DESIGN AND ANALIYSIS OF CONNECTING ROD OF AN IC ENGINE

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ABSTRACT

The connecting rod is a major link inside of combustion engine. It connects the piston to the crankshaft and is responsible for transmitting power from the piston to the crankshaft. It has to work on high revolutions per minute because of which it has to bear severe stresses which make its design vital for internal combustion engine. In this paper, a connecting rod for two wheeler is designed by analytical method. On the basis of that design a physical model is created in CATIA V5. Structural system of connecting rod has been analysed using FEA. With the use of FEA total deformation, strain, stress and masses are calculated for a particular loading conditions using FEA software ANSYS WORKBENCH 18.2. Thus, this study aims to carry out for the load, strain and stress analysis of the crank end of the connecting rod. Based on which the Aluminium 360 connecting rod will be compared with connecting rod made up of Stainless Steel , structural steel and Titanium alloy Ti-6Al-4V. The results can be used for optimization for weight reduction and for design modification of the connecting rod. The obtained results are compared on the basis of various performances with considerable reduction in weight.

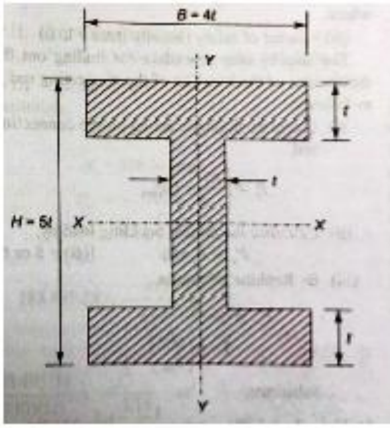
Keywords:
Connecting rod, structural steel, Finite Element Analysis (FEA),stainless steel ,titanium alloy, aluminium alloy, static structural analysis

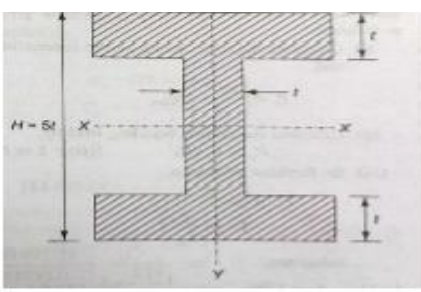
I.INTRODUCTION

Connecting Rods are used practically generally used in all varieties of automobile engines. Acting as an intermediate link between the piston and the crankshaft of an engine of an automobile. It is responsible for transmission the up and down motion of the piston to the crankshaft of the engine, by converting the reciprocating motion of the piston to the rotary motion of crankshaft. While the one end, small end the connecting rod is connecting to the piston of the engine by the means of piston pin, the other end, the bigger end being connected to the crankshaft with lower end big end bearing by generally two bolts.

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.

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 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.





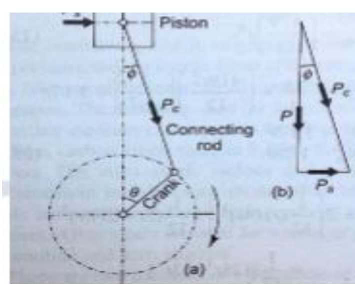


Fig 3.1 I section standard dimensions of connecting rod

Fig 3.2 dead centre position for Max gas load

• Moment of inertia about x-axis, Ixx = 34.91$t4$
• Moment of inertia about y-axis, Iyy =10.91$t4$
• Therefore Ixx/Iyy = 3.2
• Length of the connecting rod (L) = 2 times stroke length (2.3)
L = 117.2 mm
Total Force acting F = $F_P - F_I$ (2.4)
Where,

