Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 10; July-September, 2016, pp. 842-845

http://www.krishisanskriti.org/Publication.html

Static and Modal Analysis of Connecting Rod

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Abstract—*In this study we are going to accomplish static and modal analysis of a connecting rod. Different material are used for the study like Aluminium alloy, stainless steel and grey cast iron. Connecting rod is one of the most vital part of an I.C. engine and which is used to transfer the reciprocating motion of piston into the rotatory motion of crankshaft. It is heavily stressed during the operation subjected to compressive stress due to the gas pressure and tensile stress due to the Inertia force. For the different materials to be used for static analysis, Grey Cast Iron has Von Mises stress of 208Mpa with a total deformation of 1.55mm giving a factor of safety of 3.9.Grey Cast iron shows lowest natural frequency of 384Hz as compared with other materials.*

Keywords*: Static Structural Analysis, Modal Analysis, connecting rod, ANSYS, Finite Element Analysis (FEA).*

1. INTRODUCTION

Connecting rod is used to transmit the thrust from piston end to crank end .It has two ends, one is small and other is big end and the intermediate section is I-section. It is widely made up of grey cast iron and aluminium. Ps shenoy and A fatemi[1], described that connecting rod works under the complex cyclic load of 10^8-10^9 cycles. It has to work under the high compressive load of gas pressure and high tensile load of Inertia. Ashish somani and Gaurav chaure[2], has done a comparison between aluminium and steel and made a conclusion that steel has high stability, durability and high tensile strength while aluminium has lighter weight than steel, high shock absorbing capacity and superior strength ratio. Now days , connecting rod are working under high speed and power so It need to be designed for higher strength and stiffness but it should be light and cheap. We are using hexahedral mesh having 69421 elements and 156401 nodes because of its double number of cells than other meshing like triangular, quadrilateral etc. which gives it better rate of convergence and accuracy. Mohamed abdusalam , prabhat kumar and Dr Arvind saran[3], has done analysis on between aluminium alloy and forged steel and compared the different parameters like normal stress , shear stress , and von-mises stress etc. Fanil desai, kirankumar jagtap and abhijeet Deshpande[4], has done the numerical and experimental analysis of connecting rod and made a conclusion that maximum stress is obtained at shank region. Kelvin L.Hoag[5] investigated in his study that the first mode Vibration for a six cylinder crankshaft system would occur at approximately 2700rpm.

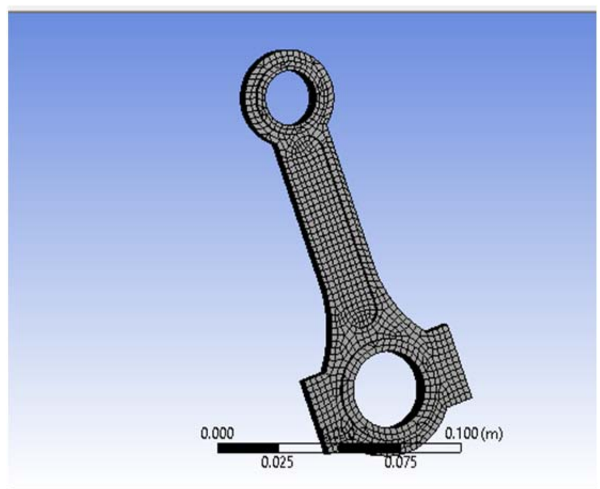


Fig. I: Hexahedral mesh of connecting rod

Table I Engine specification for connecting rod to be used for analysis

Four stroke 150cc engine	
Connecting rod length (mm)	*120*
Crank radius (mm)	*30*
Mass of piston (kg)	*1.6*
Mass of connecting rod (kg)	*0.326*
Bore diameter × stroke (mm)	*57×60*

2. SPECIFICATION OF PROBLEM

The main objective of this study is to perform static and modal analysis of connecting rod using different materials like stainless steel, Aluminium alloy and Grey cast iron and to compare the von-mises stress, total deformation and different modes of vibration. Solid modelling of the part was done on SOLIDWORKS 2014[6] and finite element analysis was performed using ANSYS 14.5[7].

