Modeling and Analysis of Connecting Rod of Two Wheeler (Hero Honda Splendor)

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***Abstract*— The connecting rod (CR) is the main moving parts and an important component of engine. The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. The main objective of this study is to explore weight reduction opportunities for a production forged steel connecting rod. In this project, finite element analysis of single cylinder four stroke petrol engines is taken as a case study; Structural systems of connecting rod can be easily analyzed using Finite Element techniques. So firstly a proper Finite Element Model is developed using Cad software Pro/E. Then the Finite element analysis is done to determine the stresses in the existing connecting rod for the given loading conditions using Finite Element Analysis software. Based on the observations of the static FEA and the load analysis results, the load for the optimization study was selected. The results are also used to determine degree of stress multiaxiality, and the fatigue model to be used for analyzing the fatigue strength. Outputs include fatigue life, damage, and factor of safety.**

Index terms:-Connecting Rod, Modeling, and Finite Element Analysis.

I. INTRODUCTION

The intermediate component between crank and piston is known as connecting rod**.** Connecting rod is also known as conrod and is used to connect the piston to crankshaft. As a connecting rod is rigid, it may transmit either a push or a pull and so the rod rotates the crank through both halves of a revolution, i.e. piston pushing and piston pulling. Earlier mechanisms, such as chains, could only pull. In a few two-stroke engines, the connecting rod is only required to push.

Today, connecting rods are best known through their use in internal combustion piston engines, such as automotive engines. These are of a distinctly different design from earlier forms of connecting rods, used in steam engines and steam locomotives. One source of energy in automobile industry is internal combustion engine. Internal combustion engine converts chemical energy into Mechanical energy in the form of reciprocating motion of piston. Crankshaft and Connecting rod convert reciprocating motion into rotary motion. Connecting rod is one of the important driving parts of Light vehicle engine it forms a simple mechanism that converts linear motion into rotary motion that means the connecting rod is used to transfer linear, reciprocating motion of the piston into rotary motion of the crankshaft.

Connecting rod must be capable of transmitting axial tension, axial compression, and bending stress caused by the thrust and pull of the piston and by centrifugal force.

The Internal combustion Engine connecting rod is critical component which is subjected to complex loading. There are various forces acting on the connecting rod i.e. force on the piston due to gas pressure and inertia of the reciprocating parts, force due to inertia of connecting rod or inertia bending forces, force due to friction of piston rings and of the piston, force due to friction of piston pin bearing and crank pin bearing. The inertia loads on connecting rod are varying time to time under in-service conditions. Connecting rod design is very complex because the connecting rod works in very complicated condition. Connecting rod is among large volume production component in the internal combustion engine. The Maximum stress occurs in the connecting rod near the piston end due to thrust of the piston. The tensile and compressive stresses are produced due to the gas pressure, and bending stresses are produced due to centrifugal effect. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight.

The automobile engine connecting rod is a high volume production critical component. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine. So the connecting rods are designed generally of I-section provide maximum rigidity with minimum weight. The maximum stress produced near the piston end could be decreased by increasing the material near the piston end.

The classification of connecting rod is made by the cross sectional point of view i.e. I – section, H – section, Tabular section, Circular section. In low speed engines, the section of the rod is circular, with flattened sides.

In high speed engines either an H – section or Tabular section is used because of their lightness. The rod usually tapers slightly from the big end to the small end. To provide maximum rigidity with minimum weight the main cross section of the connecting rod is made an I-section is made to blend smoothly into two rod ends called the small end (piston end) and big end (crank end).

In modern automotive internal combustion engine, the connecting rods are most usually made of steel for production engine. But can be made of aluminum or titanium for high performance of engines of cast iron for application such as motor scooters.

