Experimental Analysis of Connecting Rod Hero - CBZ using FEA Software

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Abstract— The connecting rod is intermediate member between the piston and the crankshaft. Connecting rods are widely used in variety of engine. The function of connecting rod is to transmit the thrust of the piston to the crank shaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crank shaft. It consists of a pin-end and crank-end. Pin end and crank end holes are machined to permit accurate fitting of bearings. Connecting rods are subjected to forces generated by mass and fuel combustion. These two forces results in axial load and bending stresses. A 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. Finite element Modal (FEM) is a modern way for analysis the modeling geometry. Existing connecting rod is manufactured by using SCM 415. The present work describes analysis of connecting rod. Structural systems of Connecting rod easily analyzed using Finite Element techniques. So firstly a 2D drawing is drafted from the calculations and the dimensions of the selected connecting rod are found using vernier calipers, screw gauge etc. According to the dimensions of model of them connecting rod, Finite Element Model is developed using CAD SOFTWARE Creo then it is imported into design modeler of ANSYS to determine the von-misses stresses and strains for the given loading conditions. Finally the static analysis is done to determine the von Misses stress, elastic strain, total deformation in the present design of connecting rod for the given loading conditions using Finite Element Analysis Software ANSYS Workbench 13.0. These analytically obtained results are compares with experimental results.

Key words: FEA, Connecting Rod Hero - CBZ

I. Introduction

Connecting rod is a high volume production critical component that being used in automotive internal combustion engine. It connects the piston to rotating crankshaft. Connecting rods are highly dynamically loaded components used for power transmission in combustion engines. The most common type of manufacturing processes is casting, forging, and powdered metallurgy. However, connecting rods could be produced by casting. Connecting rods are widely used in variety of car and two wheeler engines. The function of connecting rod is to transmit the thrust of the piston to the crankshaft and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. Generally, circular section is used for low speed engines while I-section is preferred for high speed engines. One end of the connecting rod is connected to the piston by the piston pin and the other end revolves with the crankshaft. The objective of this study was to optimize a forged steel connecting rod for its weight and manufacturing cost, taking into account recent developments. Typically, an optimum solution is the minimum or maximum possible value the objective function could achieve under a defined set of constraints. The optimization carried out here, however, is not in the true mathematical sense, since while reduce n g mass, manufacturing feasibility and cost reduction are integral parts of the optimization. In addition, software used in this work imposed restrictions in performing optimization under fatigue life constraint. Therefore, rather than using numerical optimization techniques for weight reduction.

Connecting rod is the main component of the combustion engines which main purpose are transfer the energy from the pistons to crankshafts and convert the linear, reciprocating motion of a piston into the rotary motion of a crankshaft, from the viewpoint of functionality; also it connects reciprocating piston to rotating crankshaft and some other design connected direct to the crosshead and then transmitting the thrust of the piston to the crankshaft of the Automobile Engine. Where in the automobile engine con rod moves are in both a rotating motion in to a big end and reciprocating motion in to a small end. Connecting rods must have the highest possible rigidity at the lowest weight. In Automobile internal combustion engine connecting rod is a high volume production component subjected to complex loading. Bending stresses appear due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore, a connecting rod must be capable of transmitting axial tension, axial compression, and lower cost due to their simple bending stresses caused by the thrust and pull on the piston and by centrifugal force. During the operation of the engine, the connecting rod undergoes is prone to tensile, compression, and buckling loading. In many cases, the major reason behind or causing catastrophic engine failure is the occurrence of the connecting-rod failure and sometimes, such a failure can be attributed to the broken connecting rod's shank especially when there is a probability of being pushed through the side of the crank-case, thereby making the engine irreparable. However, specifically describing such a failure, it is important to point out at the different reasons for this failure such as fatigue near a physical defect in the rod, the overheating of the engine, cracking, lubrication failure in a bearing which is usually caused by inaccurate or faulty maintenance, failure of the rod bolts which is due to defect, improper tightening, and re-use of already used (stressed) bolts where not recommended. Figure 1 shows the failure on connecting rod. 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 en-gines, 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 rods are subjected to forces generated by mass and fuel combustion. These two forces results in axial and bending stresses. Therefore, a connecting rod must be capable of transmitting axial tension, axial compression, and bending stresses caused by the thrust and pull of the piston and by Centrifugal force. A connecting rod is subjected to many millions of repetitive cyclic loadings. It undergoes high cyclic loads of the order of 10^8 to 10^9 cycles, which range from high compressive loads due to combustion to high tensile loads due to inertia. Therefore, durability of this component is critical importance. Due to these factors, the connecting rod has been the topic of research for different aspects such as production technology, materials, performance, simulation, fatigue etc. Schematic diagram for connecting rod as shown in figure 1.