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F_P= force acting on the piston
= force of inertia
$F_P = \frac{\pi}{4} D^2 \times$Gas pressure (2.5)
Where, D = Bore Diameter
$FP = (\frac{\pi}{4})\ 57^2 \times 15.48 = 38275$ N
$F = m \times \omega^2 \times r \left(\cos\emptyset + \frac{\cos\emptyset}{n}\right)$ (2.6)
Where, M = Mass
$\omega = 2\pi\ 8500 / 60$
$= 890.118\ rad/sec$

n = length of connecting rod(l) / crank radius(r)
$=(2 \times stroke)/(stroke/2)$
$=117.2/29.3$
$\therefore n = 4$
Refer fig for $\emptyset$,
The maximum gas load occurs shortly after the dead centre position at $\emptyset = 3.3°$
$\cos(3.3) = 0.9983 \cong 1$
$\therefore FI = 0.110214 \times (890.118)^2 \times 0.0293(1+\frac{1}{4})$
$=3200$

$$F = \sigma_c A \Big/ \left(1 + \alpha \left(\frac{1}{Kxx}\right)^2\right)$$ rmula, (2.7)

Where
A = c/s area of connecting rod
l = Length of connecting rod
δc= Compressive yield stress
F = Buckling load

$$35075 = \frac{170 \times 11t^2}{1+0.002(117.2/1.78t)^2}$$

end fixity coefficient
ection about x – x and y – y axis respectively.

By solving this, t =5.5 mm
Therefore,
Width B = 4t = 22 mm (2.8)
Height H = 5t = 27.5 mm (2.9)
Area A = $11t^2 = 332.75\ mm^2$
Height at the small end H1 = 0.75H to 0.9 H (2.10)
H1 = 0.9× 27.5= 24.75 mm
Height at the big end H2 = 1.1H to 1.25H (2.11)
H2 = 1.25× 27.5 = 34.375 mm

3.3 DESIGN OF SMALL END
Load on the small end (Fp) = Projected area ×Bearing pressure (2.12)
$= dplp \times$Pbp
Where,
Fp = 38275 N load on the piston pin
dp = Inner dia. of the small end
p = length of the piston pin
$= 1.5dp$ to $2dp$
Pbp = Bearing pressure
= 10.0 for oil engines.
= 12.5 to 15.4 for automotive engines.
We assume it is a 150cc engine, thus
Pbp = 15.4 Mpa
Substituting,
$38275 = 2dp \times dp \times 15.4$

∴ dp = 35 mm
lp =2dp= 70 mm

Outer diameter of small end $= d_p + 2t_b + 2t_m$ (2.13)
= 35 + [2×2] + [2×5]
= 49 mm
Where,
Thickness of bush (t_b) = 2 to 5 mm
Marginal thickness (t_m) = 5 to 10 mm

3.4 Design of Big end
Load on the big end (F_c) = Projected Area ×Bearing pressure (2.14)
$= d_c l_c \times \mathrm{Pb_c}$
Where,
F_c = 38275 N load on the crankpin
d_c = Inner dia. of the big end
l_c = length of the crank pin
= 1.25 to 1.5dc
Pb_c = 5 to 12.6 Mpa
Substituting,
38275 = 1.5dc × dc × 12.6
∴ dc = 45 mm
lc = 1.5dc= 67.5 mm
Outer diameter of big end = $d_c + 2t_b + 2t_m + 2d_b$ (2.16)
= 45 + [2×2] + [2×5] + [2×2]
= 63 mm Where,
Thickness of bush (t_b) = 2 to 5 mm
Marginal thickness (t_m) = 5 to 10 mm
Marginal thickness of bolt (d_b)= 2 to 5 mm

PARAMETERS	SIZES(mm)
Engine Type	Four stroke, Petrol engine
Thickness	5.5
Width	22
Height	27.5
Height at the small end	24.75
Height at the big end	34.75
Inner dia. of small end	35
outer dia. of small end	49
Inner dia. of big end	45
outer dia. of big end	63
Length of the connecting rod	117.2

Table 2.1 parameters of connecting rod

III. COMPUTER AIDED DESIGN

3.1 SKETCHER: This module is responsible for the implementation of two-dimensional shapes, in preparation for make a three-dimensional commands on it.

PART DESIGN: This module is responsible for converting two-dimensional graphics to three-dimensional objects which is most famous in Catia and is closely linked with sketcher module. The part design Module it is considered from most important modules, that used by the designer to get the additional advantage from cad programs, which is stereotaxic drawing or three-dimensional drawing.

