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Modeling and Analysis of Connecting Rod in Two Wheeler by Using ANSYS

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Abstract – In this paper, the wok is carried out to measure the stress, factor of safety in connecting rod in two wheeler. 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 describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel, Forged steel, etc... A parametric model of Connecting rod is modeled using PRO-E software and to that model, and analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz...Forged steel, Aluminum alloy, carbon steel, titanium alloy, etc... The best parameters like Von misses Stress, Deformation, Factor of safety, Stiffness and weight reduction for two wheeler connecting rod are done in calculation and analyzed.

Index Terms – Stress, Total deformation, factor of safety, CREO, Analysis, ANSYS, Von misses Stress, connecting rod.

1. INTRODUCTION

A connecting rod is an engine component. That transfers motion from the piston to the crankshaft and functions as a lever arm. Connecting rods are commonly made from Castiron, Aluminum alloy and are designed to withstand dynamic stresses from combustion and piston movement. The small end of the connecting rod connects to the piston with a piston pin. The big end of the connecting rod connects to the crankpin journal to provide a pivot point on the crankshaft. 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". CREO 2.0 is the standard in 3D product design, featuring industry-leading productivity tools that Promote best practices in design while ensuring compliance with your industry and company standards. Integrated CREO CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole.

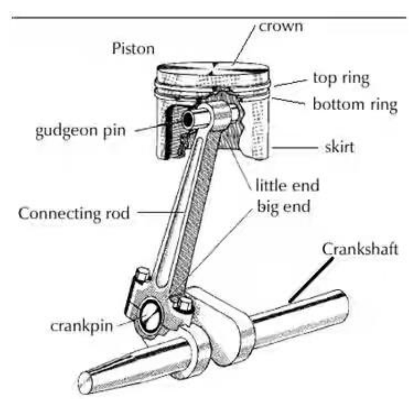

Fig: 1 Connecting rod with parts

The past literature that Leela Krishna Vegi, Venu Gopal Vegi [1].we demonstrate by the new material for forged steel and take analysis and calculation. K. Sudershn Kumar, Dr. K. Tirupathi Reddy, Syed Altaf Hussain [2] we performed by the changing material like as aluminum alloy and to reduce the weight and deformation. I.Sai Bhargav, M.Pavan Kalyan , N.Charishma [3] By checking and comparing the results of all materials Al-MWCNT, Ti-6Al-4V, E glass, Carbon Steel in the above graphs for various analysis Static, Dynamic condition and applying two loads at big and small end of the connecting rod.Ankit Gupta, Mohd. Nawajish [4].Maximum von mises stress, Maximum von mises strain and Maximum displacement are minimum in connecting rod of Beryllium alloy in comparison of rest of two materials. Connecting rod design is safe for beryllium alloy based on the ultimate strength. Arshad Mohamed Gani .P,Vinithra Banu T [5]. For the Aluminium boron silicide metal matrix composIte material factor of safety is increased compared to existing carbon steel. Weight can be reduced by changing the material of existing carbon steel connecting rod into Aluminium boron silicide metal matrix composite connecting rod.Satish Wable, Dattatray S.Galhe, Rajkumar L.Mankar [6]. Connecting rod can be designed for weight and cost reduction also to increase the life time of connecting rod. Upto some level of extent the weight of the connecting rod is lighter and having more strength as compared to the original design.

1.1 Process Methodology

In this work to start with collection of literature review of existing method and material. Then collect the drawback and to collect the material. Then observe the properties of the material and model can be design by normal specification by using CREO 2.0. Model of connecting rod is imported into preprocessing work. Preprocessing of model consist of meshing, creation of load collectors and apply boundary conditions on model. Then model is exported to ANSYS for analyse the parameters. Results of solution plotted in Hyper View which is well known postprocessor of Hyper Works software. For the optimization purpose topology. The optimized value can be used to calculate the parameters like Factor of Safety, Weight, and Stiffness.

