ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Stress Analysis on Diesel Engine Connecting Rod

G. Harish
M.Tech,
Department of Mechanical Engineering.
JNTUH College of Engineering,
Kukatpally, Hyderabad – 500 085.

Dr. G.Satish Babu, ME, Ph.D
Professor,
Department of Mechanical Engineering.
JNTUH College of Engineering,
Kukatpally, Hyderabad – 500 085.

Abstract:

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 and thus convert the reciprocating motion of the piston into rotary motion of the crank. In our project we have designed a connecting rod used in a diesel engine using theoretical calculations for two materials Carbon Steel and Aluminum alloy A360. The connecting rod is modeled in 3D modeling software CATIA. To validate the strength of the connecting rod, we have done structural analysis. We have also done modal analysis to determine number of modes. Fatigue analysis is done to determine the stress intensities under different loads.Analysis is done using two materials Carbon Steel and Aluminum alloy A360 to verify the best material for connecting rod.

Keywords:

connecting rod, diesel engine

I. INTRODUCTION:

Connecting rods are widely used in variety of car 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. It consists of a pin-end, a shank section, and a crank end. Pin-end and crank-end pin holes are machined to permit accurate fitting of bearings. One end of the connecting rod is connected to the piston by the piston pin. The other end revolves with the crankshaft and is split to permit it to be clamped around the crankshaft. The two parts are then attached by two bolts. Connecting rods are subjected to forces generated by mass and fuel combustion.

These two forces results in axial and bending stresses. 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 bending stresses caused by the thrust and pull on the piston and by centrifugal force. The connecting rod of the tractors is mostly made of cast iron through the forging or powder metallurgy. The main reason for applying these methods is to produce the components integrally and to reach high productivity with the lowest cost. Nevertheless, connecting rod design is complicated because the engine is to work in variably complicated conditions and the load on the rod mechanism is produced not only by pressure but also inertia. When the repetitive stresses occur in connecting rod it leads to fatigue phenomenon which can cause so dangerous ruptures and damages.

An example of the fatigue analysis and design was presented in 2003 by some researchers. A rupture due to the fatigue and the method of correcting the connecting rod design was also reported presented a strengthening method for the connecting rod design. Finite element (FEM) method is a modern way for fatigue analysis and estimation of the component longevity which has the following advantages compared to the other methods. Through this method, we can access the stress/strain distribution throughout the whole component which enables us to find the critical points authentically. This achievement seems so useful particularly when the component doesn't have a geometrical shape or the loading conditions are sophisticated. The influential component factors are able to change such as material, cross section conditions etc. Component optimization against the fatigue is performed easily and quickly. Analysis is performed in a virtual environment without any necessity for prototype construction.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

II.Ease of Use:
FUNCTION OF CONNECTING ROD:

The connecting rod is the intermediate member between the piston and the crankshaft. Its primary function the push and pull from the piston pin to the crank pin and thus converts the reciprocating motion of the piston into rotary motion of the crank. 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.

PRESSURE CALCULATIONS FOR DIESEL ENGINE:
Diesel Engine Specifications:

Bore = 69.6mm
Stroke = 82mm
Displacement = 1.2l = 1248cc
Capacity per cylinder = 312cc
Maximum power = 89.2 ps (88bhs)(65.6kw) @4000rpm
Specific output = 70.5bhp/liter
Maximum torque = 200 Nm @1750 – 3000rpm
Bmep = 2013.8kpa (292.1psi)
Specific torque = 160.26 Nm/l
Ratio = 0.85
Density of diesel = 820 to 950 kg/cm at 150 C
= 0.00095 kg/cm3
Density = 0.00000095 kg/mm3
Diesel $C_{10} H_{22}$ to $C_{15} H_{28}$
Molecular weight of diesel= 208g/mole
Mass =density×volume
m = 0.00000095×312000
m = 0.2964 j/mol k
PV = mRT(0.2964×8.3143×288)/(0.208×0.000312)
P = 709.73525/0.000064896 =10936502.24j/m^3
P = 10.936 N/mm2
Gas pressure P = 10.936 N/mm2

