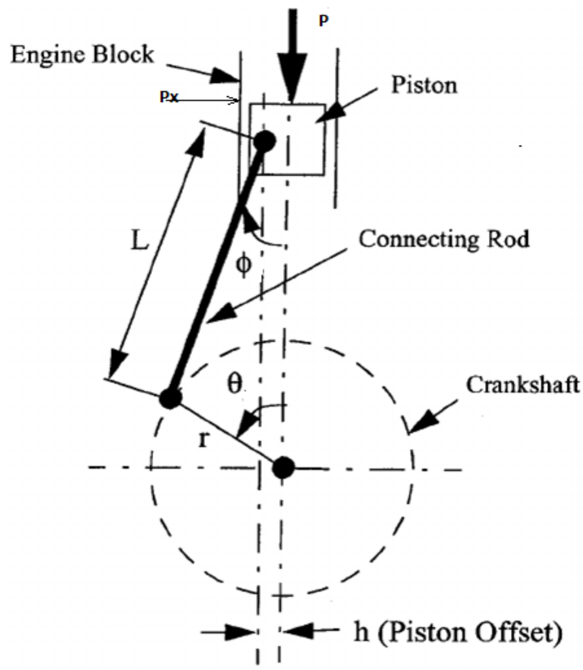

Figure 2: Connecting rod

N = length of connecting rod (l)/ crank radius(r)

= (2 x stroke) / (stroke/2)

= 117.2/29.3

n =4

The maximum gas load occurs shortly after the dead centre position at $\phi = 3.3°$

Cos 3.3= 0.9983 =1

$F_1 = 0.110214 \times 890.11822 \times 0.0293\ (1 + ¼)$

= 3200

F = 38275 -3200N =35075 N

Table 3: Connecting Rod Parameters

Parameters	**Size(mm)**
Thickness(t)	5.5
Width(4t)	22
Height(5t)	27.5
Height at the small end (H1)	24.75
Height at the big end (H2)	34.375
Inner dia. of the small end	35
Outer diameter of small end	49
Inner diameter of the big end	45
Outer diameter of big end	63

IV: Results and Discussion

Structural Analysis of connecting rod:

Combustion of gases in the combustion chamber exerts pressure on the head of the connecting rod during power stroke. The pressure force will be taken as boundary condition in structural analysis. Fixed support has given at surface of big end once and small end once. Due to the connecting rod will move from TDC to BDC(rotary motion) with the help of fixed support at big end and apply load small end. So whatever the load is applying on connecting rod due to gas explosion.

Meshing

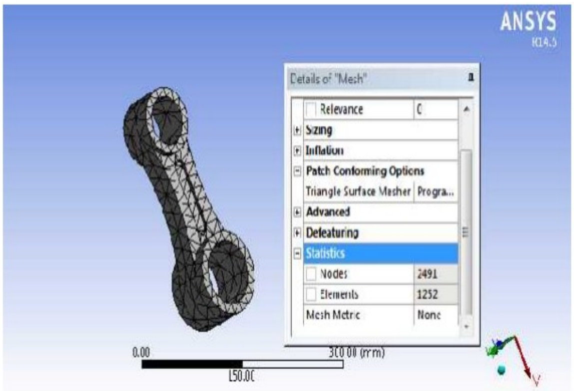

Figure 3: Maximum number of Nodes: 2491 and Elements: 1252

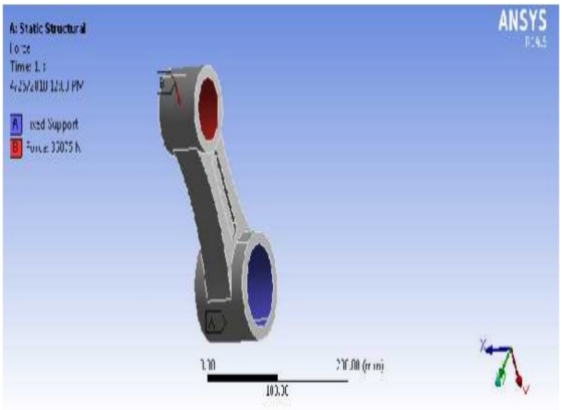

Figure 4: Connecting rod big is end fixe d and load is applied on the small end

Boundary Conditions and in Static Analysis:

Maximum apply force at the connecting rod small end 35075 N Mpa and fixed the big end.

