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Design and Analysis of Connecting Rod Using Different Materials

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Abstract
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. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Forged steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modeled using SOLID WORK 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... Aluminum Alloy. 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. Aluminum Alloy has more factor of safety, reduce the weight, reduce the stress and stiffer than other material like Forged Steel. With Fatigue analysis we can determine the lifetime of the connecting rod.
Key words: *Connecting Rod, Analysis Connecting Rod, Four Stroke Engine, Aluminum Alloy*

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I. INTRODUCTION

The connecting rod is a major link inside a combustion engine. It connects piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft & sending it to the transmission. There are different type of materials & production methods used in the design in connecting rod. The most common type of connecting rods are steel & aluminum. The most common type of manufacturing process is casting, forging, and powder metallurgy. Connecting rods are widely used in variety of engines such as, in-line engine, V-engine, opposed cylinder engines, radial engines & opposed piston engines.

A connecting rod consists of a pin end, a shank section, & a crank end. The small end attached to the piston pin or gudgeon pin which is currently most often press fit into the con rod but can swivel the piston, a "floating wrist pin design". The big end of the rod is fabricated as a unit & cut in to two to establish precision fit around the big end bearing shell. The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching & being compressed with every rotation & load increase with the third power with increasing engine speed.

Connecting rod, automotive should be lighter & should consume less fuel & at the same time they should provide comfort & safety to passengers, that unfortunately leads to increase in weight of vehicle. This tendency in vehicle construction led the invention & implementation of quite new materials which are light &meet design requirements. Lighter connecting rods help to decrease lead caused by inertia force in engine as it does not require big balancing weight on crankshaft. Geometrically it can be seen that longer connecting rod will reduce the amount of sideway force & therefore lead to longer engine life. Honda Company had already started the manufacturing of aluminum connecting rods reinforced with steel continuous fibres. Ford 4.6 litter engine & Chrysler 2.0 litter engine have connecting rod made by powder metallurgy which allows more precise control of size & weight with less machining & less excess mass to be machined off for balancing.

THEORETICAL ANALYSIS

In this project the theoretical analysis of connecting rod for 162 CC bike has been done by using the concept of buckling load in two dimensional sections as I section, considering the Inertia force due reciprocating parts as well as the weight of the connecting rod has been taken into the account. The factor of safety is very much effect has been also considered to get safe design.

i. The buckling of connecting rod in the plane of motion, the ends of connecting rod is hinged in the crank pin & piston pin. Therefore, for buckling about the X-X axis, the end fixity co-efficient (n) is one.

ii. The buckling of connecting rod in a plane perpendicular to the plane of the motion is the ends of the connecting rod are fixed due to constraining effect of bearings at the crank pin & piston pin. Therefore, for buckling about the Y-Y axis the end fixity co-efficient (n) is four.

iii. Therefore, the connecting rod is four times stronger for buckling about the Y-Y axis as compared to buckling about the X-X axis.

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile force. Since the compressive force are much higher than the tensile forces.

According to Rankin's formula

$$F = [(\sigma\times A)/\{1+a\ (l/K_{xx})^{2}\}]$$

Crippling load about X- axis

$F = [(\sigma\times A)/\{1+a\ (L/K_{xx})^2$ (l=L) (for both end hinged)

Crippling load about Y-axis

$F = [(\sigma\times A)/\{1+a(L/2K_{yy})^2\}]$ [l=L/2] (for both Fixed)

We get by equating the Crippling load about X-axis and Y-axis,

$I_{xx} / I_{yy} = 3.2$

SELECTION OF THE DIMENSION OF CONNECTING ROD

Thickness of flange & web of the section=t

B	H	A	X_c	Y_c	I_{xx}	I_{yy}	I_{xx}/I_{yy}	K_x
3t	5t	$9t^2$	1.5t	2.5t	$26.75t^4$	$4.75t^4$	5.64	1.72t
4t	5t	$11t^2$	2t	2.5t	$34.91t^4$	$10.91t^4$	3.2	1.78t
4t	6t	$12t^2$	2t	3t	$56t^4$	$11t^4$	5.09	2.16t

Table-1 : Selection of Dimension of Connecting Rod

From above table it is observed that the value of I_{xx}/I_{yy}= 3.2 which is less than 4 so the design becomes safe. For this condition the width and the height of the **I** section will be

