IJITCE

ISSN 2347- 3657

International Journal of
Information Technology & Computer Engineering

Email : ijitce.editor@gmail.com or editor@ijitce.com

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 12, Issue 2, 2024

Design and Analysis of Connecting Rod using Different Materials

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Abstract:
Connecting rods are practically generally used in all varieties of automobile engines connecting rod acting as a converting intermediate link between the piston and the crankshaft of the engine, by the reciprocating motion of the piston to the rotary motion of crankshaft. Thus, this study aims to carry out for the load strain, stress, total deformation and analysis of factor of safety of pin end of the connecting rod of different materials. The components are big shank, a small end and a big end. It sustains force generated by mass & fuel combustion. The resulting bending stresses appear due to eccentricities, crank shaft, case wall deformation & rotational mass. FEA approach deals with structural analysis along with various parameters which affects its working & define best solution to overcome the barriers associated with it. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modelled using CATIA V5 R20 software and to that model, analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz. For C70 Steel, Belgium. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two-wheeler piston were done in ANSYS software.

Keywords: Connecting Rod, Analysis of Connecting Rod, Four Stroke Engine Connecting Rod, Forged Steel Connecting Rod, Design and Analysis of Connecting Rod.

I. INTRODUCTION

Internal Combustion engine has many parts like cylinder, piston, connecting rod, crank and crank shaft. The connecting rod is very important part of an engine. Working of the connecting rod is to transmit power of piston to crank pin. Connecting rod has two ends one is pin end and other is crank end. Pin end is attached with piston. The big end (crank end) is attached to the crank pin by a crank shaft. The function of crank shaft is to transmit the reciprocating motion of piston into rotary motion. The connecting rod should be such that it can sustain the maximum load without any failure during high cycle fatigue. The connecting rod has generally three parts pin end, crank end, and long shank. Design of shank can be different type like rectangular, tubular, circular, I-section and Hsection. Circular section is generally used for low speed engines. I-section is used for high speed engines. Generally connecting rods are being made up of stainless steel and aluminium alloy through the forging process, as this method provides high productivity and that too with a lower production cost. Forces generated on the connected rod are generally by weight and combustion of fuel inside cylinder acts upon piston and then on the connecting rod, which results in both the bending and axial stresses.

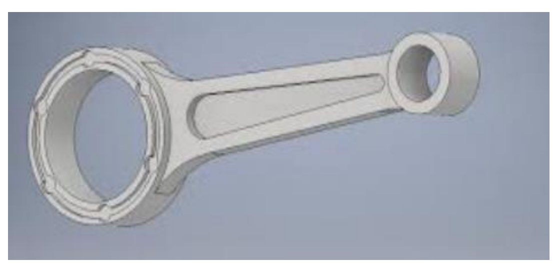


Figure1: Designing of Simple Connecting Rod.

Therefore it order to study the strain intensity, stress concentration and deformation in the crank end of the connection rod, firstly based on the working parameter and the vehicle chosen the design parameter or dimensions of the connecting rod is calculated, then the

ISSN 2347–3657

Volume 12, Issue 2, 2024

model of the connecting rod parts is prepared and finally it is analysed using Finite Element Method and results thus achieved will provide us the required outcome of the work done here .Also further study can also be carried out later on for the dynamic loading working conditions of the connecting rod and also improvement in design can also be made for operation condition and longer life cycle against failure.

Figure 2: Schematic of Connecting Rod.

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. The small end attaches to the piston pin, gudgeon pin (the usual British term) or wrist pin, which is currently most often press fit into the con rod but can swivel in the piston, a "floating wrist pin" design. The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance or from failure of the rod bolts from a defect, improper tightening, or re-use of already used (stressed) bolts where not recommended. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control. When building a high performance engine, great attention is paid to the connecting rods, eliminating stress risers by such techniques as grinding the edges of the rod to a smooth radius, shot peening to induce compressive surface stresses (to prevent crack initiation), balancing all connecting rod/piston assemblies to the same weight and Magna fluxings to reveal otherwise invisible small cracks which would cause the rod to fail under stress. In addition, great care is taken to torque the con rod bolts to the exact value specified; often these bolts must be replaced rather than reused. The big end of the rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell. Recent engines such as the Ford 4.6 liter engine and the Chrysler 2.0 liter engine have connecting rods made using powder metallurgy, which allows more precise control of size and weight with less machining and less excess mass to be machined off for balancing. The cap is then separated from the rod by a fracturing process, which results in an uneven mating surface due to the grain of the powdered metal. This ensures that upon reassembly, the cap will be perfectly positioned with respect to the rod, compared to the minor misalignments, which can occur if the mating surfaces are both flat. A major source of engine wear is the sideways force exerted on the piston through the con rod by the crankshaft, which typically wears the cylinder into an oval cross-section rather than circular, making it impossible for piston rings to correctly seal against the cylinder walls. Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore lead to longer engine life. However, for a given engine block, the sum of the length of the con rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the