III.DESIGN CALCULATIONS :
MATERIAL – CARBON STEEL:

1.Dimensions of cross section of connecting rod:

T = Thickness of flange and web of the section
B = 4t = Width of the section
H = 5t = Height of the section
Area of the section
A = 2(4txt)+3txt = 11t2
Moment of Inertia of section about x-axis
Ixx = 419/12 t4
Moment of Inertia of section about Y-axis
Iyy = 131/12 t4
Ixx/ Iyy = 3.2
Stroke lenth l = 82 mm
Bore diameter D = 69.6 mm
No.of cylinders = 4
Length of the connecting rod = 2 times the stroke length
L = 2 l = 2x 82 =164 mm
Buckling load WB =maximum gas force x factor of safety
fc =max gas load
fc = p xA
A = π/4 D2 = 3802.6656 mm2
fc = 10.936 x 3802.6656
fc = 41585.95 N
Factor of safety =5 to 6
WB = 41585.95 x 6
= 249515.7 N
WB = σc x A/[1+a(L/Kxx)]
σc = compressive yield strength =285 N/mm2
Kxx = Ixx/A = [419/12 t2] =3.17 t2
[11t2]
KXX =1.78 t
a = constant = σc / π2E
E = 200000 N/mm2
a = 285 /π2(200000) =0.0001445
249515.7 = 285 x 11t2/[1+0.0001445(164/1.78t)2
t4-79.59t2-97.0998=0
t = 8.98mm=9mm
B = 4t =4x 9 = 36 mm
H = 5t = 5x 9 =45 mm
Depth near the small end H1 =0.75H to 0.9 H
H1 = 0.9 x 7.5 =40.5 mm
Depth near the big end H2 =1.1H to 1.25H
H2 = 56.25 mm

2. Dimensions of the crank pin at the big end:

Load on the crank pin = projected area x bearing pressure
FL =dC x x Pbc
lC = 1.25 x dc to 1.5 dc
Pbc = Allowable bearing pressure at the crank pin
Pbc = 50 N/mm2
FL = π/4 D2 x P =π/4 x(69.6)2 x 10.936

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

FL = 41585.951
41585.951 = 1.5dc 2 x 50
dc 2 = 41585.951/1.5x50
dc = 23.54mm
lC =1.5 dc =35.32 mm

3. Size of bolts for securing the big end

Inertia force of the reciprocating parts EI =mR xω2r (cos+cos2/l/r)
ω = Angularspeed of the engine in rad/sec
ω = 4000rpm =418.87 rad/sec
mass of piston =1.36 kg
mass of piston pin = 35gms =0.035
mass of connecting rod =0.352 kg
mR =mass of reciprocating parts in kg=1.747kg
Angle of inclination of crank with the line of action =0
r = radius of crank
l = length of connecting rod
l/r =4
Force on the bolts = π/4(dcb)2 σt nb
σt = Allowable tensile stress
Bolts can be made of high carbon steel (or) nickel alloy steel
σt =380-620 mpa
dcb = core diameter of the bolt in mm
nb = no. of bolts = 2
FI = mR xω2r (cos+cos2/l/r)
FI = mR xω2r(1+r/l)
Radius of crank = l/4 = 164/4 =41mm
FI =1.747(418.87)2 x 0.041(1+1/4)
FI = 12567.1(5/4)
FI = 15708.88
FI = π/4(dcb)2 σt nb
15708.88 = π/4(dcb)2x380x 2
15708.88 = 596.6(dcb)2
dcb =5.13mm
Nominal (or) major diameter of bolt
db = dcb/0.84 =5.13/0.84 =6.1mm

4. Thickness of big end cap

Maximum bending moment Mc =FI x X/6
X = distance between bolt centre
X = dia of crank pin (dc) + 2 x Thickness of bearing +clearance
X = 23.54+2x3+3 =32.54mm
bc = width of cap in mm =length of crank pin
bc = 35.32mm
section modulus for the cap
ZC = bc (tc)2/6
Bending stress σb = MC / ZC = FI x X/ bc (tc)2
σb =230 N/mm2
230 = 15708.88x32.54/35.32 (tc)2
(tc)2 =62.92
tc =7.93mm