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}

$I_{xx} = [4t\times(5t)^3 - 3t\times (3t)^3/12] = 34.91t^4$

Moment of inertia about y-axis I_{yy}

$I_{yy} = 2\times[1/12 \times t \times (4t)^3 + 1/12\ (3t)t^3] = 10.91t^4$

So, $I_{xx}/I_{yy} = 3.2$ (since $I_{xx}/I_{yy} < 4$), design is safe

SPECIFICATION of 160cc bike

SL NO	Model NO	Engine capacity(cc)	Max power	Max Torque	speed(RPM)	Tank capacity	Bore (mm)	Stroke(mm)	Cylinders	Length(mm)
1	Bajaj Pulsar NS160	160.3	17.03bhp/9000rpm	14.6Nm	7250	12L	58	60.7	1	120
2	Hero Extreme 160R	163	15bhp/8500rpm	14Nm	6500	12L	57.34	63.3	1	120
3	TVS Apache RTR 160 4V	159.7	17.39bhp/9250rpm	15.73Nm	7250	12L	62	52.9	1	120

Table -2 : Specification of 160 cc Bike

Design of Connecting rod of Bajaj Pulser
Material Selected: Carbon Steel

1) Engine type: -I-Type
   Bore dia. (d) =58 mm (big end)
   Stroke length =60.7 mm
2) Displacement = 160.3 cc
3) Density of petrol at 288 k = 737.22 * 10^{-9} kg/mm^3.
4) Molecular weight (M) =114.228 g/mole.
5) Ideal gas constant (R) = 8.314 kj/mole.k.

CALCULATION OF NET FORCE:-

p = Fuel Pressure =15.453 N/mm^2

L = length of the connecting rod.
= (2 × stroke length) = 2 × 60.7 mm = 121.4 mm.

$F_p = (\pi d^2/4) \times p$ = (3.14 × 58^2 × 15.45)/4 = 40828 N

DESIGN CALCULATION OF CARBON STEEL

σ_c = Compressive yield stress = 550 N/mm^2
a = 1/1600,
Using the Rankine Equation for critical load of buckling as

$$W_{cr} = \sigma_c \times A / [1+a(L/K_{xx})^2]$$

Piston load taken i,e $W_{cr} = F_p$ x fos

For Calculation of factor of safety (fos) using ANSYS software to analysis of stress and deformation of connecting rod under given fuel pressure shown in Fig-2,3, and 4 where normal stress variation along x-axis ,normal stress along Y-axis and shear stress along X-Y plane shown and values of maximum and minimum stress for Aluminum and carbon steel tabulated as