1.2 Methodology

- Drawback of Existing model
- Collect detail of the drawback
- Collect the Material of connecting rod
- Design of connecting rod
- Analysis of connecting rod
    - Total deformation
    - Shear stress
    - Equivalent stress
- Calculation of parameters
    - Factor of safety
    - Weight
    - Stiffness
    - Result and discussion

2. SELECTION OF MATERIALS

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Systematic selection of the best material for a given application begins with properties and costs of candidate materials. For example, a thermal blanket must have poor thermal conductivity in order to minimize heat transfer for a given temperature difference. Systematic selection for applications requiring multiple criteria is more complex.

The following material can be selected by analysis and manufacturing of connecting rod.

Titanium alloy, Beryllium alloy and Cast iron

Table 1 Materials Properties

S. no	Properties	Titanium alloy	Beryllium alloy	Cast iron
1	Density (kg/m^3)	4800	8360	7250
2	Young's Modulas (Gpa)	90	131	180
3	Poission ratio	0.34	0.29	0.26
4	Yield stress (Mpa)	250	240	215
5	Tensile stress (Mpa)	435	370	350

3. DESIGN 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 as a strut and the rankine formula is used [9]. 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 [9]. 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.According to rankine formulae

Wcr about x-axis

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

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

$[\ \therefore for\ both\ ends\ hinged\ L = l]$

Wcr about y-axis

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

$= [\sigma_c \times A] / (1 + (a[l/2K_{yy}]^2)$

$[\therefore for\ both\ ends\ fixed\ L = l/2]$

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

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

$= [\sigma_c \times A] / (1 + (a[l/2K_{yy}]^2)$ [or]

$[l/K_{xx}]^2 = [l/2K_{yy}]^2$

$K^2_{xx} = 4K^2_{yy}$ [or]

$I_{xx} = 4I_{yy}$ $[\therefore I = A \times K^2]$

This shows that the connecting rod is four times strong in buckling about y-axis than about-axis. If $I_{xx} > 4I_{yy}$, Then buckling will occur about y-axis and if $I_{xx} < 4I_{yy}$, then buckling will occur about x-axis .In Actual practice I_{xx} is kept slightly less than $4I_{yy}$. It is usually taken between 3 and 3.5 and the Connecting rod is designed for buckling about x-axis. The design will always be satisfactory for buckling about y-axis [8]. The most suitable section for the connecting rod is I-section with the proportions shown Fig 2

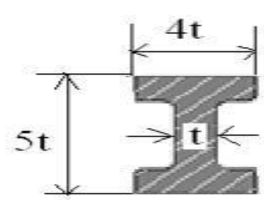

Fig 2 Standard Dimension of I – Section

Area of the cross section

$= 2[4t \times t] + 3t \times t = 11t^2$

Moment of inertia about x-axis $= 2[4txt] + 3txt = 11t^2$

Moment of inertia about x-axis

$I_{xx} = (1/12)\,[4t\,\{5t\}^3 - 3t\,\{3t\}^3]$

$= (419/12)\,[t^4]$

Moment of inertia about y-axis

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

$= 131/12[t^4]$

$I_{xx}/I_{yy} = [419/12] \times [12/131]$

$= 3.2$

Since the value of I_{xx}/I_{yy} lies between 3 and 3.5 m therefore I-section chosen is quite satisfactory.

Pressure Calculation for 150cc Engine

Suzuki 150 cc Specifications

Engine type air cooled 4-stroke

Bore x Stroke (mm) = 57×58.6

Displacement = 149.5 CC

Maximum Power = 13.8 bhp @ 8500 rpm

Maximum Torque = 13.4 Nm @ 6000 rpm

Compression Ratio = 9.35/1

Density of Petrol C_8H_{18}

$= 737.22 kg/m^3$

$= 737.22E^{-9}\ kg/mm^3$

Temperature = 60^o F

$= 288.855^o$ K

Mass = Density × Volume

$= 737.22E^{-9} \times 149.5E^3$

= 0.11kg

Molecular Weight of Petrol =114.228g/mole

From Gas Equation,

PV = Mrt R = Rx/Mw

= 8.3143/114228 = 72.76

$P = (0.11 \times 72.786 \times 288.85) / (149.5\ E^3)$

P = 15.5 Mpa.

