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Comparative Study of Stress Analysis on Connecting Rod Using FEM

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Abstract*— Lightweight with high strength is the need of an hour. Connecting rod (CR) is necessary component of any engine, either engine is working on the principal of Compression Ignition system or Spark-Ignition system. The production of the connecting rod is done on very large scale due to the necessity of the connecting rod use in new vehicles production and also replacement of connecting rod in older vehicle and it increase exponentially day by day. Connecting rod (CR) is deliver to very large cyclic loading which is multiple of 108 to 109 cycles, there are two type of load are acting under the working of connecting rod (CR) fist one is high compressive load due to the combustion which is undergoes in cylinder and second one is the huge tensile load offered by inertia force. Objective of this research and analysis is to minimize weight of the connecting rod (CR) by changing the materials by epoxy reigns and analyses the behavior of stress distribution by through Finite Element Method (FEM) by using ANSYS 21.1 Firstly prepare a geometrical model of connecting rod of two wheeler bike engine of capacity 100 cc using SOLIDWORKS. This study analyses static load stress analysis of connecting rod (CR), which is building by using material epoxy reign. and simulate it on ANSYS Workbench – 21.1 and obtained the result of maximum stress analysis and verify this value through mathematical data.

***Index Terms*— Connecting rod, ANSYS, Epoxy Resin, Von-mises stress, equivalent stress, deformation**

I. INTRODUCTION

In the IC (internal combustion) engine either it is SI (spark ignition) or CI (combustion ignition) engine, connecting rod is an essential component which transfer the motion of piston to crankshaft by acting a mechanism lever arm. Generally connecting rod (CR) is made up of the cast aluminum alloys, steel alloys and titanium alloys. And this is designed to resist to dynamic load induced by combustion and the inertia of the piston. The piston end which is small circular end of the connecting rod (CR) is joined through the piston with the piston pin and this connecting pin is known as connecting pin. And it run as a pivot. Spring clips frequently known as piston pin locks, which is used at the place of the piston pin. The large circular end (crank end) of a connecting rod (CR) is connected to crank pin journal for produce a critical point on the crankshaft. One piece of connecting rod (CR) is offered, the rod is joint to the connecting rod by using two cup screws for setup and separation from the crankshaft.

Shete et al. [1] studied a comparative study of stress distribution of an internal combustion engine piston using Photoelastic and finite element techniques**,** Mekalke et. al. [2] investigate the behavior of supplementary loading on a pre-stretched plate with circular hole using different types of meshes. (Gopinath & Sushma in 2021, [3] A study of the static loading and development of a connecting rod (CR) was carried out. Geometry was designed in Catia, and the stress induced was assessed using FEA on the rod with ANSYS 11.0. The FEA analysis was performed on three materials: steel, aluminum, and titanium, finding differences in von Mises stress between the three this is done in the year of 2015.

According to the literature evaluations, numerous studies are still looking for the most rigid and lightweight materials for the highly stressed sections of a connecting rod. These studies provide a greater emphasis on analyzing the design of two-wheeler connecting rods made of various materials. The analytical and numerical findings for the various materials chosen are assessed since the current study covers the modelling of connecting rod using SOLIDWORKS 2021 and its analysis with using material epoxy resign by using ANSYS workbench. As a result, these composites are recommended for the production of connecting rods for automobiles.

II. MATERIAL DETAILS

Epoxy resin is very widely used materials in now days this is very light weight and having very high strength here is some property of epoxy resin are given bellow-

Table -1: property of epoxy resin

Property	Data
Density	1160 kg/m^3
Young's Modulus (E)	3.78×10^6 MPa
Poisson's Ratio (v)	0.35
Bulk Modulus (K)	4.2×10^6 MPa
Shear Modulus (G)	1.4×10^6 MPa
Tensile Yield Strength	5.46×10^4 MPa

The solidification time for the epoxy resin is approximately 24 hours at the normal environment which is generally at room temperature. When we use the epoxy with hardener in the ratio of 1:3.

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III. CONNECTING ROD DESIGN

Connecting rod (CR) is an essential component of automobile engine, which consist mainly three component shank-rod, crank end (big circular end) and small circular end. There are the specifications of the connecting rod (CR) is given bellow-

Table -2: Specifications of Bajaj Discover 100cc.