3. THEORETICAL CALCULATION OF CONNECTING ROD

Pressure calculation

Maximum power -13.8bhp at 8500rpm

Maximum torque -12.5bhp at 6500rpm

Compression ratio- 9.35/1

Density of petrol at 288.85k = $737.22*10^{-9}$kg/mm^3

Molecular weight = 114.228g/mole

Ideal gas constant = 8.314J/mol.K

From gas equation

$$PV = MR_ST$$

Where P= Pressure

V= Volume

M = Mass

R_S= Specific gas constant

T =Temperture

M=Density*Volume= ($737.22*10^{-9}$) ($150*10^3$) =0.11kg

R_S=$\frac{R}{M}$= 8.314/0.114 = 72.76

$$P = \frac{MR_ST}{V}$$

= 0.114*72.76*288.85)/150e^3

= 16MPA

Design calculation of I section

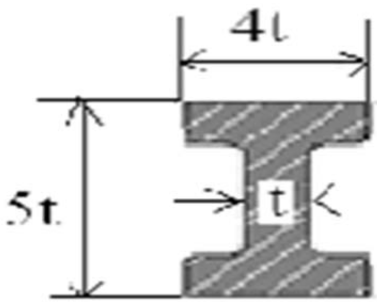


Table II Dimensions of connecting rod

Length of I section	5t
Width	4t
Thickness	t
Area	$11t^2$

Moment of inertia about X-axis (I_{xx})=$34.91t^4$
I_{yy}=$10.91t^4$

$\frac{I_{xx}}{I_{yy}}$ = 3.2
Length of connecting rod =2 times of stroke
Total force acting on connecting rod
=$F_P - F_i$
F_P=Force acting on piston
F_i=Inertia force

$$F_P = \frac{\pi}{4}D^2 * gas\ pressure$$

= (π/4)d^2*16MPa
=39473.1543N

$$F_i = 100wrv^2cos\theta \pm \frac{cos2\theta}{n}$$

Where
w=weight of reciprocating part
= 1.6*9.81= 15.696N
r=Crank radius=stroke/2=30mm
θ=Assuming connecting rod is at TDC=0^0
n=l/r=4

$$v = r\omega$$

=$r * \frac{2\pi n}{60}$
($30e^{-3}$*2*3.14*8500)/60
=26.08m/s
Now,
F_i= 9285.5481N
Total force = $F_P - F_i$
= 30187.6062N
According to Rankine - Gordon formula[8]

$$F = \frac{f_c * A}{1 + a(\frac{l}{k_{xx}})^2}$$

Where
f_c=compressive yield stress=0.6 MPa
l=length of connecting rod
k_{xx}=Radius of gyration about X-axis
F=Buckling load
a=$\frac{\sigma_c}{\pi^2 E}$

$$= \frac{0.6e^6}{3.14^2 * 180e^9}$$

Value of E for stainless steel =$180e^9$Nm^{-2}

= 0.0000003380

=$3.38*10^{-7}$

$$30187.6062 = \frac{0.6e^5 * 11t^2}{[1 + 0.0000003380(\frac{120e^{-3}}{1.78t})^2}$$

t= $4.57*10^{-3}$m
=4.57mm
H= 5t =22.85mm
B=4t=18.28mm
A=229.73mm^2

4. STATIC STRUCTURAL ANALYSIS

In present study the Connecting rod modal was analysed to find the values of von Mises Stress .we used the multizone hexahedral mesh with load value of 0.6Mpa at small end. Connecting rod is fixed from bigger end. The von mises stress was found to be maximum in Aluminium alloy with a value of 277Mpa and this value was compared with the Ultimate Tensile strength of aluminium giving a factor of safety of 1.11. Figures below are presenting the part with higher stress regions in Red.

Table III: The parts material parameter

s. no.	Material	Modulus of elasticity(GPa)	Poisson's ratio	Density(kg/m^3)
1	Aluminium alloy	710	0.33	2270
2	Grey cast iron	110	0.28	7200
3	Stainless steel	193	0.31	7750