ASSEMBLY: This module is responsible for assembling the parts previously produced in Part Design, and it is most important for those who work in the field of machinery design or design in general, because it is the one who shows the inter-relationships between the parts of the machine or any mechanical establishment

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STRESS ANALYSIS: This module is responsible for testing parts designed to withstand the loads expected occurrence on it, and shows how the mechanical parts are affected by the colors, where they can learn the most dangerous points in terms of emotion through the distribution of colours.

DRAFTING: This module is responsible, for converting what you see on the screen to standard engineering drawings can be traded in the workshop for manufacturing or save them for documentation.

SURFACE AND WIREFRAME: With this module surfaces can be drawing with zero size and weight and has its uses in the aerospace, automotive, ships and Mold Design.

SIMULATION: This module is responsible for obtaining a similar movement of the natural movement, which is expected to occur during the actual operation of the machine or mechanical establishment whatever.

product designers needs it, such as Mobile or furniture or antiques designers. and other modules such as: Sheet Metal, Mold Design, Welding, Aerospace Sheet Metal.The surprise is that all of the above follows the one field which is mechanical design field , while there are other fields such as: Analysis, Machining and Ergonomics

IV FINITE ELEMENT ANALYSIS

4.1 Ti-6Al-4V

Fig 4.1 shows the equivalent elastic strain of connecting rod (TI-6AL-4V) after load applied on connecting rod and the red indicate the maximum deformation and blue indicates minimum deformation

Fig 4.2 shows stresses on of connecting rod (TI-6AL-4V) when applied force. In this the blue indicates for minimum stresses and red indicates for maximum stresses.

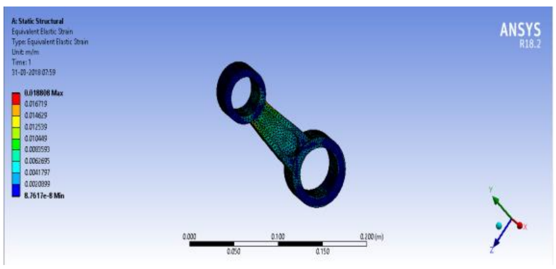


Fig 4.1 Equivalent elastic strain of TI-6AL-4V

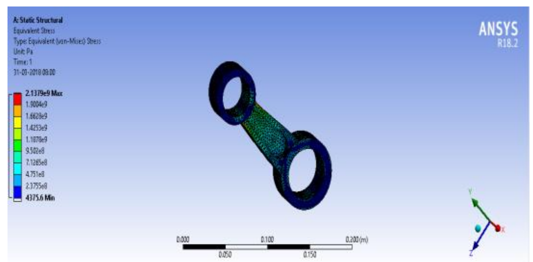


Fig 4.2 Equivalent stress of TI-6AL-4V

4.2 AL 360

Fig 4.4 shows the equivalent elastic strain of connecting rod (AL 360) after load applied on connecting rod and the red indicate the maximum deformation and blue indicates minimum deformation

Fig 4.5 shows stresses on of connecting rod (AL 360) when applied force. In this the blue indicates for minimum stresses and red indicates for maximum stresses.

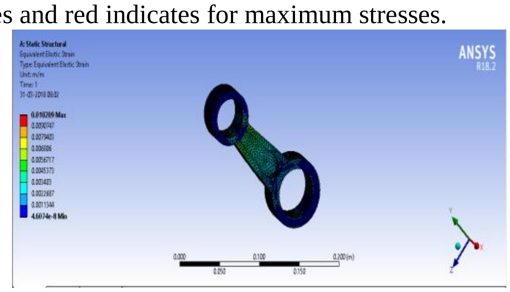


Fig 4.4 Equivalent elastic strain of AL 360

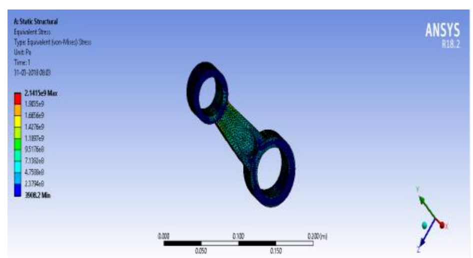


Fig 4.5 Equivalent stress of AL 360

4.3 STRUCTURAL STEEL

In the above image shows the equivalent elastic strain of connecting rod (structural steel) after load applied on connecting rod and the red indicate the maximum deformation and blue indicates minimum deformation