The constructed connecting rod in catia is analyzed using ANSYS V14.5 and the results are depicted below. Combustion of gases in the combustion chamber exerts force on the head of the connecting rod small end during power stroke. Fixed support has given at big end Because the piston will move from top dead centre to bottom dead centre.

Analysis of C70 ST EEL Connecting Rod

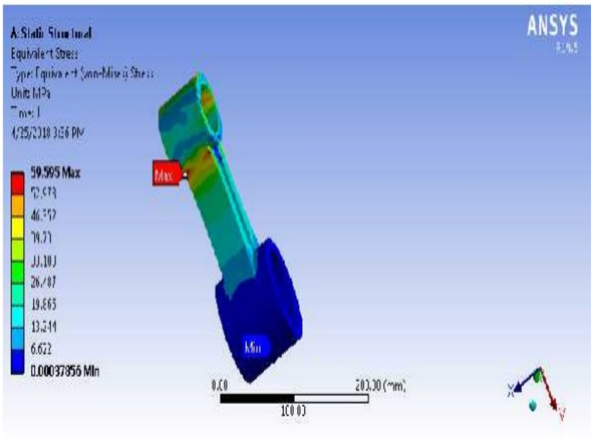

Figure 5: Stress of C70 ST EEL Connecting Rod

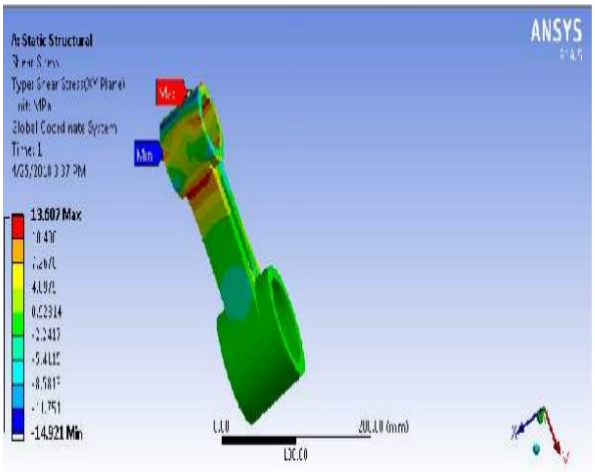

Figure 6: Shear Stress of C70 ST EEL Connecting Rod

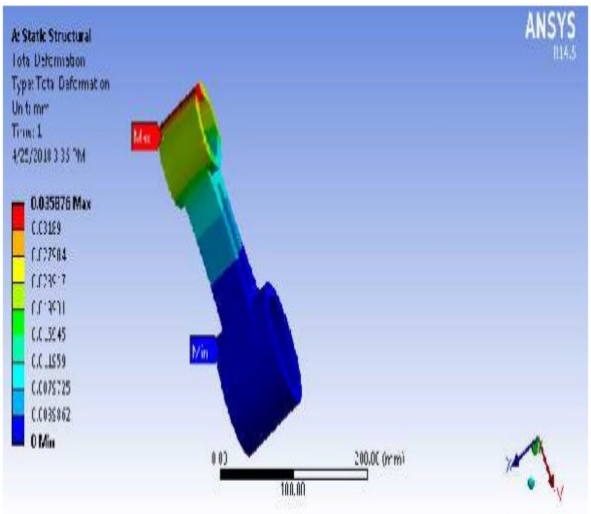

Figure 7: Total Deformation of C70 ST EEL Connecting Rod

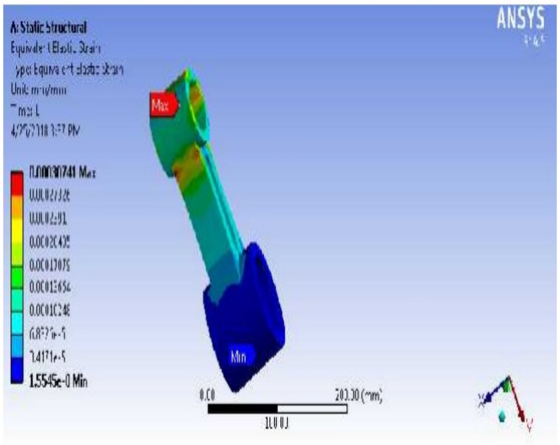

Figure 8 : Strain of C70 ST EEL Connecting Rod

Analysis of Aluminium Alloy (AL-SIC) Connecting Rod