Design Calculations for Existing Connecting Rod

Thickness of flange & web of the section = t

Width of section B= 4t

The standard dimension of I - SECTION.

Height of section H = 5t

Area of section A= 2(4t×t) +3t×t

$A = 11t^2$

M.O.I of section about x axis:

$I_{xx} = (1/12)\ [4t\ \{5t\}^3 - 3t\ \{3t\}^3]$

$= (419/12)\ [t^4]$

MI of section about y axis:

$I_{yy} = (2\times1/12) \times t\times \{4t\}^3 + (1/12)\ \{3t\}\ t^3$

$= (131/12)\ [t^4]$

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

Length of connecting rod (L) = 2 times the stroke

L = 117.2 mm

Buckling load W_B = maximum gas force × F.O.S

$WB = (\sigma_c \times A) / (1 + (a\ (L/K_{xx})^2)$

= 37663N

σ_c= compressive yield stress = 415MPa

$K_{xx} = I_{xx}/A$

$K_{xx} = 1.78t$

$a = \sigma_c/\pi^2 E$

a = 0.0002 by substituting σ_c, A, a, L, K_{xx} on W_B then

= 4565t4-37663t2-81639.46 = 0

$t^2 = 10.03$

t = 3.167mm

t = 3.2mm

Width of section B = 4t

= 4×3.2

= 12.8mm

Height of section H = 5t

= 5×3.2

= 16mm

Area $A = 11t^2$

=11×3.2×3.2

$= 112.64mm^2$

Height at the big end (crank end) = H_2

= 1.1H to 1.25H

= 1.1×16

H_2 =17.6mm

Height at the small end (piston end) = 0.9H to 0.75H

= 0.9×16

H_1 =12mm

Stroke length (l) =117.2mm

Diameter of piston (D) =57mm

$P=15.5N/mm^2$

Radius of crank(r) =stroke length/2

=58.6/2

=29.3 mm

Maximum force on the piston due to pressure

$Fl = \pi/ (4xD^2xP)$

$= (\pi/4)\ x\ (57)^2 x15.469$

=39473.16N

Maximum angular speed W_{max}= [2πNmax]/60 ([2π×8500]/60)

$A= \pi r^2$

=768 rad/sec

Ratio of the length of connecting rod to the radius of crank

N= l/r

=112/ (29.3) = 3.8

Maximum Inertia force of reciprocating parts

$F_{im} = M_r\ (W_{max})^2\ r\ (\cos\theta + (COS2\theta/ n))$ (Or)

$F_{im} = M_r\ (W_{max})^2\ r\ (1+ (1/n))$

$= 0.11x\ (768)^2\ x\ (0.0293)\ x\ (1+ (1/3.8))$

F_{im} = 2376.26N

Inner diameter of the small end

$d1 = F_g/(P_{b1}\ x\ l_1)$

$= 6277.167/ (12.5\times1.5d_1)$

= 17.94mm

Where, Design bearing pressure for small end P_{b1}=12.5 to $15.4N/mm^2$

Length of the piston pin l_1= (1.5to 2) d_1

Outer diameter of the small end

$= d_1+2t_b+2t_m$

= 17.94 + [2×2] + [2×5] = 31.94mm

Where, Thickness of the bush (t_b) = 2 to 5 mm

Marginal thickness (t_m) = 5 to 15 mm

Inner diameter of the big end d_2=Fg/ (P_{b2}×l_2) =6277.167/ (10.8×1.0d_1)