Result

Von-mises stress for different materials

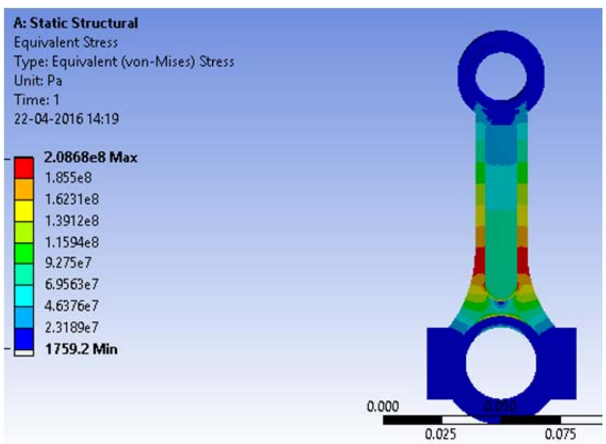


Figure II Von-mises stress of stainless steel

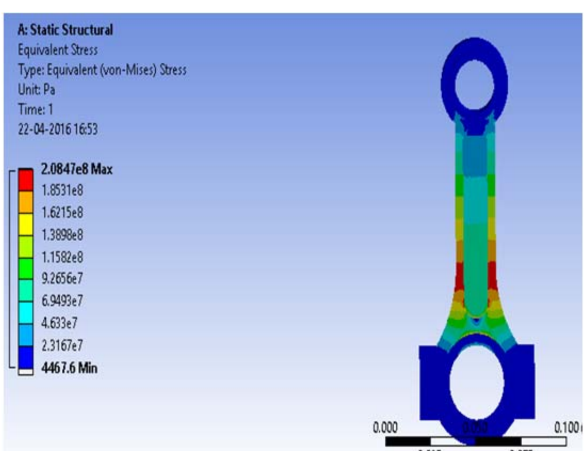


Fig. III Von-mises stress of grey cast iron

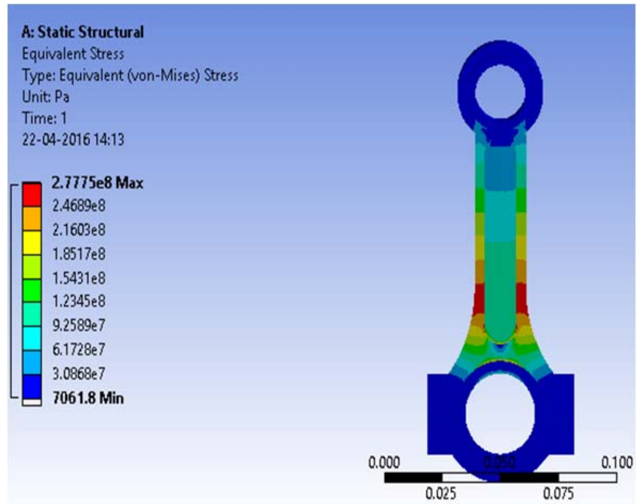


Fig. IV Von-mises stress of Aluminium alloy

Total deformation for different material:

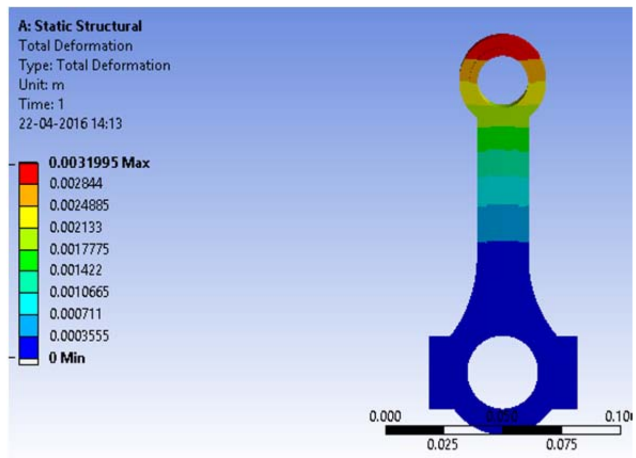


Figure V Total deformation of Aluminium alloy

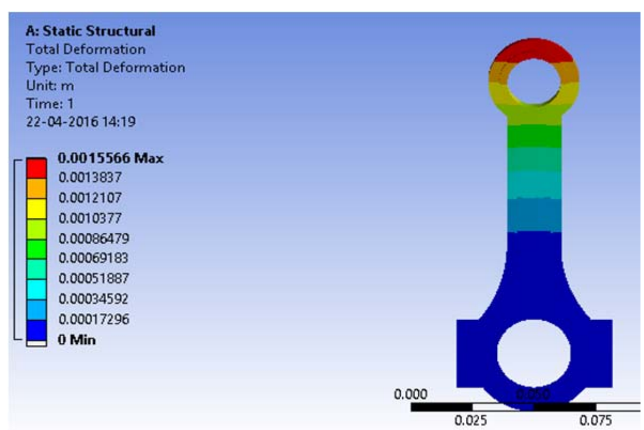


Fig. VI Total deformation of grey cast iron

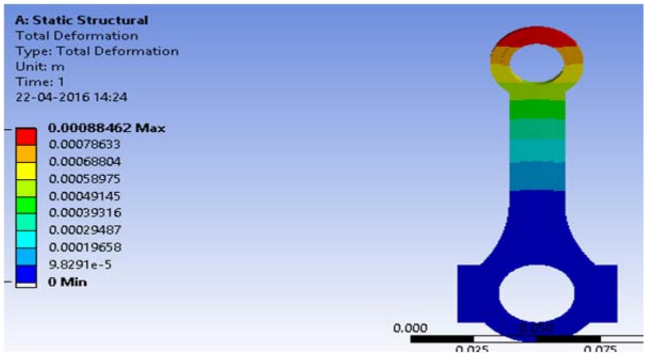


Fig. VII Total deformation of stainless steel

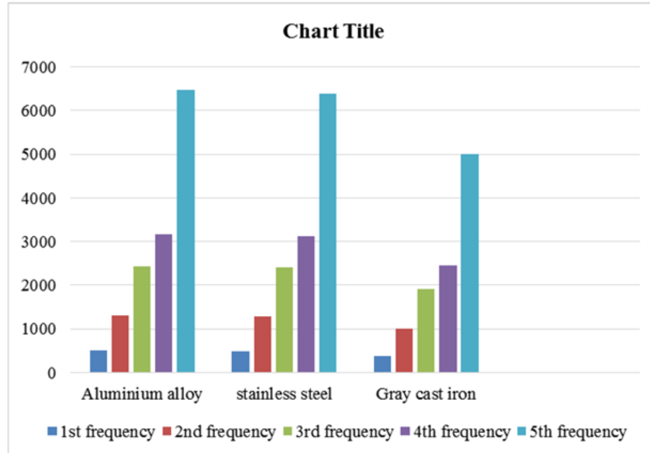
Table IV

S.no.	Material	Ultimate strength (MPa)	Maximum Von-mises stress(MPa)	Total deformation (mm)
1.	Aluminium alloy	310	277	3.1995
2.	Grey cast iron	820	208	1.5566
3.	Stainless steel	586	208	0.88462

5. MODAL ANALYSIS

A connecting rod is subjected to mechanical vibrations during its operation and it possess several degree of freedom, due to which it has several natural frequencies. In many cases only the first mode of vibration needs to be considered as the higher modes have little energy. In the present study the connecting rod model was analysed for free vibrations to know the fundamental natural frequency. The grey cast iron was found to have the lowest natural frequency and aluminium was having the highest natural frequency among the other materials. A four stroke engine (150cc) of Pulsar DTSi Bike has maximum torque of 12.5N-m[9] at 6500 RPM and it corresponds to a forced frequency of 108.33Hz. For the above model, resonance would not occur as the forced frequency is below the lowest natural frequency mode for all materials. Table 5 below presents the result of modal analysis for Different materials of connecting rod model.Table V

s.no.	Material	1^{st} frequency (Hz)	2^{nd} frequency (Hz)	3^{rd} frequency (Hz)	4^{th} frequency (Hz)	5^{th} frequency (Hz)
1	Aluminium alloy	499.28	1308.2	2435.6	3175.8	6478.9
2	Stainless steel	491.5	1289.7	2416.8	3126.9	6389.7
3	Gary cast iron	384.3	1010.6	1912.6	2445.7	5013



6. CONCLUSION AND FUTURE SCOPE

The connecting rod model was safe during the structural Analysis providing a factor of safety more than one for all of the materials considered for the Analysis. During The Modal Analysis the Resonating Frequencies were found to be order of 384-499Hz, far above the values computed from Excitation frequency. This work is very helpful during the shape optimization and transient analysis of static and dynamic stress distribution of multibody system. By using equivalent static load method we can transform dynamic load into equivalent static load to obtain stress distribution of multibody system at an arbitrary time and we can analyse the effect of dynamic loading and perform shape optimization on connecting rod or on any other automobile components.

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