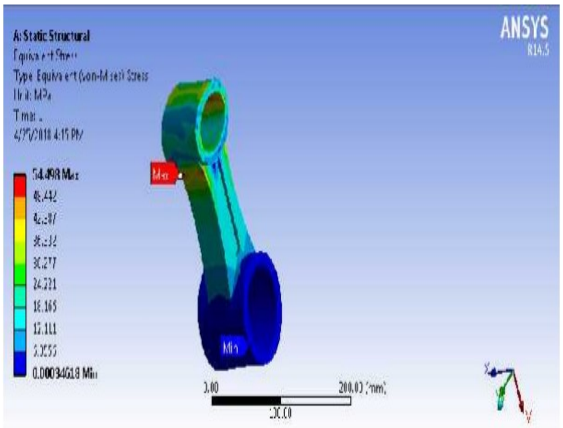

Figure 9: Stress of Aluminium Alloy (AL-SIC) Connecting Rod

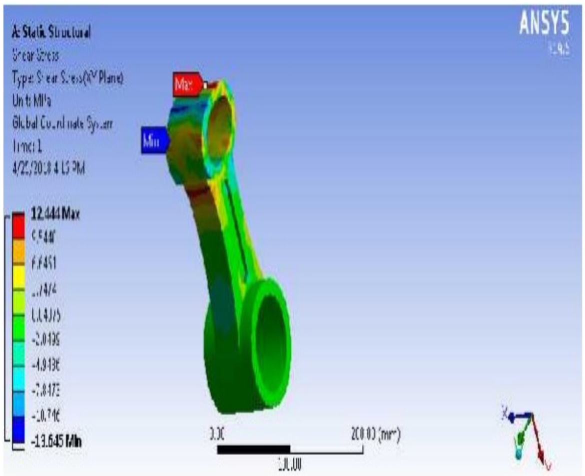

Figure 10: Shear Stress of Aluminium Alloy (AL-SIC) Connecting Rod

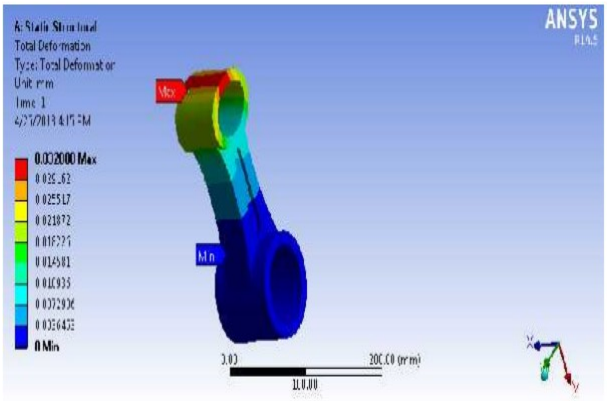

Figure 11: Total Deformation of Aluminium Alloy (AL-SIC) Connecting Rod

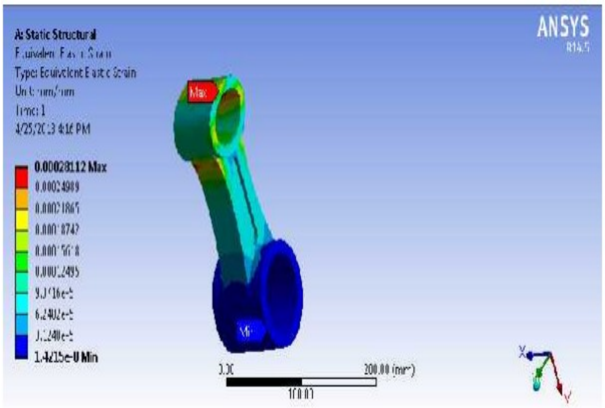

Figure 12: Strain of Aluminium Alloy (AL-SIC) Connecting Rod

Thermal Analysis

C70 Steel Connecting Rod

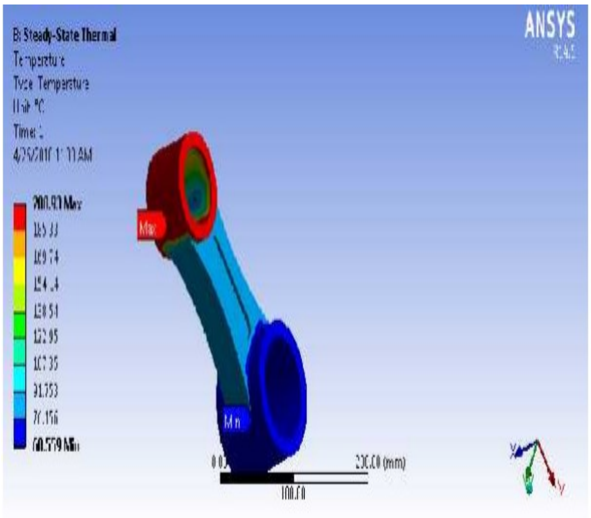

Figure 13: Temperature Distribution on C70 Steel

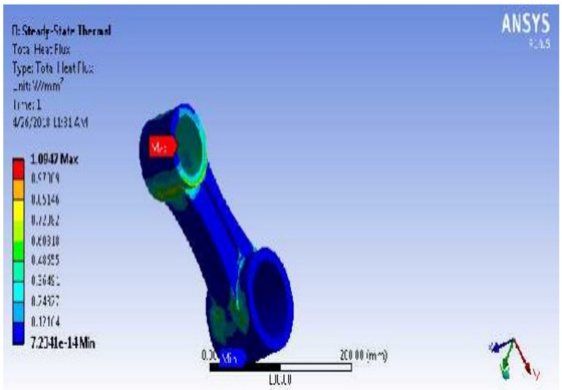

Figure 14: Total Heat Flux on C70 Material

AL-SIC Connecting Rod

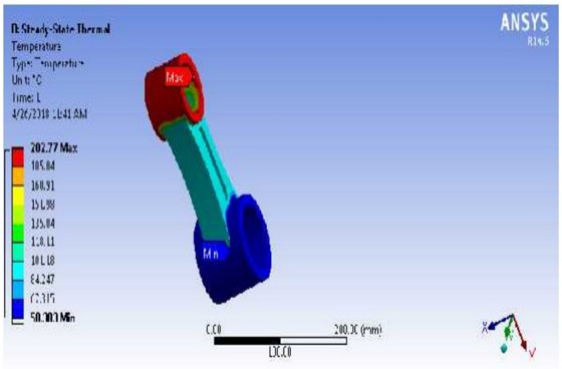

Figure 15: Temperature Distributions on AL-SIC