MATERIAL – ALUMINUM:

1.Dimensions of cross section of connecting rod

T = Thickness of flange and web of the section
B = 4t = Width of the section
H = 5t = Height of the section
Area of the section
A = 2(4txt)+3txt = 11t2
Moment of Inertia of section about x-axis
Ixx = 419/12 t4
Moment of Inertia of section about Y-axis
Iyy = 131/12 t4
Ixx/ Iyy = 3.2
Stroke lenth l = 82 mm
Bore diameter D = 69.6 mm
No.of cylinders = 4
Length of the connecting rod = 2 times the stroke length
L = 2 l = 2x 82 =164 mm
Buckling load WB =maximum gas force x factor of safety
fc =max gas load
fc = p xA
A = π/4 D2 = 3804.594 mm2
fc = 10.936 x 3804.594
fc = 41607.044 N
Factor of safety =5 to 6
WB = 41607.044 x 6
= 249642.264 N
WB = σc x A/[1+a(L/Kxx)]
σc = compressive yield strength =172 N/mm2
Kxx = Ixx/A = [419/12 t2] =3.17 t2
[11t2]KXX =1.78 t
a = constant = σc / π2E
E = 200000 N/mm2
a = 172 /π2(80000) =0.0002178
249642.264 = 172 x 11t2/[1+0.000217(164/1.78t)2
t4-131.946t2-243.054=0
t = 11.56=11mm

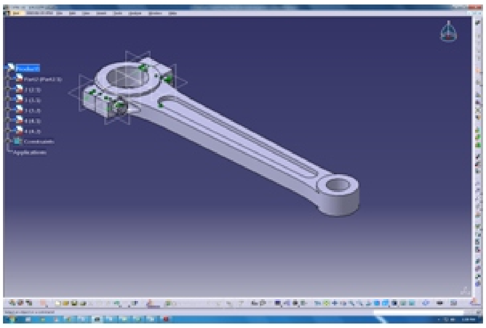
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

B = 4t =4x 9 = 36 mm
H = 5t = 5x 9 =45 mm
Depth near the small end H1 =0.75H to 0.9 H
H = 0.9 x 7.5 =40.5 mm
Depth near the big end H2 =1.1H to 1.25H
H2 = 56.25 mm
2.Dimensions of the crank pin at the big end
Load on the crank pin = projected area x bearing pressure
FL =dC x x Pbc
lC = 1.25 x dc to 1.5 dc
Pbc = Allowable bearing pressure at the crank pin
Pbc = 50 N/mm2
FL = π/4 D2 x P =π/4 x(69.6)2 x 10.936
FL = 41585.951
41585.951 = 1.5dc 2 x 50
dc 2 = 41585.951/1.5x50
dc = 23.54mm
lC =1.5 dc =35.32 mm
3. Size of bolts for securing the big end
Inertia force of the reciprocating parts EI =mR xω2r (cos+cos2/l/r)
ω = Angularspeed of the engine in rad/sec
ω = 4000rpm =418.87 rad/sec
mR =mass of reciprocating parts in kg=1.747kg
mass of piston =1.36 kg
mass of piston pin = 35gms =0.035
mass of connecting rod =0.352 kg
Angle of inclination of crank with the line of action =0
r = radius of crank
l = length of connecting rod
l/r =4
Force on the bolts = π/4(dcb)2 σt nb
σt = Allowable tensile stress
Bolts can be made of high carbon steel (or) nickel alloy steel
σt =380-620 mpa
dcb = core diameter of the bolt in mm
nb = no. of bolts = 2
FI = mR xω2r (cos+cos2/l/r)
FI = mR xω2r(1+r/l)
Radius of crank = l/4 = 164/4 =41mm
FI =1.747(418.87)2 x 0.041(1+1/4)
FI = 12567.1(5/4)
FI = 15708.88
FI = π/4(dcb)2 σt nb
15708.88 = π/4(dcb)2x380x 2
15708.88 = 596.6(dcb)2
dcb =5.13mm
Nominal (or) major diameter of bolt
db = dcb/0.84 =5.13/0.84 =6.1mm