The above figure shows stresses on of connecting rod (structural steel)when applied force. In this the blue indicates for minimum stresses and red indicates for maximum stresses.

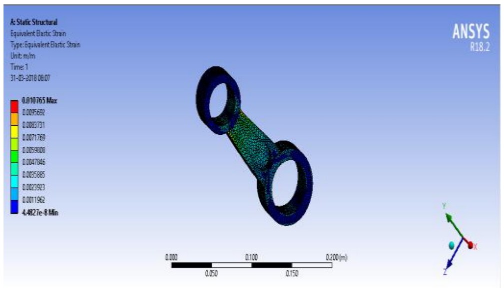


Fig 5.11 Equivalent elastic strain of structural steel

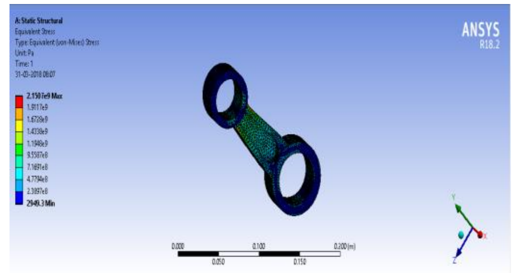


Fig 5.12 Equivalent stress of structural steel

4.3STAINLESS STEEL

Fig 4.6 shows the equivalent elastic strain of connecting rod (stainless steel) after load applied on connecting rod and the red indicate the maximum deformation and blue indicates minimum deformation.

Fig 4.7 shows the equivalent elastic strain of connecting rod (stainless steel) after load applied on connecting rod and the red indicate the maximum deformation and blue indicates minimum deformation

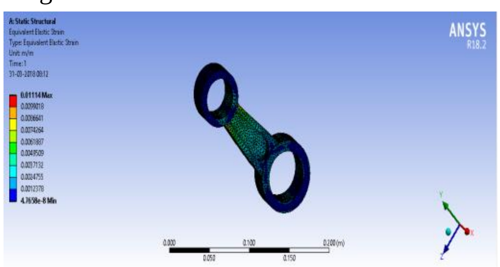


Fig 4.6 Equivalent elastic strain of stainless steel

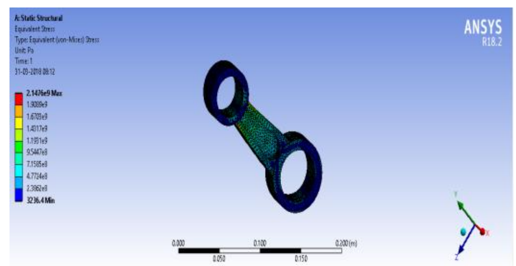


Fig 4.7 Equivalent stress of stainless steel

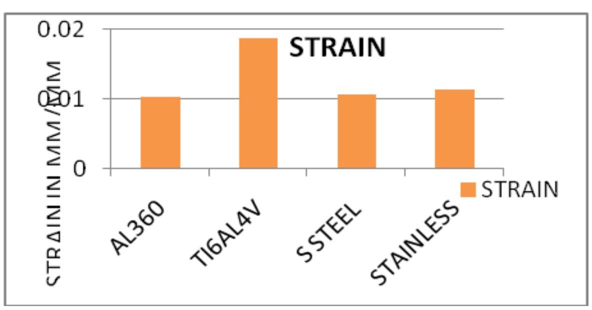
V RESULT AND DISCUSSION

Engine connecting rod is created in CATIA P3V5-6 R2015 software and part file is saved as IGES format. And IGES file is imported into ansys workbench.