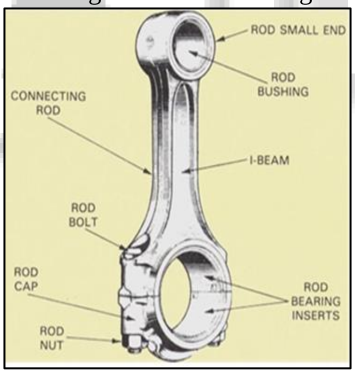

Fig. 1: Schematic diagram for connecting rod.

II. Design of connecting rod

A. Specification

Sr. no	Parameter	Value(mm)
1	Length of connecting rod	115
2	Outer Diameter of Big end	47.50
3	Inner Diameter of Big end	36
4	Outer Diameter of small end	20.75
5	Inner Diameter of small end	14

Table 1: Specification of connecting rod

Material properties	SCM-415
Young's modulus E, Gpa	200 Gpa
Poisons ratio	0.3
Density ρ, Kg/m^3	7700 Kg/m^3
Tensile strength, Mpa	670 Mpa

Table 2: Material properties for connecting rod

B. Theoretical calculations of connecting rod

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 based on the Rankin formula. 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.

In designing of a connecting rod the following dimensions are required to be determined.

1) Dimension of cross section of connecting rod.
2) Dimension of the crank pin at the big end and the piston pin at the small end.
3) Thickness of the big end.

– According to Rankine's - Gordon formula,

$$\text{F about x- axis} = \frac{F_C A}{1+a(\frac{L}{K_{xx}})^2}$$

Let,
A = Cross section area of connecting rod,
L = Length of connecting rod,
Fc = Compressive
F = Buckling load,
yield stress,
Ixx and Iyy= Radius of gyration of the section about x - x and y - y axis respectively.
Kxx and Kyy =Radius of gyration of the section about x - x and y - y axis respectively.
For both ends hinged or free, L = IL

$$= \frac{F_C A}{1+a(\frac{L}{K_{xx}})^2}$$

For both ends fixed,

$$L = \frac{L}{2}$$

In order to have a connecting rod equally strong in buckling about both the axes, the buckling loads must be equal, i.e.

$$\frac{F_C A}{1+a(\frac{L}{K_{xx}})^2} = \frac{F_C A}{1+a(\frac{L}{2K_{xx}})^2}$$

OR

$$(\frac{L}{K_{xx}})^2 = (\frac{L}{2K_{yy}})^2$$

$$K_{xx}^2 = 4K_{yy}^2$$

$$I_{xx} = 4I_{yy}$$

C. Pressure Calculation

Consider a 149.2cc engine, Engine type air cooled 4-stroke
Bore × Stroke (mm) = 57.3mm×57.8mm = 3311.94 mm^3
Displacement = 149.2CC
Maximum Power = 15.6bhp (11.64kW) @ 8500rpm
Maximum Torque = 13.50 Nm @ 8500rpm
Compression Ratio = 10:1

– Density of petrol at C8H18 at 288.85K = 737.22 ×10^{-9} kg/mm3
– Molecular weight M = 114.228 g/mole
– Ideal gas constant R =8.3143 J/mole.k

From gas equation,
PV = m.r.T
Where,

P = Gas pressure in Mpa
V = Volume in mm^3
M = Mass in kg
r = Specific gas constant in J/kg K
T = Temperature in K
But,
Mass =density × volume
$M = 737.22\times10^{-3}\times(149.2\times10^{3})$
M = 0.10999 kg
r = R/M
r = 8.3143/0.114228
r = 72.786
P = m.r.T/V
P = 0.07165×72.786×288.85/97.2E3
P = 15.499 MPa
P ~ 15.5 MPa