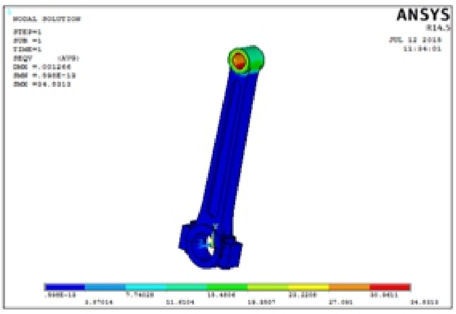
4. Thickness of big end cap

Maximum bending moment Mc =FI x X/6
X = distance between bolt centre
X = dia of crank pin (dc) + 2 x Thickness of bearing +clearance
X = 23.54+2x3+3 =32.54mm
bc = width of cap in mm =length of crank pin
bc = 35.32mm
section modulus for the cap
ZC = bc (tc)2/6
Bending stress σb = MC / ZC = FI x X/ bc (tc)2
σb =230 N/mm2
230 = 15708.88x32.54/35.32 (tc)2
(tc)2 =62.92
tc =7.93mm

A.MODEL OF CONNECTING ROD USING CARBONSTEEL

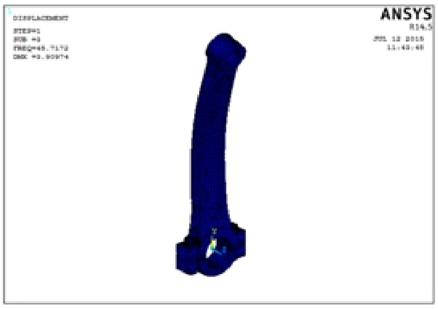


B.STRUCTURAL ANALYSIS USING CARBON STEEL :

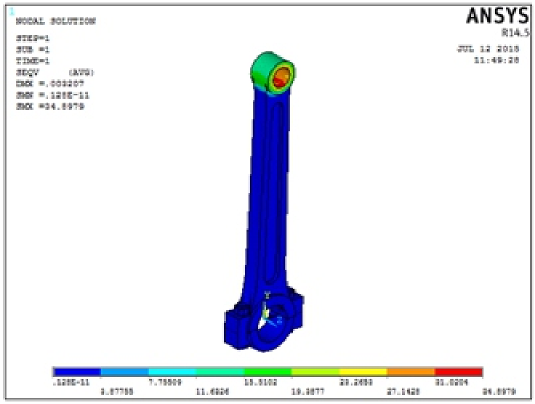


ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

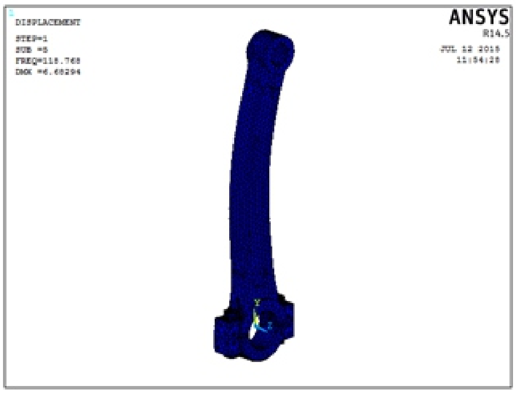
C.MODAL ANALYSIS:



D.STRUCTURAL ANALYSIS USING A360

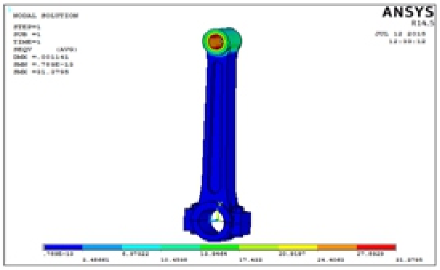


E.MODAL ANALYSIS

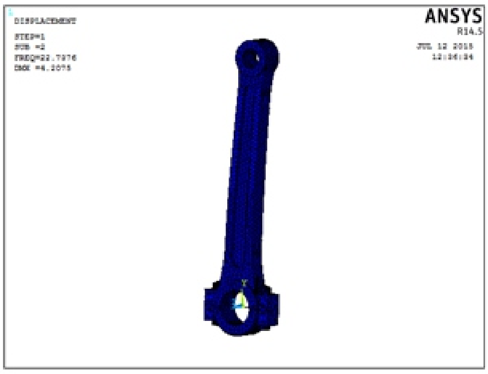


IV.USING THE TEMPLATE

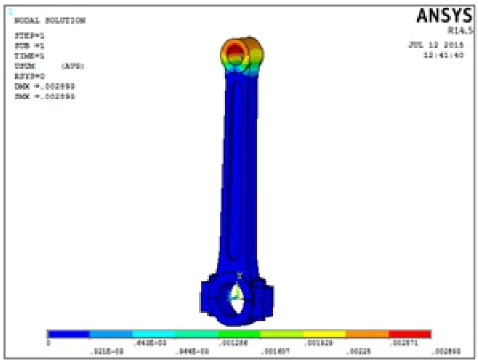
F.STRUCTURAL ANALYSIS USING CARBON STEEL FOR MODIFIED MODEL



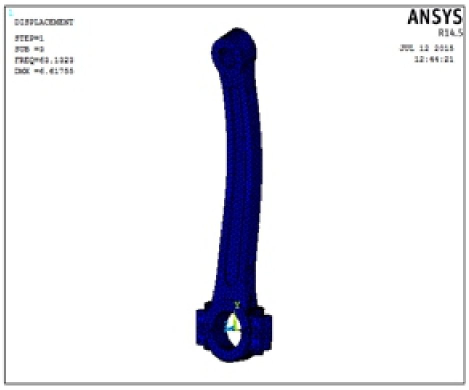
G. MODAL ANALYSIS



H. STRUCTURAL ANALYSIS USING A360 FOR MODIFIED MODEL



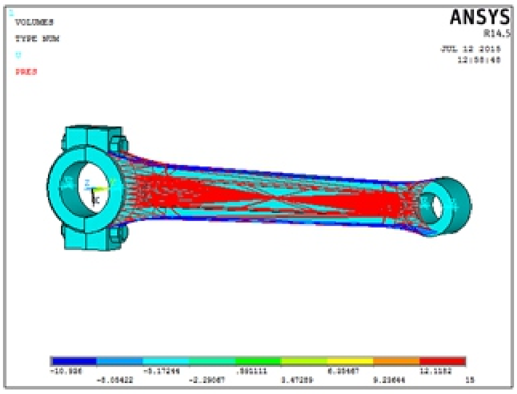
I. MODAL ANALYSIS



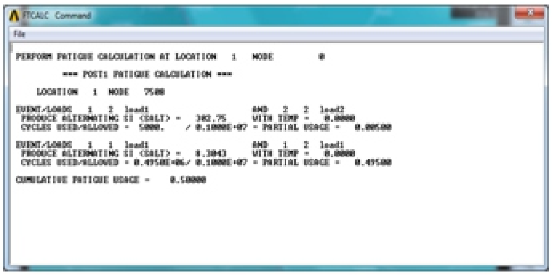
ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

J. FATIGUE ANALYSIS – Carbon Steel
Four load cases are applied:

a. 10.936. The time at the end of the load step is 10 seconds.
b. -10.936. The time at the end of the load step is 20 seconds.
c. 15. The time at the end of the load step is 30 seconds.
d. -15 the time at the end of the load step is 40 seconds.