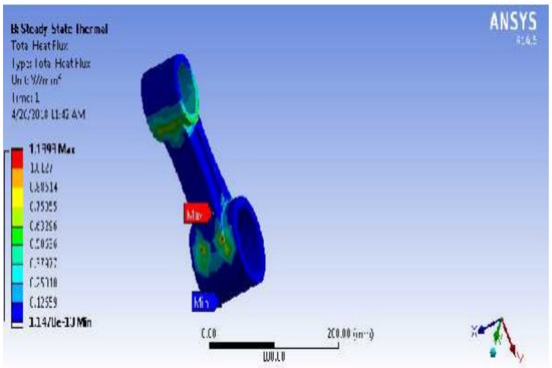

Figure 16: Total Heat Flux on AL-SIC Material

The static structural analysis of C70 Steel, Al-sic are done we are taking load conditions are fixed big end and apply load small end and results are obtained for Equivalent (Von-Mises) stress, shear stress, strain, total deformation. These results are plotted graphic ally and a comparison is made between these results.

Von-Mises Stress(Mpa):

We can observe that in case of equivalent (von-mises) stress, connecting rod made of c70 steel and Al-sic finally alsic is found to have least stress of 54.498Mpa as shown in figure 17.

Equivalent Strain

We can observe that in case of strain, connecting rod made of c70 steel and Al-sic finally Alsic is found to have least strain of 0.00028Mpa as shown in figure 18.