Specification	Data
Compression Ratio	9:1
Displacement	94 cc
Number of Cylinders	1
Maximum Power	8 brake HP at 7500 rpm
Maximum torque	8 N-m at 5000 rpm
Bore	47 mm
Stroke length	54 mm
Valves per cylinder	2
Fuel delivery through	Carburetor
Type of Fuel	Petrol
Type of Ignition	Digital CDI
Spark Plugs	2 per cylinder
Type of Cooling system	Air cooling
Number of gears	4
Type of Gear box	Manual
Transmission type	Chain drive
Type of Clutch	Wet multiplate

Table -3: Dimensions of the connecting rod used for analysis.

Dimension	Value
Overall length	126.5 mm
Width of CR	40 mm
Thickness of CR	14 mm
Shank thickness	5.50 mm
Big end inner diameter (crank end)	30 mm
Small end inner diameter (pin end)	13 mm
Big end outer diameter (crank end)	40 mm
Small end outer diameter (pin end)	17 mm
Length from centers of both ends	97 mm

Design and Sketch diagram of CR in solid works 2021

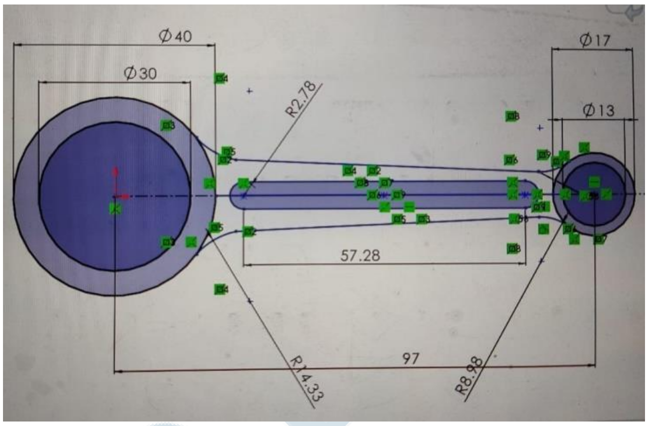

Fig -1 sketch of CR

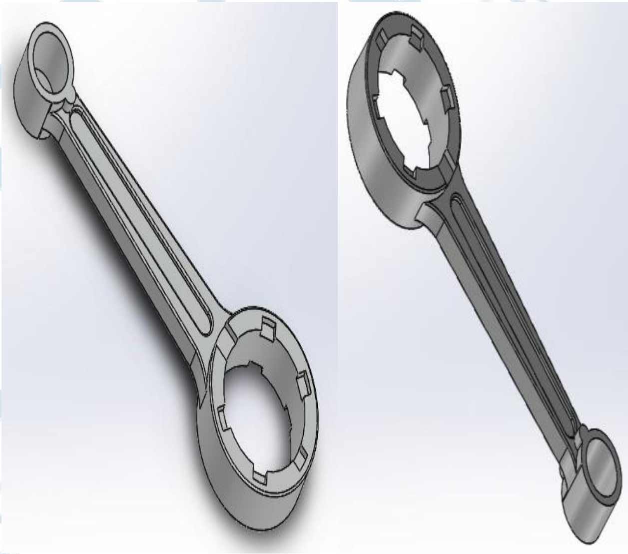

Fig - 2 design of CR

IV. MATHEMATICAL FORMULATIONS

In a complete revolution of a crankshaft, connecting rod (CR) is exerted two type of load which is direct compressive load and tensile load. Maximum compressive force exerted by the connecting rod (CR) is corresponding to the force generate on piston due to the maximum combustion pressure.