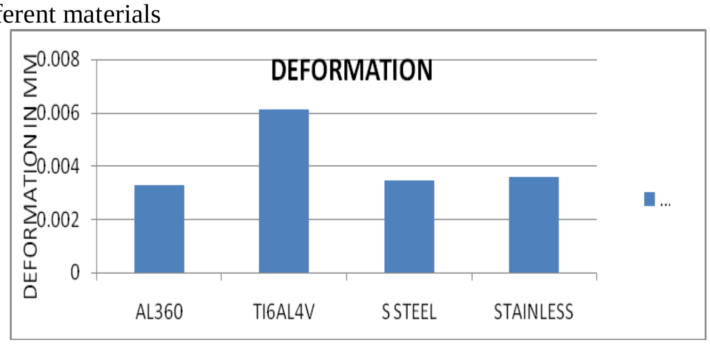
RESULTS FOR STATIC STRUCTURAL ANALYSIS OF CONNECTING ROD

S.NO	MATERIAL	DEFORMATION	STRESS	STRAIN
1	AL 360	0.0033	214.1	0.0102
2	TI-6AL-4V	0.0061	213.7	0.0188
3	STRUCTURAL STEEL	0.0034	215	0.0107
4	STAINLESS STEEL	0.0036	214.7	0.0114

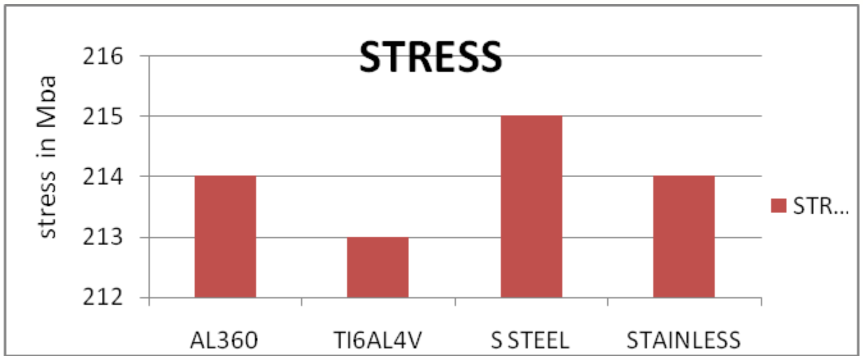
Table 5.1 structural analysis results with different materials



Graph 5.2 strain for different materials.



Graph 5.3 structural deformations for different materials.



Graph 5.4 stresses for different materials.

Weight of connecting rod
1.AL 360
Weight = mass (kg) x gravity(m/s^2)
=0.2492 x 9.81
=2.44N
2.TI-6AL-4V
Weight = mass (kg) x gravity(m/s^2)
=0.398 x 9.81
=3.90N
3.STRUCTURAL STEEL
Weight = mass (kg) x gravity(m/s^2)
=0.706 x 9.81
=6.92N
4.STAINLESS STEEL
Weight = mass (kg) x gravity(m/s^2)
=0.697 x 9.81
=6.84N

VI CONCLUSION:

AL 360 is the only material with low weight of 2.44N and total deformation of 0.033 when compared to other three materials
When AL 360 is compared with other three materials
1)Weight of the connecting rod is reduced by 140 grams when compared to TI-6AL-4V
2) Weight of the connecting rod is reduced by 450 grams when compared to structural steel
3) Weight of the connecting rod is reduced by 480 grams when compared to stainless steel

Finally AL 360 is the best material suitable for manufacturing connecting rod because of its less in weight and minimum total deformation

Above project gives the idea about designing of the connecting rod. It explains about different materials used and comparing the result of all material. Also most of the researchers used the CATIA software for the modelling and ANSYS software for analysis. These can be used for designing any connecting rod in Automobile. Connecting rod can be designed for weight and cost reduction also to increase the life time of connecting rod. Up to some level of extent the weight of the connecting rod is lighter and having more strength as compared to the original design.

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