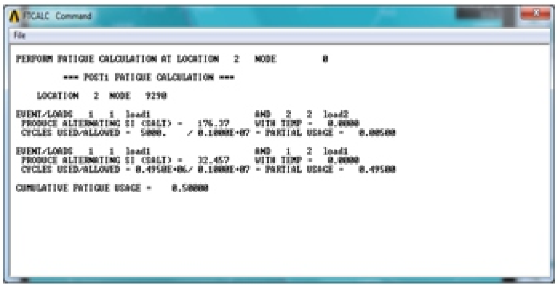


J. RESULTS
NODE AT CONSTRAINED AREA



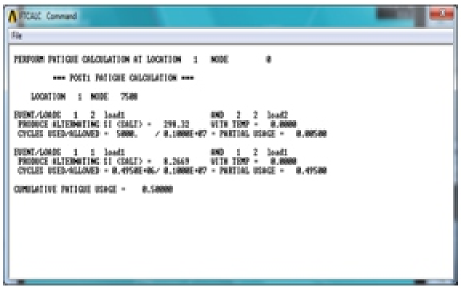
```
PERFORM FATIGUE CALCULATION AT LOCATION   1   NODE        0

        *** POST1 FATIGUE CALCULATION ***

    LOCATION   1  NODE   7500

EVENT/LOADS   1   2  load1                AND   2   2  load2
 PRODUCE ALTERNATING SI (SALT) =   302.75     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED =  5000.    / 0.1000E+07 = PARTIAL USAGE =   0.00500

EVENT/LOADS   1   1  load1                AND   1   2  load1
 PRODUCE ALTERNATING SI (SALT) =   8.3043     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED = 0.4950E+06/ 0.1000E+07 = PARTIAL USAGE =   0.49500

CUMULATIVE FATIGUE USAGE =    0.50000
```

NODE AT PRESSURE AREA



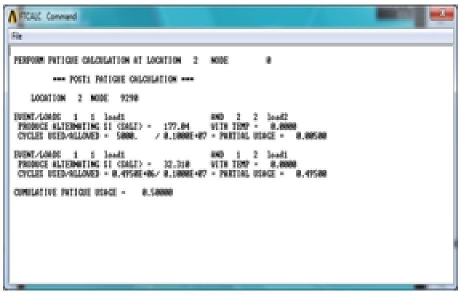
```
PERFORM FATIGUE CALCULATION AT LOCATION   2   NODE        0

        *** POST1 FATIGUE CALCULATION ***

    LOCATION   2  NODE   9290

EVENT/LOADS   1   1  load1                AND   2   2  load2
 PRODUCE ALTERNATING SI (SALT) =   176.37     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED =  5000.    / 0.1000E+07 = PARTIAL USAGE =   0.00500

EVENT/LOADS   1   1  load1                AND   1   2  load1
 PRODUCE ALTERNATING SI (SALT) =   32.457     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED = 0.4950E+06/ 0.1000E+07 = PARTIAL USAGE =   0.49500

CUMULATIVE FATIGUE USAGE =    0.50000
```

K. FATIGUE ANALYSIS - Aluminum Alloy A360
RESULTS:
NODE AT CONSTRAINED AREA



```
PERFORM FATIGUE CALCULATION AT LOCATION   1   NODE        0

        *** POST1 FATIGUE CALCULATION ***

    LOCATION   1  NODE   7500

EVENT/LOADS   1   2  load1                AND   2   2  load2
 PRODUCE ALTERNATING SI (SALT) =   298.32     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED =  5000.    / 0.1000E+07 = PARTIAL USAGE =   0.00500

EVENT/LOADS   1   1  load1                AND   1   2  load1
 PRODUCE ALTERNATING SI (SALT) =   8.2669     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED = 0.4950E+06/ 0.1000E+07 = PARTIAL USAGE =   0.49500

CUMULATIVE FATIGUE USAGE =    0.50000
```

NODE AT PRESSURE AREA



```
PERFORM FATIGUE CALCULATION AT LOCATION   2   NODE        0

        *** POST1 FATIGUE CALCULATION ***

    LOCATION   2  NODE   9290

EVENT/LOADS   1   1  load1                AND   2   2  load2
 PRODUCE ALTERNATING SI (SALT) =   177.04     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED =  5000.    / 0.1000E+07 = PARTIAL USAGE =   0.00500

EVENT/LOADS   1   1  load1                AND   1   2  load1
 PRODUCE ALTERNATING SI (SALT) =   32.310     WITH TEMP =   0.0000
 CYCLES USED/ALLOWED = 0.4950E+06/ 0.1000E+07 = PARTIAL USAGE =   0.49500

CUMULATIVE FATIGUE USAGE =    0.50000
```