$F = \frac{\pi}{4} d^2 \times$ maximum combustion pressure = 5321.172 N

Rankine's formula is taken from machine design book [12], for the mathematical formulations and to find the value of thickness.

$$W_B = \frac{\sigma_c . A}{1+a\left(\frac{L}{K_{xx}}\right)^2}$$

t = 3.1 mm ……… W_B = maximum combustion force × Factor of safety

I- section width, (B) = 4t = 4× 3.1 = 12.4 mm

I- section height, (H) = 5t = 5× 3.1 = 15.5 mm

All these dimension of connecting rod (CR) is taken at intermediate section of connecting rod (CR). Width of the CR is uniform over the length, but height of the CR is varying throughout the length. To find dimension of large circular end and small circular end balance the load to the maximum combustion force,

Height nearby large circular end (crank end), H_1= 1.2H = 1.2×15.5 = 18.4 mm

Height nearby small circular end (piston end), H_2= .85H = 0.85×15.5 = 13.2 mm

Diameter of the large end bearing (d_c) = 29.79 mm

Crank pin length, l_c = 1.3 d_c = 38.72 mm

External diameter of large circular end = d_c + $2t_m$ = 35.79 mm

Diameter of the small end bearing (wrist pin) (d_p) = 13.3 mm

Wrist pin length, l_p = 2 d_p = 26.63598 mm

External diameter of small circular end = d_p + $2t_m$ = 16.421mm

All of these dimensions of connecting rod (CR) is approximately to the dimensions of actual connecting rod (CR) of two wheeler bike. By taking the measured dimension, a 3-D design of connecting rod (CR) of two wheeler bike made by using SOLIDWORKS 2021 platform. The design shown in fig-2.

A. MESH GENERATION OF CONNECTING ROD (CR)

Mesh generation is known as the grid generation, which is dominated for the accurate solution. Normally meshing have important role on convergence rate, precise solution and processing time.

According to the size changes of meshing element at point than the stress value also changes at that point. Here in this analysis parabolic tetrahedral element is taken with another element. 2.5 mm length elements having 4472 elements, 2mm length element having 8614 elements, 1.5 mm length element having 17579 elements and 1mm length element having 28667 elements. For fine mesh size we conducted convergence test. Von-mises stresses is located at critical position which shown in analysis Including all positions shown in the figure 3 show that the changing area takes place with 1.5mm size in element length. The local mesh size is used in place of some very sensitive area in simulation, having element length of 1mm. According to the figure 3. it shown that the convergence has to been attained with 1.5 mm element length and local mesh element length 1mm.

According to the fig .3 it shown that the meshed model of connecting rod having total 20798 elements and 34974 number of nodes.

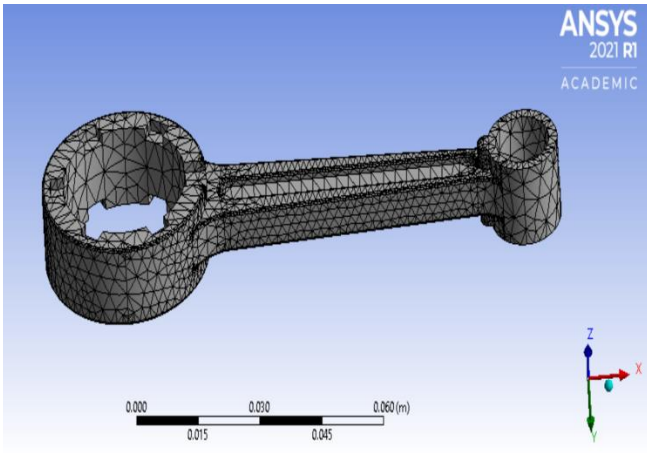

Fig - 3 Mesh generation of CR

B. TWO CASE OF BOUNDARY CONDITIONS

The study of stress of forged steel connecting rod under static load condition was operated in both tension and compression for compressive load 5321.072N (Maximum combustion force).

The general combustion pressure applied to the piston is given by,

P_0 = P Cos (Θ)------------ where P_0 is Normal pressure constant

The force exerted on connecting rod is find out by using the pressure (P), and this acting force is similar to the maximum force acting on the piston end applied due to burning of fuel (combustion). The large circular end (Crank pin) and small circular end (piston pin) generate the sinusoidal load deliver under tensile load throughout the contact surface and this load are scattered throughout an angle of 18o (webster.et.al) and it show in fig .4, the total tensile load is calculated by,

$P_t = P_0 / r' \, t' \, \frac{\pi}{2}$ ..... P_t = Tensile load along the length of CR,