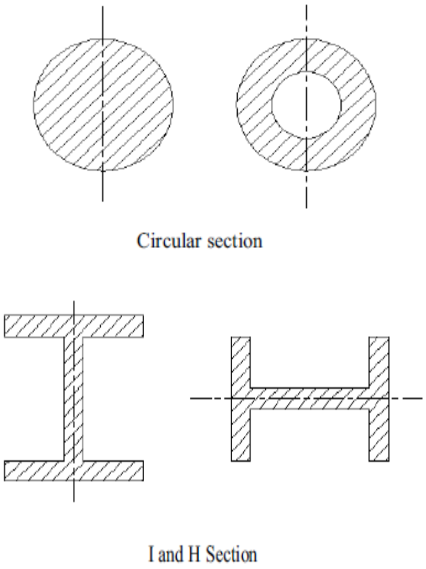

Figure 1.1: Schematic illustrations of types of section

A. MATERIALS

The connecting rod of internal combustion engines are mostly manufactured by drop forging. It should have adequate strength and stiffness with minimum weight. The materials of connecting rods range from mild or medium carbon steels to alloy steels. In industrial engines, carbon steel with ultimate tensile strength ranging from 550 to 670 Mpa is used. In transport engines, alloy steel having strength of about 780 to 940 Mpa is used e.g., manganese steel is commonly used. For connecting rods of low speed horizontal gas engines, the material may be sometimes steel casting. For high speed engines, the connecting rods may be made of duralumin and aluminum alloys.

B. STRESSES IN CONNECTING ROD

The stresses in connecting rod are set up by a combination of forces. They are induced in a connecting rod as combinations of axial stresses, bending stresses and thermal stresses which are subjected to during its operation. The axial stresses are produced due to cylinder gas pressure (compressive only) and the inertia force arising on account of reciprocating action (both tensile as well as compressive), where as bending stresses are caused due to the centrifugal effects. The various forces acting on the connecting rod are:

1. The combined effect of gas pressure on the piston and the inertia of the reciprocating parts.
2. Friction of the piston rings and of the piston.
3. Inertia of the connecting rod.
4. The friction of the two end bearings i.e. of the piston pin bearing and the crank pin bearing.
5. Thermal stresses.

C. STATIC LOAD

A static load is a mechanical force applied slowly to an assembly or object. This can be contrasted with a dynamic load, which is a force that is applied rapidly. Tests of static load are useful in determining the maximum allowable loads on engineering structures, such as bridges, and they can also be useful in discovering the mechanical properties of materials. This force is often applied to engineering structures that peoples' safety depends on because engineers need to know the maximum force a structure can support before it will collapse. Any force applied steadily without moving an object is considered a static load, and the knowledge of how much loading a structure can handle is useful for setting safety margins for the structure. Limiting the loading to one half of a structure’s maximum load bearing capacity giving a higher factor of safety. An elevator is an example where static loading occurs. When ten people stand in an elevator waiting for the doors to close, they are exerting a load on it that is static because the people and the elevator are not moving relative to each other. The stresses within the elevator have time to reach equilibrium under such conditions. An elevator must be tested to establish a maximum weight limit with an acceptable margin of safety.

II.SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and optimize a connecting rod based upon its fatigue life. Steel and aluminum are used to analyze the connecting rod. The material of connecting rod will be optimized depending upon the analysis result. CAD model of connecting rod will be created in Pro-E and it’ll be analyzed in ANSYS, FEMFAT and OPTISTRUCT. After analysis a comparison will be made between existing material and alternate material which will be suggested for the connecting rod in terms of weight, factor of safety, stiffness, deformation and stresses.

III. OBJECTIVES

1. To reduce weight of the existing connecting rod with desired strength.
2. To determine the Von Misses stresses, Shear stresses, and Equivalent Alternating stress, Total Deformation, Fatigue life and to optimize in the existing Connecting rod design.
3. To calculate stresses in critical areas and to evaluate if these stresses fall within 5% of critical stress value (yield).
4. Stress values within 5% of yield value then design would be optimized, else if the stresses are within elastic limit fatigue life calculation would be done to evaluate the fatigue life cycle of the connecting rod.

The main aim of the project is to determine the von-misses stresses, thermal stresses, principle stresses and tresca (maximal shear stress) and Optimize the existing connecting rod. If the existing design shows the failure, then suggest the minimum design changes in the existing connecting rod.

IV. STEPS IN MODELING OF CONNECTING ROD

Connecting Rod has been modeled with the help of PRO/E software. The Orthographic & final Solid Model of connecting rod is shown in figures below. The following is the list of steps that are use to create the required model.

- 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.
- A cut-feature is created on the second feature.
- Creation of plane perpendicular to axis for first hole.
- Creating the first hole at the piston end (with the help of Make HOLE Option).
- Creation of plane perpendicular to axis for second hole.
- Creating the second hole at the piston end (with the help of Make HOLE Option).