=23.88mm

Where,

Design bearing pressure for big end

P_{b2} = 10.8 to 12.6N/mm^2

Length of the crank pin l_2 = (1.0 to 1.25) d_2

Root diameter of the bolt

$= ((2F_{im})/ (\pi x St))^{1/2}$

$= (2\times6277.167\ \pi\times56.667)^{1/2}$

= 4mm

Outer diameter of the big end

$= d_2 + 2t_b + 2d_b + 2t_m$

= 23.88+2×2+2×4+2×5

= 47.72mm

Where,Thickness of the bush [t_b] = 2 to 5 mm

Marginal thickness [t_m] = 5 to 15 mm

Nominal diameter of bolt [d_b] = 1.2 x root diameter of the bolt = 1.2×4 = 4.8mm

Table 2 Specifications of connecting rod

Sno	Parameters (mm)
1	Thickness of the connecting rod (t) = 3.2
2	Width of the section (B = 4t) = 12.8
3	Height of the section(H = 5t) = 16
4	Height at the big end = (1.1 to 1.125)H =17.6
5	Height at the small end = 0.9H to 0.75H=14.4
6	Inner diameter of the small end = 17.94
7	Outer diameter of the small end = 31.94
8	Inner diameter of the big end = 23.88
9	Outer diameter of the big end = 47.72

3.1 Model of Connecting Rod

Fig: 1 Connecting Rod Sketch For Creo 2.0

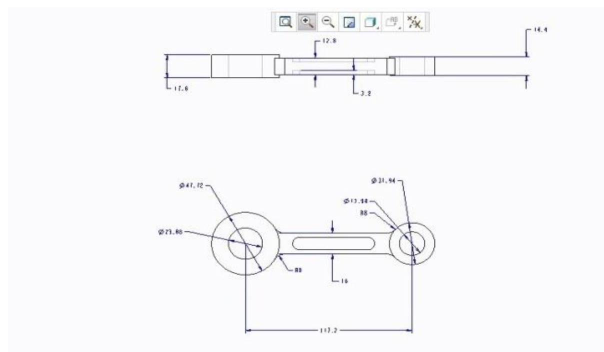

Fig 2. 2d drawing for connecting rod

3.2 Analysis

The 3D part model was then imported into Ansys Workbench analysis software. The material properties were assigned to the geometry as shown in table. The model was then meshed /divided into a finite number of elements using fine mesh option.