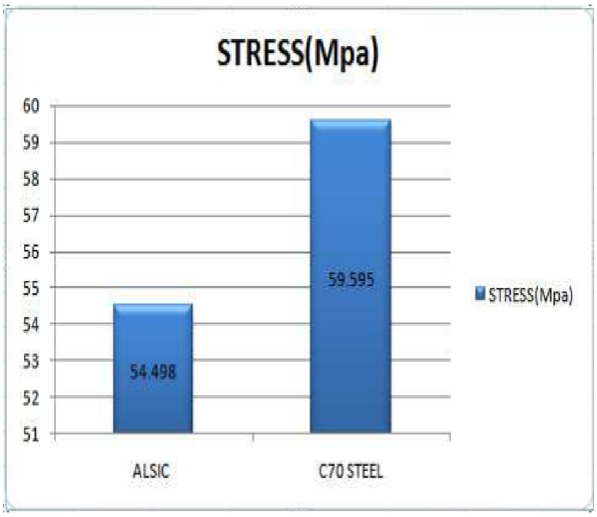

Figure 17:Variation of Stress in different materials

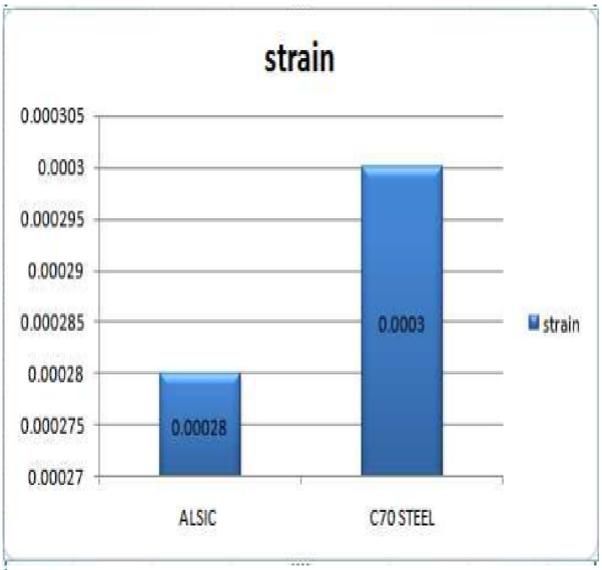

Figure 18: Variation of Strain in different materials

Total Deformation: From Graph total deformation, connecting rod made of c70 steel and Al-sic finally Alsic is found to have least deformation of 0.00028 as shown in figure 19.

Shear Stress: From graph Shear stress, connecting rod made of c70 steel and Al-sic finally Alsic is found to have least shear stress of 12.44Mpa as shown in figure 20.