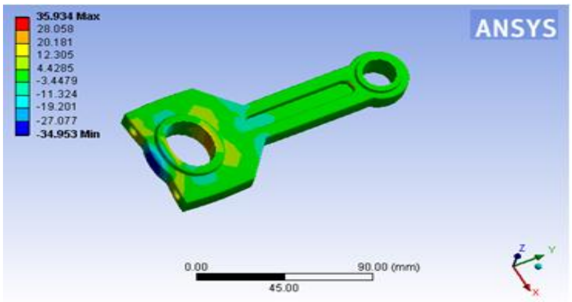

Fig-2: Normal Stress along X-axis

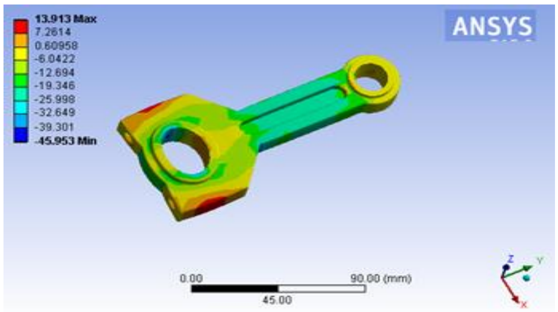

Fig-3: Normal Stress along Y-axis

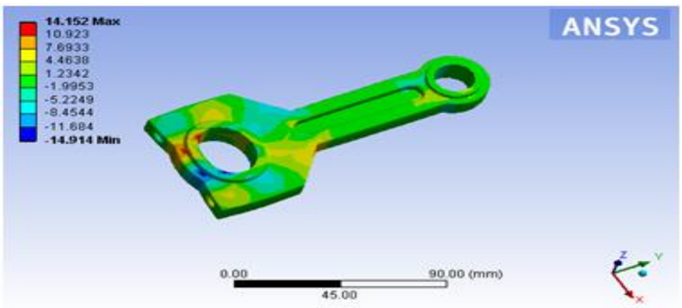

Fig-4 :Shear Stress XY Plane

Sl No	Types	Stresses of Aluminum Alloy		f Carbon Steel	
		Max(Mpa)	Min(Mpa)	Max(Mpa)	Min(Mpa)
1	Normal stress(x-axis)	35.934	-34.953	25.283	-15.692
2	Normal stress(y-axis)	13.913	-45.953	28.088	-15.485
3	Shear stress(xy plane)	14.152	-14.914	20.166	-20.183

Table-3: Variation of normal stress and shear stress

Sl no	Mechanical Properties	Aluminum Alloy	Carbon Steel
1	Modulus of elasticity,(Gpa)	73.1	200
2	Yield strength, YS,(Mpa)	683	450
3	Ultimate strength, Su,(Mpa)	710	650
4	Fatigue Strength,(Mpa)	159	340

Table-4 : Mechanical and Physical Properties

CALCULATION

Calculation for factor of safety of connecting rod

f.s=factor of safety, σ_m=Mean stress, σ_y= Yield stress,σ_v=Variable stress, σ_e= Endurance stress

$$1/fos=\sigma_m/\sigma_y+\sigma_v/\sigma_e$$

For Aluminium Alloy

σ_{max}=35.934 σ_{min}=13.913 Mpa

$\sigma_m=(\sigma_{max}+\sigma_{min})/2$= 24.923 Mpa

$\sigma_y=683 Mpa$

σ_e=0.5∗683=Mpa

$\sigma_v=(\sigma_{max}- \sigma_{min})/2$=11.0

Using, $1/Fos=\sigma_m/\sigma_y+\sigma_v/\sigma_e$

Fos=14.57

For Carbon steel

σ_{max}=28.08 σ_{min}=20.166

$\sigma_m=(\sigma_{max}+\sigma_{min})/2$= 24.123 Mpa

$\sigma_y= 450\ Mpa$

$\sigma_v=(\sigma_{max}- \sigma_{min})/2$=3.957

σ_e=0.5∗450=225 Mpa

Using

$$1/fos=\sigma_m/\sigma_y+\sigma_v/\sigma_e$$

Fos = 14

Taking Fos =14, the value of thickness of flange obtained as
t=9.86 mm which is almost actual thickness of connecting rod

DIMENSION OF BIG END AND SMALL END BEARING :-

Diameter and length of Big end bearing (crank pin bearing) are d_C and l_c
Bearing pressure range taken as 10.8 N/mm^2 to 12.5 N/mm^2 and
lc/dc ratio taken as 1.25 to 1.5 .
For this analysis, Bearing pressure $(P_b)_c$ = 12 N/mm^2 and l_c/d_c = 1.25
Load on Big end bearing :

$$d_c \times l_c \times (p_b)_c = d_c \times 1.3 d_c \times 12 = 15.6\,(d_c)^2$$

$$\mathbf{d_c = 51\ mm} \text{ and } \mathbf{l_c = 1.3 \times d_c = 66\ mm}$$

Diameter and length of Small end bearing (piston pin bearing) are d_p and l_p
Bearing pressure range taken as 12.5 N/mm^2 to 17 N/mm^2 and,
l_p/d_p ratio taken as 1.5 to 2.4 .
For this analysis, Bearing pressure $(P_b)_p$ = 17N/mm^2 and l_p/d_p = 2
Load on Small end bearing:

$$d_p \times l_p \times (p_b)_p = d_p \times 2d_p \times 15 = 30\,(d_p)^2$$

$$\mathbf{d_p = 37\ mm} \text{ and } \mathbf{l_p = 2 \times dp = 74mm.}$$

COMPARISON OF THEORETICAL AND ACTUAL DIMENSION OF COMPONENTS OF CONNECTING ROD:-

Components	Theoretical Dimension (in mm)	Actual Dimension (in mm)
Thickness of connecting rod	9.86	10.2
length of connecting rod	121.4	120
Width Of Section(B)	39.4	41
Height of Section(H)	49.3	50
Height of Smaller Head Section(H1)	25.5	25.4
Height Of Bigger Head Section(H2)	36	35.5
Outer Dia Of Big Head	95	94.2
Outer Dia Of Small Head	51	50.4