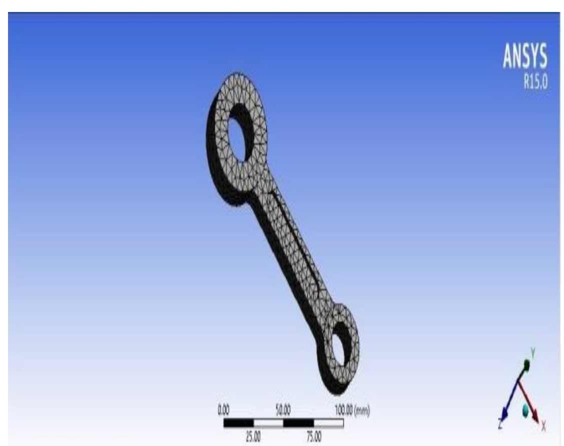

Fig: 3 Meshing Of Connecting Rod in Tetrahedra

3.3 Titanium Alloy

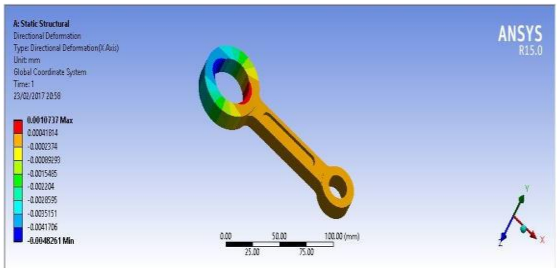

Fig 4 Directional Deformation For X Axis

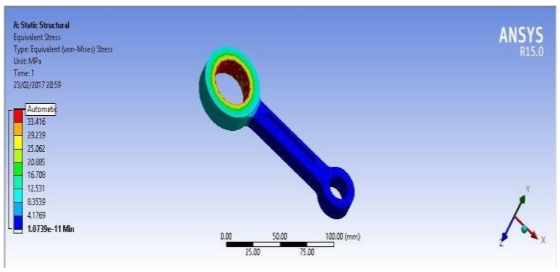

Fig 5 Equivalent Stress

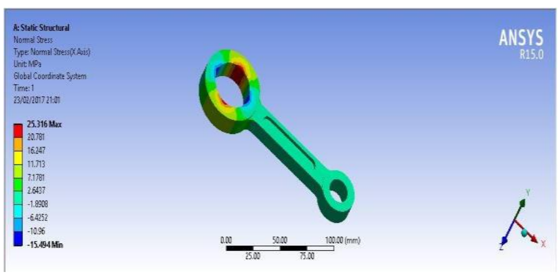

Fig 6 Normal Stress For X Axis

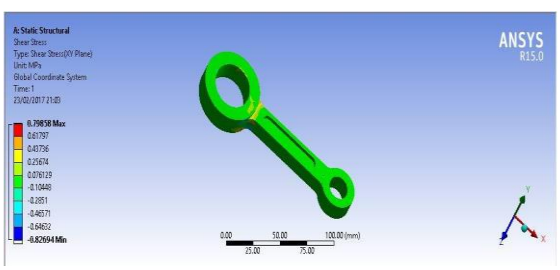

Fig 7 Shear Stress For Xy Plane

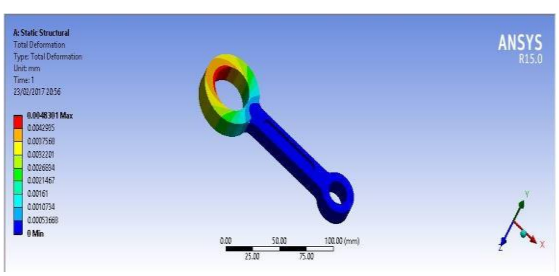

Fig 8 Total Deformation

3.4 Beryllium alloy

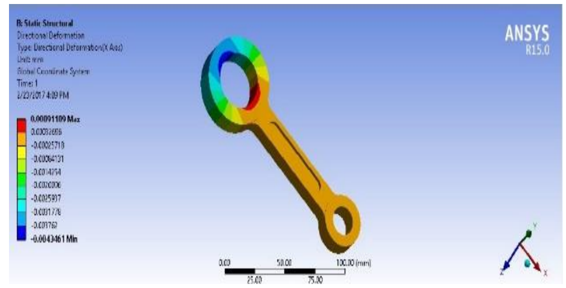

Fig 9 Directional Deformation For X Axis

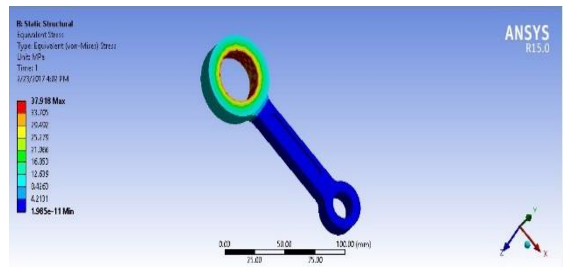

Fig 10 Equivalent Stress

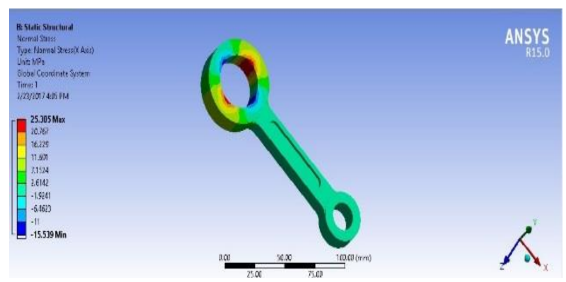

Fig 11 Normal Stress For X Axis

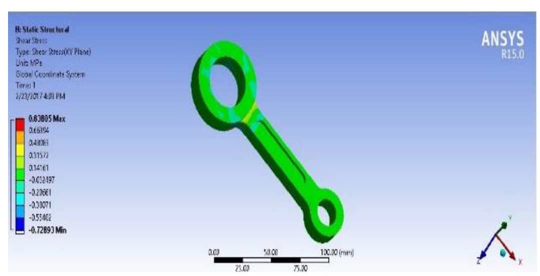

Fig 12 Shear Stress for XY Plane

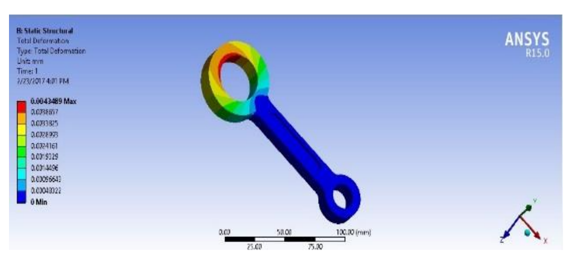

Fig 13 Total Deformation

3.5 Cast iron

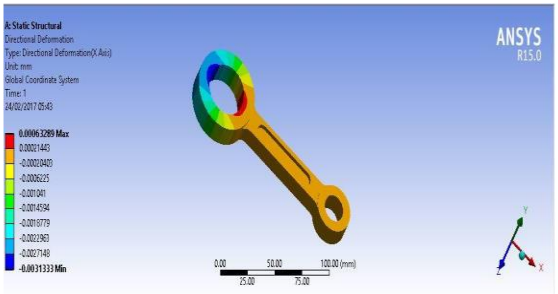

Fig 14 Directional Deformation For X Axis

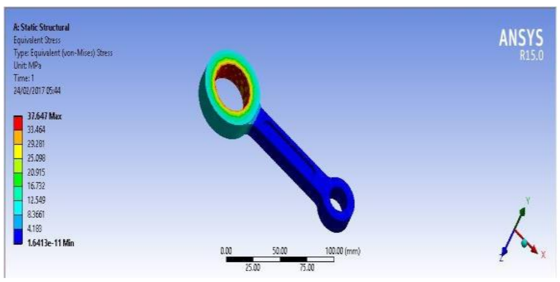

Fig 15 Equivalent Stress

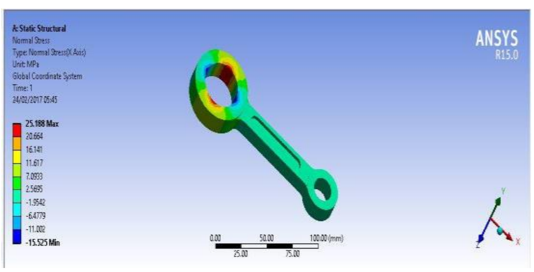