	Carbon Steel	A360 Alloy
Constrained area Event 1 Load1, Event 1 Load 2	8.3043 N/mm^2	$8.2669 N/mm^2$
Event 2 Load1, Event 2 Load 2	$302.75 N/mm^2$	298.32 N/mm^2

Pressure area		
Event 1 Load1,	32.475 N/mm^2	32.310 N/mm^2
Event 1 Load 2	176.37 N/mm^2	177.04 N/mm^2
Event 2 Load1,		
Event 2 Load 2		

L. CONCLUSION:

In our project we have designed a connecting rod using Carbon Steel and Aluminum alloy A360. The models are created using 3D modeling software CATIA.Present used material for connecting rod is Carbon Steel. We are replacing with Aluminum alloy. The density of Aluminum alloy is less than that of Carbon Steel. So weight of the connecting rod reduces by using Aluminum alloy. By using carbon steel, the weight of the connecting rod is 273.912gms and that by using Aluminum alloy is 95.277gms.

We have done structural and modal analysis on the connecting rod using materials Carbon Steel and Aluminum alloy A360. By observing the analysis results, the stress values are less than their respective yield stress values. So using Aluminum alloy A360 is safe for connecting rod.

Fatigue analysis is also done on connecting rod to verify the stress values at the selected nodes. The nodes are selected at constrained area, pressure area and open area. For both the materials the number of cycles allowed for Connecting rod is 100000 cycles. By observing the fatigue analysis results, the stress values are less for Aluminum alloy than cast Iron.So we can conclude that using Aluminum alloy A360 is better for connecting rod.

References:

[1] Pai, C. L., 1996, "The shape optimization of a connecting rod with fatigue life constraint," Int. J. of Materials and Product Technology, Vol. 11, No. 5-6, pp. 357-370.

[2]Serag, S., Sevien, L. Sheha, G. and El-Beshtawi, I.,1989,"Optimal design of the connecting-rod", Modeling, Simulation and Control, B, AMSE Press, Vol.24,No.3, pp. 49-63.

[3] Yoo, Y. M., Haug, E. J., and Choi, K. K., 1984, "Shape optimal design of an engine connecting rod," Journal of Mechanisms, Transmissions, and Automation in Design, Transactions of ASME, Vol. 106, pp. 415-419.

[4] El-Sayed, M. E. M., and Lund, E. H., 1990, "Structural optimization with fatigue life constraints," Engineering Fracture Mechanics, Vol. 37, No. 6, pp. 1149-1156.

[5] Balasubramaniam, B., Svoboda, M., and Bauer, W., 1991, "Structural optimization of I.C. engines subjected to mechanical and thermal loads," Computer Methods in Applied Mechanics and Engineering, Vol. 89, pp. 337-360.

[6] Rabb, R., 1996, "Fatigue failure of a connecting rod," Engineering Failure Analysis, Vol. 3, No. 1, pp. 13-28.

[7]Pravardhan S. Shenoy, "Dynamic load analysis and optimization of connecting rod",2004, Master's thesis, University of Toledo.

[8] Ali Fatemi and Mehrdad Zoroufi, "Fatigue Performance Evaluation of Forged Versus Competing Process Technologies: A Comparative Study", 24th Forging Industry Technical Conference, Cleveland, Ohio, 2002.

[9] Park, H., Ko, Y. S., Jung, S. C., Song, B. T., Jun, Y. H., Lee, B. C., and Lim J. D., 2003,"Development of Fracture SplitSteel Connecting Rods," SAETechnical Paper Series, Paper No. 2003-01-1309.

[10] Joseph C. Slater, "Wright Finite Element Method: An easily extensible research-oriented finite element code", April 5, 2004