ISSN 2347–3657

Volume 12, Issue 2, 2024

cylinder block where the cylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

II. LITERATURESURVEY

This section includes the literature survey of earlier research work made by various researchers on connecting rod. Various researchers presented the different techniques in the development of connecting rod and their optimization. This section presents the summary of these research works.

B. Anusha et al (2018) presented work on "Comparison of materials for Two wheeler Connecting Rod using ANSYS. The modeled connecting rod imported to ANSYS software for analysis. Analysis is done to determine von misses stresses, shear stresses and strain. In this study two materials are selected and analyzed. The result is helpful and utilize in designing the connecting rod.

Singh (2013) had conducted a study in which the conventional material of connecting rod i.e. steel or cast iron is replaced with composite material (E-Glass/Epoxy). By using FEA method von misses stresses, distortion and other effective parameters are ascertained. There was reduction of 33.9% of stresses when comparing with present material replaced with (E- Glass/Epoxy).

Leela Krishna Vegi (2018) had carried out a study in which the present material of the connecting rod is replaced by forged steel material. By comparing both the material on ANSYS the result indicates the factor of safety and stiffness increases comparable to carbon steel connecting rod. Also, there is a reduction in weight and an increase in life cycle of connecting rod having forged steel material.

Ramakrishna and Venkat (2013) had carried out a study of connecting rod of petrol engine of LML freedom. The work focused on optimization of the material in which current 4340 alloy steel connecting rods are replaced by AlSiC 9 results in a 61.65 % reduction in weight.

Prem Kumar (2015) had carried out a study in which the present material Al 6061 is replaced by Al 6061 + B4C. When compared with present material, Al 6061 + B4C have lower deformation and also sustain a low Von misses strain. Thus, result in high hardness. Bin Zheng, Yongqi Lou and Ruixiang Liu [6] had carried out a study in which the material utilized for connecting rod in small commercial vehicle is 40Cr. It was analysis that maximum compression condition increases and factor of safety of connecting rod increases by 59%.

G. Naga MalleshwaraRao et al. (2017) “Design Optimization and Analysis of a Connecting Rod using ANSYS” The aim of this work is to find opportunities for weight reduction by analyzing various material like Genetic Steel, Aluminium, Titanium and Cast Iron.

III. METHODOLOGY

The base feature is created on three orthogonal datum planes.

- Creating two circular entities on either sides of rod crank and piston pin end (with the help of sketcher Option).
- Filling the material between the crank and piston pin End (With the help of EXTRUDE Option).
- The second feature is also created on datum planes.
- Using the EXTRUDE option the second feature is generated in between the two ends of the connecting rod.
- Using the Protrude CUT option, the cut feature is generated on the second feature inorder to get the I section.
- Then the CATIA file is converted into .iges file for exporting it into the ansys software for further processing.

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the rankine formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod,{or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 12, Issue 2, 2024

3.1 Construction and Functions of Connecting Rod

There are two types of ends small end and big end bearings. The big end is split at right angles to its length as at (a) or at an angle as at (b), in order that it may be assembled on the crankpin. A cap is fixed to the body of the connecting rod by two bolts and nuts. Modern engines do not have bearing metal fused to the bore of a big end, but it uses separate low carbon steel bearing shells.

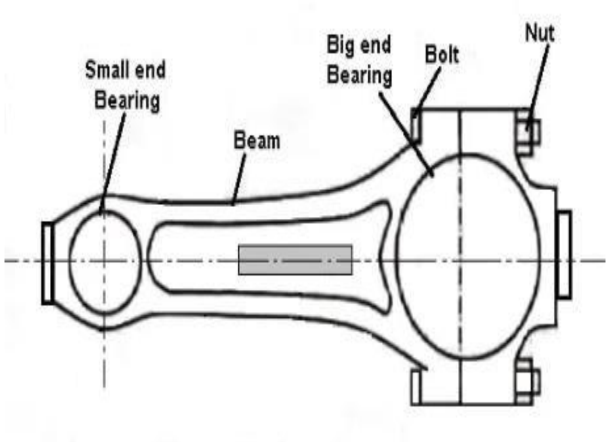


Figure 3: Construction of Connecting Rod.