Fig 16 Normal Stress For X Axis

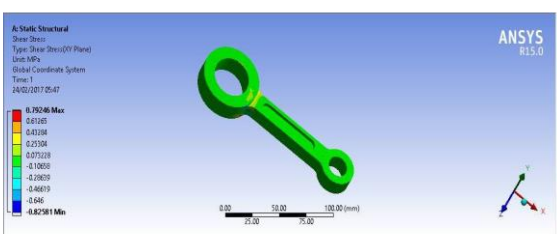

Fig 17 Shear Stress for XY Plane

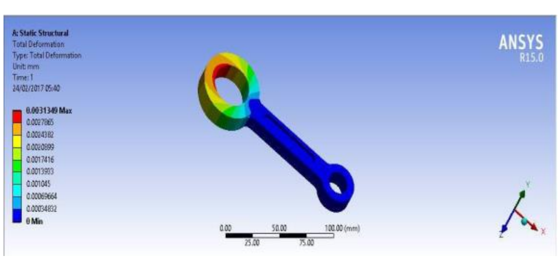

Fig 18 Total Deformation

4. CALCULATION FOR FACTOR OF SAFETY OF CONNECTING ROD

f.o.s = factor of safety

σm = mean stress

σy = yield stress

σv = variable stress

σe = endurance stress

$1/f.o.s = (\sigma m/\sigma y)+(\sigma v/\sigma e)$

For Titanium alloys

$\sigma max = 33.416$ $\sigma min = 1.0739\times10^{-11}$

$\sigma m = (\sigma max + \sigma min)/ 2 = 16.708$

σy = 748Mpa

$\sigma v = (\sigma max-\sigma min)/2 = 16.708$

$\sigma e = 0.6\times748=448.8$Mpa

$1/f.o.s = 0.059$

Factor of safety [F.O.S] = 17.69

4.1 Calculation for Weight and Stiffness For titanium alloy:

Density of titanium alloy = 4.6×10^{-6} kg/mm3

Volume = 41050 mm3

Deformation = 0.0048301 mm

Weight of titanium alloy = volume ×density = $=41050\times4.6\times10^{-6}$

= 0.188kg

= 0.188×9.81 = 1.8524 N

Stiffness = weight/deformation

= 1.8524/0.0048301

=383.51 N/mm

Fatigue calculation Result for fatigue of connecting rod:

$N=1000(sf/(0.9\sigma u))^{3/(\log(\sigma e'/(0.9\times\sigma u)))}$

Where,

N = No. of cycles

σe = Endurance Limit

σu = Ultimate Tensile Stress

$\sigma e'$ = Endurance limit for variable axial stress

k a = Load correction factor for reversed axial load = 0.8

ksr = Surface finish factor = 1.2

ksz = Size factor = 1

$\sigma e'$ = σe×ka×ksr×ksz

sf = (f.o.sx σv)/(1−($f.s\sigma m/\sigma u$))

For titanium alloy

σu=962.5 Mpa

σe= σu×0.5

= 962.5×0.5

= 481.25 Mpa

$\sigma e'$= σe×ka×ksr×ksz

= 481.25×0.8×1.2×1

= 462 Mpa

sf = (f.o.sxσv)/(1−(f.o.s×σm)/σu))

= (17.69×16.708)/(1−((17.69×16.708)/962.5))

= 426.54 Mpa

N = $1000(sf/0.9\sigma u)^{3/\log(\sigma e'/(0.9\times\sigma u))}$

= $1000(426.54/(0.9\times962.5))^{3\log(462/(0.9\times962.5))}$

N= 2405.03× 10^3 cycles

4.2 Calculation for Weight and Stiffness for Beryllium Alloy:

Density of beryllium alloy = 8.36×10^{-6}kg/mm^3

Volume = 41050 mm^3

Deformation = 0.0043489 mm

Weight of beryllium alloy = volume ×density

=$41050\times8.36\times10^{-6}$

= 0.3431kg

= 0.3431×9.81 = 3.36 N

Stiffness = weight/deformation

= 3.36/0.0043489

=772.609 N/mm

Fatigue calculation Result for fatigue of connecting rod:

N=$1000(sf/(0.9\sigma u))^{3/(\log(\sigma e'/(0.9\times\sigma u)))}$

Where,

N = No. of cycles

σe = Endurance Limit

σu = Ultimate Tensile Stress

$\sigma e'$ = Endurance limit for variable axial stress

ka = Load correction factor for reversed axial load = 0.8

ksr = Surface finish factor = 1.2

ksz = Size factor = 1

$\sigma e'$ = σe×ka×ksr×ksz

sf = (f.o.s×σv)/(1−((f.o.s×σm)/σu))

For beryllium alloy

σu=370Mpa

σe= σu×0.5

= 370×0.5

= 185 Mpa

$\sigma e'$= σe×ka×ksr×ksz

= 185×0.8×1.2×1

= 177.6Mpa

sf = (f.o.s×σv)/(1−((f.o.s×σm)/σu))

= (4.747×18.9575)/(1−((4.747×18.9575)/370))

= 118.91Mpa

N = $1000(sf/0.9\sigma u)^{3/\log(\sigma e'/(0.9\times\sigma u))}$

= $1000(118.91/(0.9\times370))^{3\log(177.6/(0.9\times370))}$

N=1000.186× 10^3 cycles.

4.3 Calculation for factor of safety of connecting rod

f.o.s= (σm/σy)+(σv/σe)

For cast iron

σmax = 37.647 σmin = 1.6413×10^{-11}

σm = (σmax + σmin)/ 2 = 18.82

σy = 503Mpa

σv = (σmax−σmin)/2 = 18.82

σe = 0.6×503=301.8

1/f.o.s = 0.099

Factor of safety [F.O.S] =10.02

Calculation for Weight and Stiffness for cast iron

Density of cast iron = 7.15×10^{-6}kg/mm^3

Volume = 41050 mm^3

Deformation = 0.0031349 mm

Weight of cast iron =volume ×density

=$41050\times7.15\times10^{-6}$

= 0.29kg

= 0.29×9.81 = 2.87 N

Stiffness = weight/deformation

= 2.87/0.0031349 =918.49 N/mm

Fatigue calculation Result for fatigue of connecting rod
$N=1000(sf/(0.9\sigma u))^{3/(\log(\sigma e'/(0.9\times\sigma u)))}$
Where,