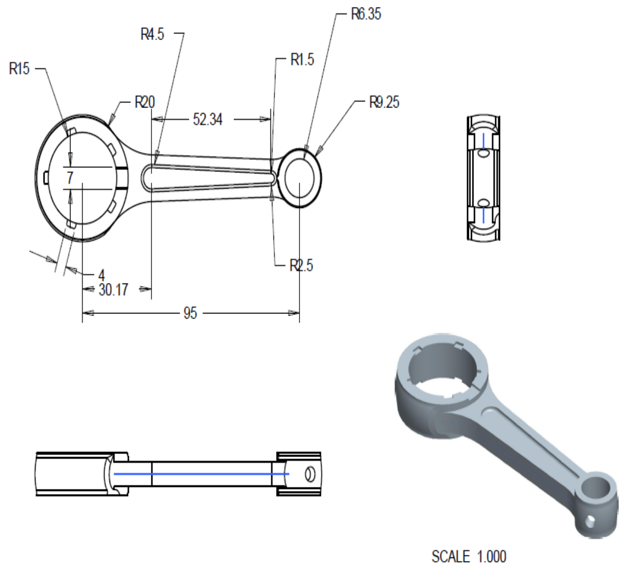

Fig 2 Orthographic view of connecting rod.

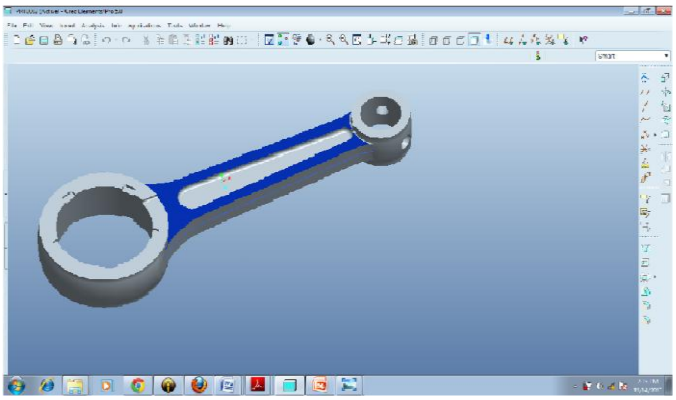

Fig 3: - Final Solid Model of Connecting Rod

V. PRESSURE CALCULATION FOR 100CC ENGINE

(Hero Honda Splendor)

Hero Honda Splendor specification

Engine type air cooled 4-stroke
Bore x Stroke 50.0 x 49.5 mm
Displacement 97.2 cc
Max. Power 5.74 KW (7.8 Ps) @ 7500 rpm
Max. Torque 8.04 N-m @ 4500 rpm
Compression Ratio 9.0: 1
Density of petrol C_8H_{18}= 737.22kg/m^3 =737.22E^{-9}kg/mm^3
Flash point for petrol (Gasoline)
Flash point = -43°c (-45°F)
Auto ignition temp. = 280°c (536°F) = 553k
Mass = Density x volume
= 737.22E^{-9} x 97.2E^3
= 0.0716kg
Molecular weight of petrol = 114.228g/mole
= 0.11423 kg/mole

From Gas equation,

$$PV = mRT$$

Where, P = pressure, MPa
V = volume,
m= mass, kg
Ro = universal gas constant, 8314.8 Nm/moleK
R = gas constant, Nm/kg K
m= n * M
Where, n = number of moles
M = molecular weight of gas.
= 8.3145/0.11423
= 72.787 Nm/kg K
P = (0.0716 x 72.787 x 553) / 9.72 * 10^-5
= 29.65 MPa

Assuming that the temperature between piston and cylinder remains constant at 533^{o}K, calculation of pressure is done. Calculated pressures at different displacements are as below.

SR. NO.	CRANK ANGLE (deg)	VOLUMETRIC DISPLACEMENT (cm³)	PRESSURE VALUE (Mpa)
1	0	0	0
2	18	9.72	296.798
3	36	19.44	148.248
4	54	29.16	98.832
5	72	38.88	74.124
6	90	48.6	59.299
7	108	58.32	49.416
8	126	68.04	42.357
9	144	77.76	36.062
10	162	87.48	32.944
11	180	97.2	29.65

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