The shell bearing has adjustment for wear but gives the control over running and side clearance, providing the bearing cap to correct fit. Sometimes, thin pieces of metal known as shins are used when spur bearings are employed.

These can be filled thinner to compensate for the wear of the bearing and also to secure the correct bearing clearance between the connecting rod and the crankshaft. The small end is usually a solid eye fitted with a phosphor bronze bush and a screw to close the eye around thepin.

All the connecting rods in an engine must be of equal weight otherwise noticeable vibration may occur. In the assembly, the connecting rods and caps are individually matched to each other. It usually carries identifying numbers so that they may not be mixed if the engine is dissembled for service.

3.2 Theoretical Calculations

1. Pressure calculation: Consider a 150cc engine
2. Engine type air cooled 4-stroke Bore × Stroke (mm) = 57×58.6
3. Displacement = 149.5CC
4. Maximum Power = 13.8bhp at 8500rpm
5. Maximum Torque = 13.4Nm at 6000rpm

6. Compression Ratio = 9.35/1
7. Density of petrol at 288.855 K - 737.22*10-9• kg/mm3
8. Molecular weight M - 114.228 g/mole
9. Ideal gas constant R – 8.3143 J/mol.k
10. From gas equation, PV=m.Rspecific.T
11. Where, P = Pressure V = Volume m = Mass
12. Rspecific = Specific gas constant T = Temperature But, mass = density 13. volume m =737.22E-9*150E3 m = 0.11 kg
14. Rspecific = R/M Rspecific = 8.3143/0.114228 Rspecific = 72.76 P = m.
15. Rspecific.T/V P = 0.11*72.786*288.85/150E3 P = 15.4177 MPa P ~ 16 MPA

- Type : air cooled 4-stroke
- SOHC Bore x stroke (mm) = 79.5 x 80.5 mm
- Displacement - 1598 Cm3
- Maximum power = 77
- 5250rpm Maximum torque = 153 -3800 rpm
- Compression ratio = 9.35/1
- Density of petrol = 0.00000073722 kg/mm3
- Temperature = 600F

Density of petrol C8H18 = 737.22 kg/m3 at 60 0F = 0.00073722 kg/cm3 = 0.00000073722 kg/mm3

T = 600F =15.550C = 288.855K

Mass = density x volume = 0.00000073722 x 159800

= 0.1178kg Molecular cut for petrol 114.2285 g/mole

PV = mRT P = (0.1178 x 8.3143 x 288.555) / (0.11422 x 0.0001598)

P = 12287695.65 j/m3 = N/m2 Gas pressure, P =12.287 N/mm2 Mean effective pressure,
Pm = 2 π (Tnc / Vd) = 153 x 2 x 3.14 / 1598 = 1.202

Indicated power IP = (Pm x l x A x n)/60 = (1.202 x 80.5 x 3.14 x 79.52 x 4)/(4 x 60) = 128018.57 kw
Brake power BP = (2 π N T) / 60

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 12, Issue 2, 2024

= (2 x 3.14 x 5250 x 153) / (4 x 60)

= 84073.5 kw Mechanical efficiency,

= BP / IP = 84073.5 / 128078.57

= 0.656 = 65.6%

Piston Material: Cast Iron Temperature at the centre of piston head Tc = 2600c to 2900c Temperature at the edge of piston head.

IV. FINITE ELEMENT ANALYSIS

4.1 Material properties of connecting rod

In this analysis three types of materials are used to reduce its weight. These materials are (Table I)

- Structural steel, c-70
- Steel and beryllium.
- Sec D-D at the Small End.
- Sec A-A at the root of Big End.

From the theoretical and Finite Element Analysis it is found that

- The stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end.
- Therefore, the chances of failure of the connecting rod may be at fillet section of both end.
- Consider connecting rod with I section beam for further analysis with different materials. The materials are structural steel, C-70 steel and beryllium are considered for this analysis.
- In this analysis equivalent stresses, normal stresses in X, Y and Z directions, shear stresses in XY, YZ and ZX planes, total deformation in X, Y and Z directions and factor of safety. The results are tabulated and compared each other.