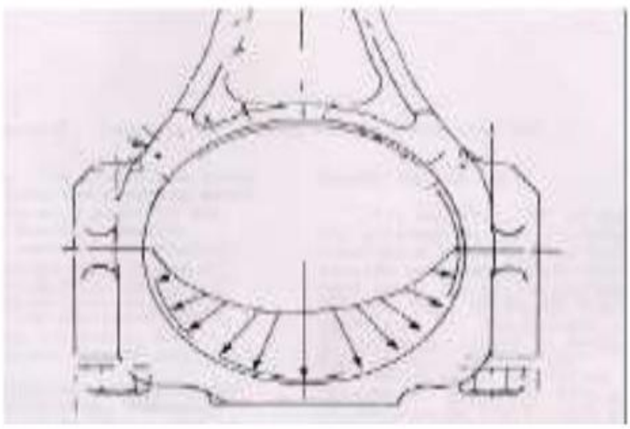

Fig - 4 Tensile loads generation [8]

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Under the compressive loading the crank pin and piston pin is exerted to equal distributed load throughout contact surface and this load are scattered throughout an angle of 120. The overall compressive load is given by,

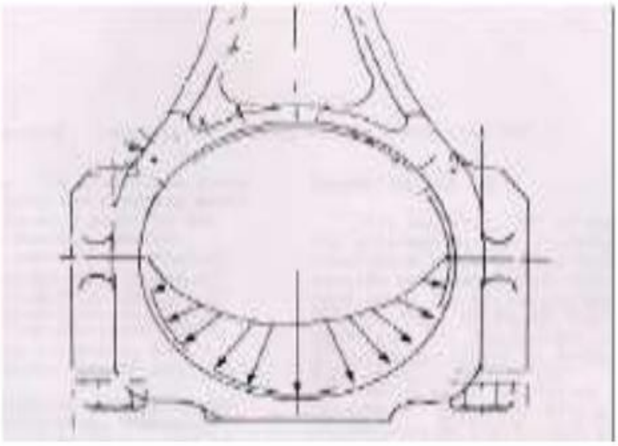

Fig - 5 Compressive loads generation [8]

$P_c = P_0 / r' \, t' \sqrt{3}$ .... P_c = Compressive force along length of connecting rod,

In this study and analysis all data is belong to linear static analysis. In this analysis there are two conditions which were analyzed for each case, in the first conditions the small circular end (piston end) is fixed and the load is acting at the large circular end (crank end), and in the second situations the load is acting at the small circular end (piston end) and the large circular end (crank end) is fixed. In this study prove, load is applied axially is equal to the maximum combustion force i.e. 5321.072 N in the both conditions either it is compressive or tensile.

Compressive loading

At crank end, $P_0 = \frac{5321.072}{15\times12.4\times\sqrt{3}} = 16.516$ MPa

At piston end, $P_0 = \frac{5321.072}{6.5\times12.4\times\sqrt{3}} = 38.115$ MPa

Tensile load

At crank end, $P_0 = \frac{5321.072\times2}{15\times12.4\times\pi} = 18.221$ MPa

At piston end, $P_0 = \frac{5321.072\times2}{6.5\times12.4\times\pi} = 42.049$ MPa

V. RESULT OF STATIC STRUCTURAL STRESS ANALYSIS

In this first condition analysis, the maximum von-mises stresses distributions on connecting rod by using materials epoxy resin under the operating and loading conditions. The maximum value of equivalent stress is 500.94 MPa over axial compressive load when the small circular end is fixed and the load is providing to the large circular end.

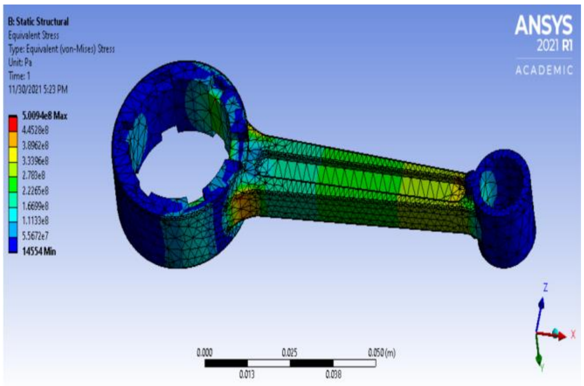

Fig - 6 von-mises stress under compressive load at crank end

In the second conditions analysis, the maximum value of equivalent stress is 1628.1 MPa under the compressive load conditions. Where the fixed support is provided on the large circular end and the load is subjected to the small circular end.