N = No. of cycles

σe = Endurance Limit

σu = Ultimate Tensile Stress

$\sigma e'$ = Endurance limit for variable axial stress

k a = Load correction factor for reversed axial load = 0.8

ksr = Surface finish factor = 1.2

ksz = Size factor = 1

$\sigma e' = \sigma e\times ka\times ksr\times ksz$

$sf = (f.o.s\times\sigma v)/(1-((f.o.s\times\sigma m)/\sigma u))$

For cast iron

σu=675Mpa

σe= σu×0.5

= 675×0.5

= 337.5 Mpa

$\sigma e' = \sigma e\times ka\times ksr\times ksz$

= 337.5×0.8×1.2×1

= 324.24Mpa

$sf = (f.o.s\times\sigma v)/(1-((f.o.s\times\sigma m)/\sigma u))$

= (10.02×18.82)/(1−((10.02×18.82)/675))

= 261.683 Mpa

$N = 1000(sf/0.9\sigma u)^{3/\log(\sigma e'/(0.9\times\sigma u))}$

$= 1000(261.683/(0.9\times675))^{3\log(324/(0.9\times675))}$

N=1045.77× 10^4 cycles.

Table 3 Result for Factors

Material	Fos	Weight	Stiffness
Titanium alloy	17.69	1.8524	383.51
Beryllium alloy	4.747	3.36	772.609
Cast iron	10.02	2.27	918.49

Table 4 stress and deformation of Titanium alloy

Types	Max(Mpa)	Min (Mpa)
Directional Deformation For X Axis	0.0010737	-0.0048261
Equivalent Stress	37.593	$1.0739\text{x}10^{-11}$
Normal Stress For X Axis	25.316	-15.494
Shear Stress for XY Plane	0.79858	-0.26694
Total Deformation	0.0048301	0

Table 5 stress and deformation of Beryllium alloy

Types	Max(Mpa)	Min (Mpa)
Directional Deformation For X Axis	0.00185381	-0.0083612
Equivalent Stress	37.918	$1.98\text{x}10^{-11}$
Normal Stress For X Axis	25.305	-15.539
Shear Stress for XY Plane	0.83805	-0.72893
Total Deformation	0.0043489	0

Table 6 stress and deformation of Cast iron

Types	Max(Mpa)	Min (Mpa)
Directional Deformation For X Axis	0.00063289	-0.0031333
Equivalent Stress	37.647	$1.6413\text{x}10^{-11}$

Normal Stress For X Axis	25.188	-15.525
Shear Stress for XY Plane	0.79246	-0.82581
Total Deformation	0.0031349	0

5. RESULTS AND DISCUSSION

The design parameters (Von Mises stress, normal stress, shear stress, Directional deformation, and total deformation) obtained from the analysis were used to study the behavior of materials on the connecting rod.

From the Table 3, and Table 6, the maximum factor of safety, Minimum weight and maximum stiffness obtained for the overall component using cast iron material. Also, the maximum Equivalent Stress and maximum total deformation values obtained from the analysis are 37.647Mpa and 0.0031349mm which are very less than the deformation limit of material (1mm).

6. CONCLUSION

By checking and comparing the results of materials in Finalizing the results are shown in below.

Considering the parameters

1. ANSYS equivalent stress for the both the materials are same.
2. For the cast iron material factor of safety (from soderberg's) and stiffness is increased compared to existing forged steel.
3. The weight of the cast iron material is less then the existing connecting rod.
4. From the fatigue analysis life time of the connecting rod can be determined.
5. And also no.of.cycle for Cast iron is (1045.77×10^4) is more than the existing connecting rod (8500×10^3).
6. When compared to both the materials, cast iron is cheaper than the existing connecting rod material.

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