D. Design Calculation

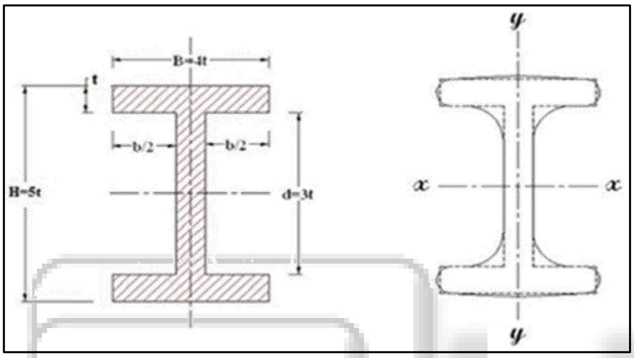

Fig. 2: I-Section of connecting rod

From standards,

1) Thickness of flange and web of the section = t
2) Width of the section B = 4t
3) Hight of the section H = 5t
4) Area of the section = 2(4t * t)+ (3t * t) = $11t^2$
5) Moment of inertia about X axis Ixx = 1/12 (4t * (5t)^3 – 3t (3t)^3 = 34.91 t^4
6) Moment of inertia about Y axis Iyy = 1/12[2(t × (4t)^3)+(3t) × t^3] = 10.91t^4
7) Therefore Ixx/Iyy = 3.2
8) Kxx^2 = Ixx/ A = [419t^4] / [12 ×11t^2] = 3.18t^2 2
9) Length of connecting rod (L) = 2 times the stroke
10) L = 2×57.8 = 115.6 mm
11) Maximum explosion pressure(Pmax) = 2.5 Mpa
12) The maximum gas force Pgas,

$$P\ gas = \frac{\pi}{4} D^2$$

$$P\ gas = \frac{\pi}{4} (57.3)^2 = 6446.7248\ N$$

Buckling load, F = maximum gas force (Pgas) × F.O.S
= 6446.7248 × 5 (Assuming F.O.S = 5)
F = 32233.6242 N
For SCM 415 material
Compressive yield stress (Fc) = 330MPa
According to Rankine's - Gordon formula

$$P = \frac{F_C A}{1+a(\frac{L}{K_{xx}})^2}$$

Rankin constant = 1/7500 = 0.000133
According to Rankine's - Gordon formula

$$32233.6242 = \frac{330\times t^2}{1+1.33\times10^{-4}\times(\frac{115.6}{1.7832t})^2}$$

t = 3.0671
Thickness of section t = 3.06 mm = 3.1 mm

Width of the section B = 4t = 3.1 × 4 = 12.4 mm
Height of the section H = 5t = 15.5 mm
Area A = $11t^2$ = 105.71 mm^2
Height of the big end (crank end) H1 = 1.1 H = 17.05 mm
Height of the small end (piston end) H2 = 0.8H = 12.4 mm

III. FEA ANALYSIS

Finite element modeling is described as the representation of the geometric model in terms of a finite number of element and nodes. It is actually a analytical method employed for the solution of structures or a complex region. Solutions obtained by this method are rarely exact. A model is created using CREO software and then it is retrieved into ANSYS using IGES format. The proportions of connecting rod coming out from measurements of connecting rod model are used to create the model. The structural analysis allows stresses & strains to be calculated in FEA, by using the structural model. The structural analysis performed to create high & low stresses region from the input of the material, loads, boundary condition. It is used to improve optimize design.