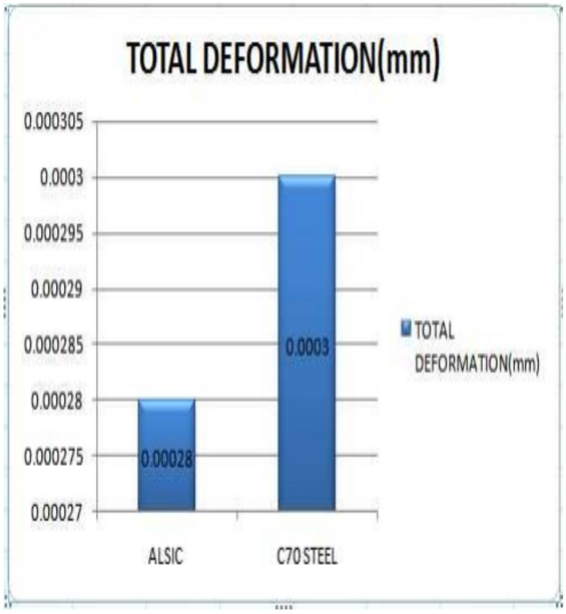

Figure 19: Variation of Total deformation in different materials

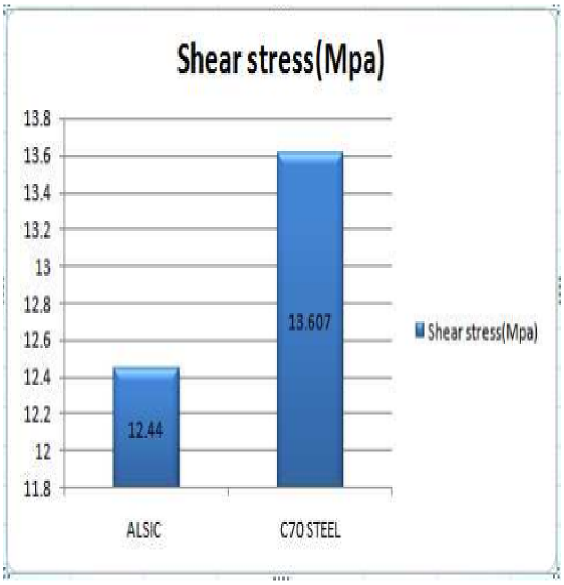

Figure 20 : Variation of Shear Stress in different materials

Temperature Distribution:

we can observe that in case of temperature distribution, connecting rod made of c70 steel and Al-sic finally Al SIC is found to have high temperature distribution as shown in figure 21.

We can observe that in case of Total heat flux, connecting rod made of c70 steel and Al-sic finally Al sic is found to have high heat transfer as shown in figure 22.

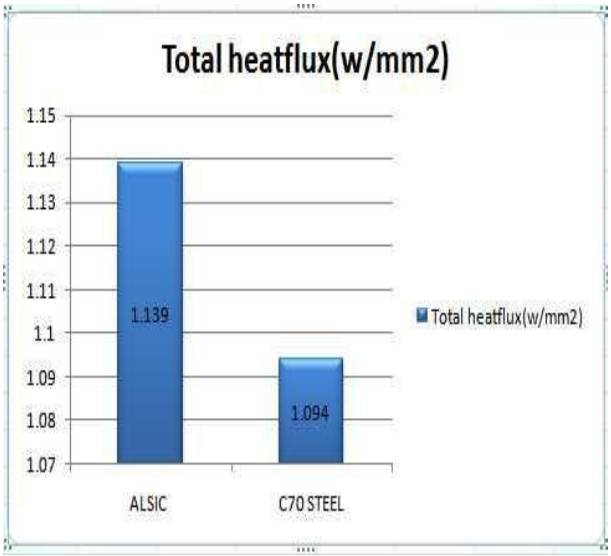

Figure 21:Variation of temperature distribution in different materials

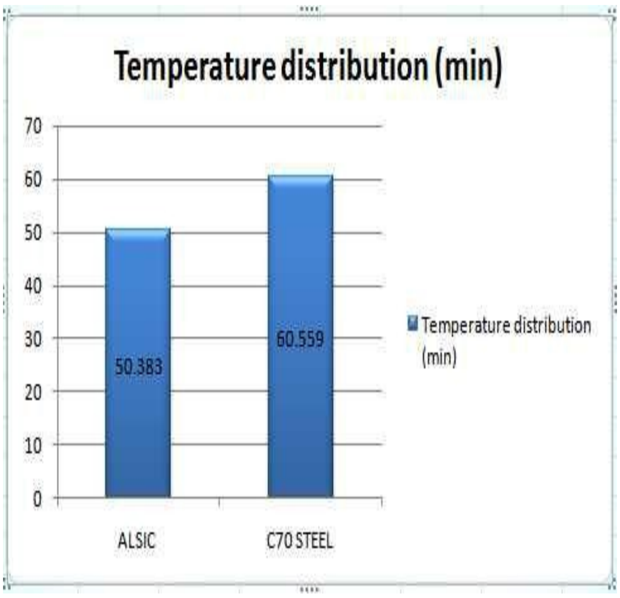

Figure 22 :Variation of Total heat flux in different materials

IV. CONCLUSION

Connecting rod plays an important role in IC engine, Design and analysis done with different materials Design of connecting rod. In this present work, connecting rod created in software CATIA we are taking specifications pulsar 150cc dimensions apply theoretical value loads different material C70 and ALSIC in ansys workbench, finally find out ALSIC material is suitable for the IC engine connecting rod we concluded based on the stresses, shear stress, strain, total deformation, temperature distribution, heat flux values so proceed manufacturing process ALSIC.

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