Table -5: Comparison of theoretical and actual dimension

Comparative Analysis Of Connecting Rod Thickness And Material Selection For Different Bikes:

Model Name	FOS	CARBON STEEL (t) in mm	ALLUMINIUM ALLOY(7075) (t) in mm
BAJAJ PULSAR NS160	6	6.57	6.34
	12	7.88	7.4
	14	9.86	9.24
HERO XTREME 160R	6	6.42	6.22
	12	8.01	7.86
	14	10	9.6
TVS APPACHE RTR1604V	6	4.16	3.9
	12	7.46	7.36
	14	10.2	9.89

Table -6 : Comparative Analysis Of Connecting Rod Thickness And Material Selection For Different Bikes :

On comparison of these results it has been observed that the actual thickness of connecting rod made with carbon steel in different bikes almost 10.2 mm, 10 mm and 9.86 mm respectively when Factor of safety taken 14 which is almost same as theoretical analysis 10.2 mm stated above calculation. Actual connecting rod made with carbon steel thickness almost 6mm of BAJAJ PULSAR NS160 given below

Fig-5: Actual connecting Rod made with carbon steel of BAJAJ PULSAR

The deformation of connecting rod has been observed in crank pin ends and details given below

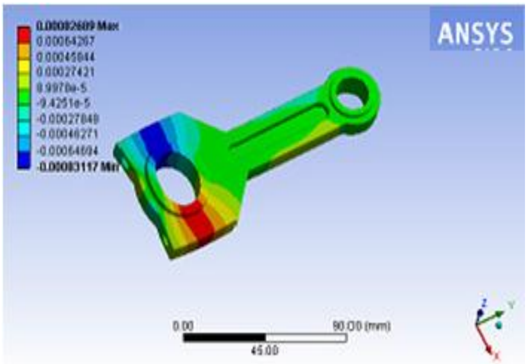

Fig-6: Directional Deformation along X-axis

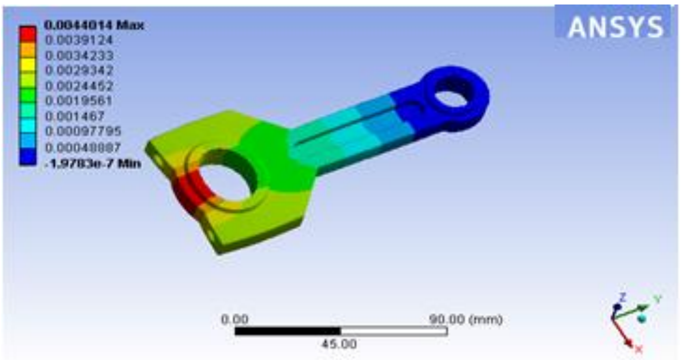

Fig-7: Directional Deformation along Y-axis

SN	Types	Deformation of Aluminum Alloy		ion of Carbon Steel	
		Max(mm)	Min(mm)	Max(mm)	Min(mm)
1	Directional deformation(x-axis)	0.00082689	-0.00083117	0.0005354	-0.0025925
2	Directional deformation(y-axis)	0.0044014	-1.9783e-7	0.0016764	-0.007687

Table -7: Directional deformation

Here the minimum stresses and deformation among all loading conditions were at crank end cap as well as at piston end. So the material can be reduced from those portions, thereby reducing material cost. For further optimization of material dynamic analysis of connecting rod is required, after considering dynamic load condition. It will give more accurate results than existing results.

II. CONCLUSION

The comparative analysis reveals that titanium, with its high strength and lightweight properties, is ideal for high-performance bikes, allowing for reduced thickness and excellent fatigue resistance but at a higher cost. Steel, being durable and cost-effective, is best suited for commuter bikes, though it results in a heavier design. Aluminum, while lightweight, requires increased thickness to ensure strength, making it suitable for moderate-performance bikes. The final material and thickness selection depend on balancing performance, cost, and safety requirements for the specific bike application.

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