Here the material for used for this analysis is C70 steel for connecting rod. After applying the same boundary conditions for this material and run the solution.

The post processor is used to calculate the equivalent stress along the length of the connecting rod for this material. The equivalent stress indicated in the figure form rod small end to the crank pin.

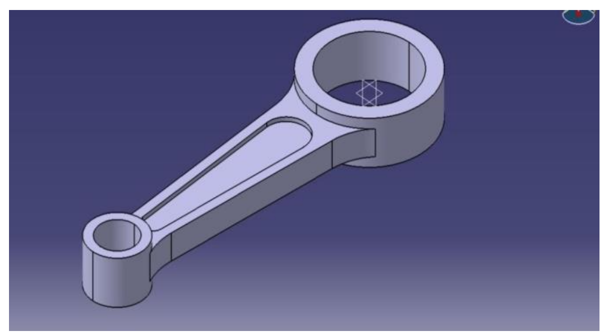
Material	Densitygram/cc	Young's modulesGPa	Poisons ratio	Yield stressMPa
Structural steel	7.85	200	0.300	250
c-70 steel	7.8	221	0.280	440
Belgium	1.85	287	0.032	240

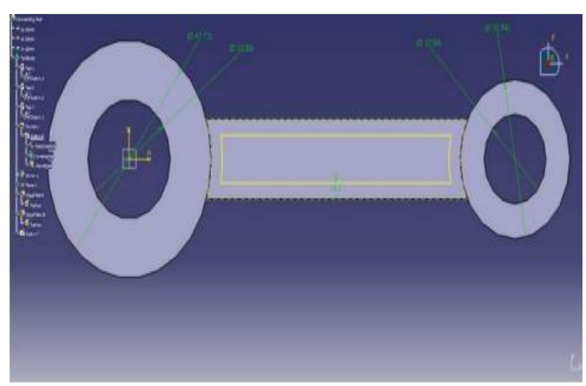
The below figures are as follows

(a) The connecting rod model by using CATIA

(b) Weight Reduction in Stem Sketch

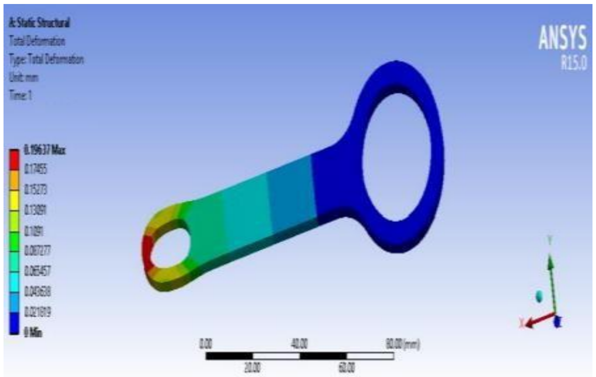
(c) Maximum principle stress at 39473.16N





ISSN 2347–3657

Volume 12, Issue 2, 2024



V.RESULTS & DISCUSSIONS

The connecting rod is used to transfer the reciprocating motion to rotary motion. While converting motion the material undergoes stresses and deformations. The stresses and deformations are calculated using finite element method. Here we are considering with and without section beams and compared for different materials like structural steel, C-70 steel and beryllium. This is the design model of connecting rod for FEM analysis. Here we have to give the names of various parts and transfer the model for meshing. This is the meshed model of connecting rod. It is used 10 node and 20 node tetra shape ofelement type solid92 and solid95.This is the input for structural analysis.

VI. CONCLUSION

This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modeled using CATIA V5 R20 software and to that model, analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz. For C70 Steel, Belgium. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two-wheeler piston were done in ANSYS software. Structural steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod. The equivalent stress of C-70 steel is 36.885 MPa.

- The shear stress XY plane of C-70 steel is 20.141 MPa
- The total deformation of C-70 steel is 0.00245
- The equivalent stress of Belgium is 36.857 MPa
- The shear stress XY plane of Belgium is 20.152 MPa
- The total deformation of Belgium is 0.0027253

FUTURE SCOPE

- Designing a connecting rod for a specific two-wheeler IC Engine, by numericalmethod.
- The connecting rod can be further modified with suitable alternate material for weight optimization.

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