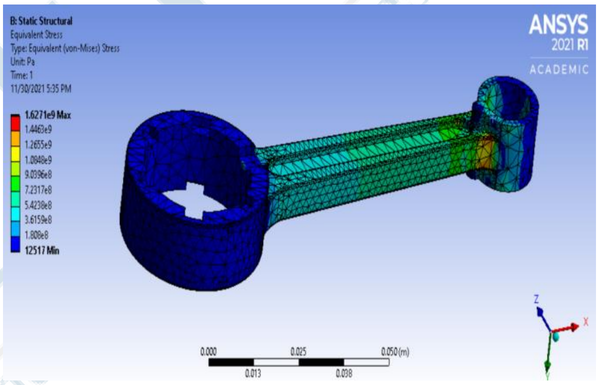

Fig - 7 von-mises stress under compressive load at piston end

In the third conditions analysis, the maximum value of equivalent stress is 1086.6 MPa under the tensile load conditions. when the small circular end is fixed and the load is subjected to the large circular end.

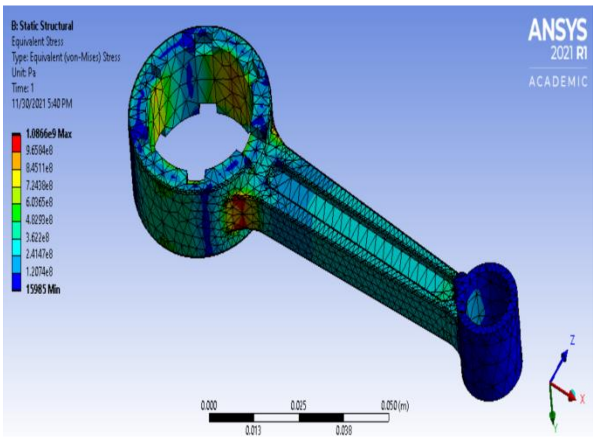

Fig - 8 von-mises stress under tensile load at crank end

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In the fourth conditions analysis, the maximum value of equivalent stress is 4588.9 MPa under the tensile load conditions. Where the fixed support is provided on the large circular end and the load is subjected to the small circular end.

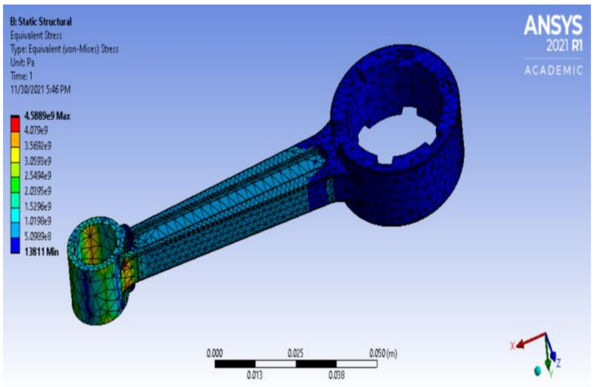

Fig - 9 von-mises stress under tensile load at piston end

VI. RESULT OF TOPOLOGY OPTIMIZATION

In this analysis during development it is found that the existing optimum connecting rod (CR) is replaceable with existing present connecting rod by changing some modifications at piston end (small circular end) by adding some extra material at the outer boundary to follow precautions and guidelines materials is remove from shank areas. The width of rib and the web may be reduced after some iteration is done for weight reduction after précising von-mises stress which is equivalent stress at defined locations of optimized connecting rod.

The actual weight of existing connecting rod is 108 grams but when we made the connecting rod of material using epoxy resin then the weight of connecting rod is 20 grams. The percentage of weight reduction is approximately 81.5 %.

VII. CONCLUSION

- This analysis conclude that the static load stress variation of epoxy based connecting rod (CR) over four load conditions.
- This study found that maximum value of equivalent stress exceeded over the yield strength of the epoxy at the small circular end of the connecting rod (CR).
- To reduce stress at small circular end of the connecting rod (CR) under tensile load by providing an offset and extra material over there.

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