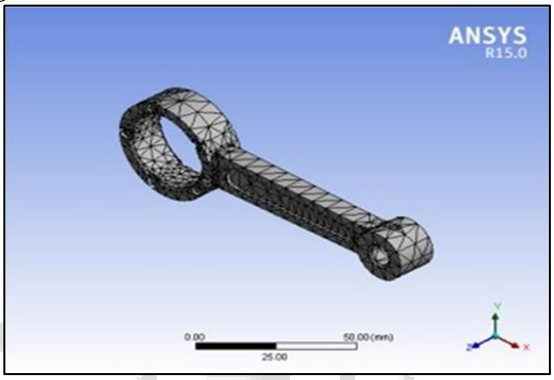

Fig. 3: Meshing of connecting rod model

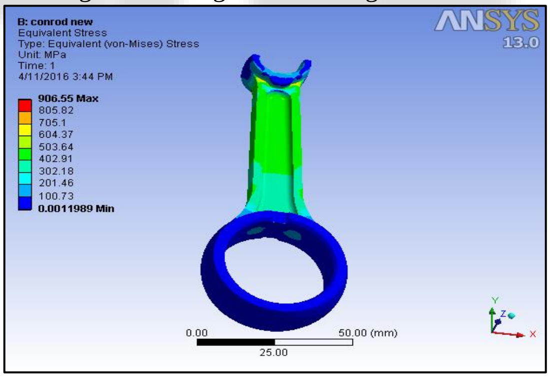

Fig. 4: Stress of new connecting rod at 3200 N

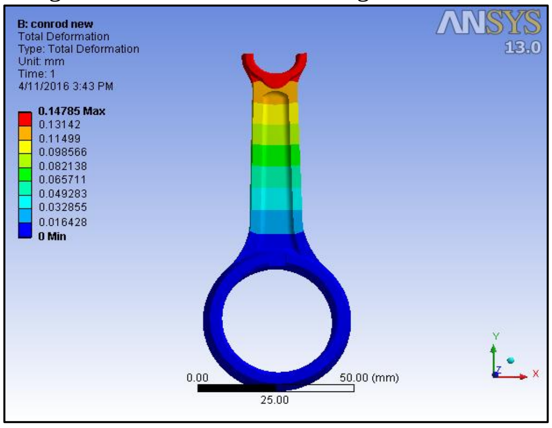

Fig. 5: Deformation of new connecting rod at 3200 N

IV. RESULT

Sr. No	Force (N)	FEA result (mm)	Experimental result(mm)	Error (%)
1	28000	0.11980374	0.133445	10.22
2	30000	0.12836115	0.139053	7.68
3	32000	0.13691856	0.154157	11.18
4	34000	0.14547597	0.159472	8.77
5	36000	0.15403339	0.167832	8.22

Table 2: Analysis of force Vs deformation original connecting rod

Sr. No	Force (N)	FEA Result (mm)	Experimental result(mm)	Error (%)
1	28000	779.52238	860.5236	9.41
2	30000	835.20255	910.8332	8.30
3	32000	890.88272	980.4532	9.13
4	34000	946.56279	1040.3246	9.01
5	36000	1002.2430	1100.1236	8.8

Table 3: Analysis of force Vs stress original connecting rod

Sr. No	Force (N)	FEA result (mm)	Experimental Result (mm)	Error (%)
1	28000	0.147848	0.133246	9.87
2	30000	0.129367	0.119049	7.97
3	32000	0.138608	0.124632	10.08
4	34000	0.157089	0.143218	8.83
5	36000	0.166329	0.152332	8.41

Table 4: Analysis of force Vs deformation new connecting rod

Sr. No	Force (N)	FEA result (mm)	Experimental Result (mm)	Error (%)
1	28000	906.5510	985.3231	8
2	30000	793.2321	890.2020	18.8
3	32000	849.8916	950.1015	10.5
4	34000	963.1204	1070.6061	10.0
5	36000	1019.8699	1135.1921	10.1

Table 5: Analysis of force Vs stress new connecting rod

V. CONCLUSIONS

1) According to this study, Finite element method is used to find out the stress, strain, deflection critical points of reciprocating components like connecting rod. In order to improve life of connecting rod we make small changes in geometry of connecting rod i.e. We increase neck radius thickness from 25mm to 28mm at crank end and 15mm to 18mm at pin end and after finding life of connecting rod.
2) According to this study we optimize the weight as well as cost of connecting rod.
3) According to this study, Finite element method is used to find out the stress, strain, deflection critical points and fatigue life time of reciprocating components like connecting rod

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