Simulation of Connecting Rod Using Finite Element Analysis

Nuha Hadi Jasim Al Hasan

Abstract: **Numbers of connected rods are used in the assembly of petroleum engines, the task of connecting rod important of converting reciprocating motion of the piston into rotary motion of the crankshaft. In this work stress analysis at various individual tensile and compressive loads acting on connecting rod at different speed was done. Simulation was performed by using Cero PTC software to obtain stress distribution in the connecting rod at static condition.**

Keywords: **Simulation, Connecting rod, Finite element, Cero PTC, Connecting rod simulation.**

I. INTRODUCTION

The plain connecting rod is most common in automotive practice; it is connecting the piston to the crankshaft for rotating it, transmitting the thrust of the piston to the crankshaft. Because of combustion, high compressive loads, to high tensile loads caused high cyclic loads. Therefore, component durability is importance, since that, the topic of researcher of the connecting rod should be for different aspects such as materials, production technology, and performance simulation, etc. This literature survey reviews brief of some researcher. P. S. Shenoy and A. Fatemi., [1] performed load analysis under service loading conditions for a typical connecting rod, followed by quasi-dynamic finite element analysis (FEA) to capture stress variations over a cycle of operation. They concluded that quasi-dynamic analysis provides more accurate results better suited for fatigue design and optimization analysis of this high volume production component. M. Ranjbarkohan, M. R. Asadi and B. N. Dardashti, [2] analyzed stress of connecting rod. They used solid Works software, meshed in ANSYS software, it is found the maximum pressure stress between pin end and rod of connecting rod occurred, the maximum tensile stress was obtained in pin end. B. Kuldeep, L.R. Arun and F. Mohammed, [3] used new material aluminum based composite material reinforced with silicon carbide and fly ash for connected rod. And it also describes the modeling and analysis using FEA analysis. They found the new material have less weight and better stiffness.

A. D. Dantale and A. J. Keche., [4] done CAE analysis of connecting rod to predict the maximum Stresses and check whether it is safe for fatigue failure. And concluded that the A1 connected rod has failed in fatigue testing at the big end. F. Desil, K. Jagtap and A. Deshpande, [5] they dealt with the compressive stress acting on forged steel connecting rod by finite element method using ANSYS and experimental analysis. And concluded that maximum stress is generated at piston end of connecting rod, and chances of failure are more at the piston end. N. U. Thakare, N. D. Bhusale, R. P.Shinde, and M. M. Patil,[6] in his paper a dynamic simulation was conducted on a connecting rod made of Al360 and new material Al 6061-9%SiC-15%fly ash using FEA. Dynamic load analysis was performed to determine von misses stress and displacement from ANSYS software. The Al 6061-9%SiC-15% fly ash optimized connecting rod is comparatively much stiffer than the Al360.

II. METHOD AND CALCULATIONS

A. Materials Used

Two steels are being considered for manufacture of as-forged connecting rods. One is AISI 4340 Cr-Mo-Ni steel capable of being heat-treated to a tensile strength of 260 kpsi. The other is a plain carbon steel AISI 1040 with an attainable *Sut* of 113 psi. The properties of material use in this work shown in table 1.

Table 1: Material propertied used for analysis

Parameters	Material(Al360)
Ultimate tensile strength(MPa)	303
Yield strength (MPa)	710
Youngs modulus (GPa)	60
Poisson's ratio	0.33
Density (g/cm^3)	2.8

B. Theoretical Calculations

After having a solid model of connecting rod use in gasoline engine as shown in Fig. 1, made with the help of Cero PTC software, it can be used for further process and for that, forces or loading need to be calculated.

Nuha H. J. Al Hasan, Department of Engineering Material, University of Basrah/College of Engineering, Basrah, Iraq, 009647803450132, (e-mail: nuhahadi1@yahoo.com.com).
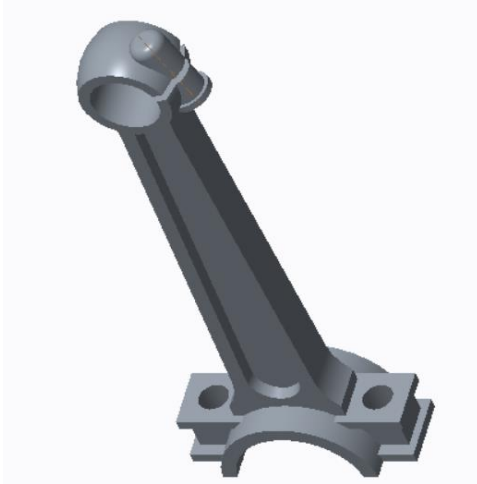
Fig. 1: Connecting rod

The load acting on the connecting rod is the maximum compressive load which is calculated on the basis of peak firing pressure, and the maximum tensile load which is calculated on the basis of inertia masses at both the ends.

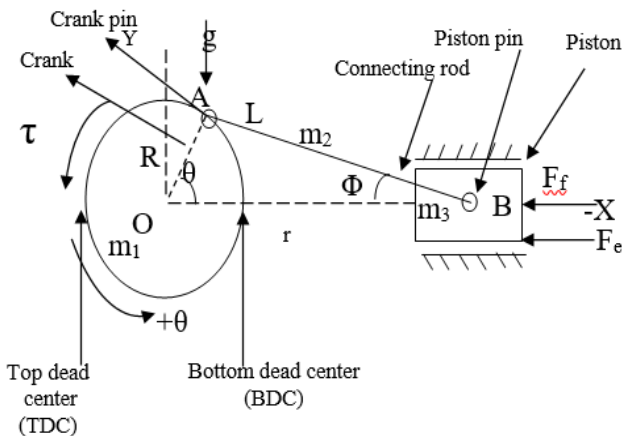If we look at Fig. 2, we can be drawn with the help of equations:

Fig. 2: Forces acting on Connecting Rod

$$\emptyset = arc\sin[\frac{R}{L}sin\theta](1)$$

$$r = R\cos\theta + L\cos\emptyset \ (2)$$

Calculate the speed Vel and the acceleration Acc by the following equations,

$$LVel = \frac{R}{L} \times \omega \times \frac{cos\theta}{cos\emptyset}(3)$$

$$Vel = -R \times sin\theta \times (\omega + LVel)(4)$$

$$Lacc = \frac{(-R \times \omega^2 \times sin\theta) + (L \times LVel^2 \times sin\emptyset)}{L \times cos\emptyset}(5)$$

$$Acc = -R \times \omega \times cos\theta(\omega + LVel)\_R \times sin\theta \times LAcc(6)$$

$$Force = \frac{\omega \times Acc}{110 \times cos\emptyset}(7)$$
Where:

r : crank radius
r = stroke of piston / 2
θ = Crank angle from the dead center
θ : Crank angle from the dead center, θ = 0 considering that connecting rod is at the TDC position
L: Length of the connecting rod, L= 2 times the stroke
ω : angular velocity in radian per second

Vel : velocity of the piston,
LVel : angular velocity of the connecting rod (in rad/s),
Acc : acceleration of the piston,
and LAcc : angular acceleration of the connection rod (in rad/s^2).
W represents the weight of the piston 0.7 kg

C. Connecting rod specifications

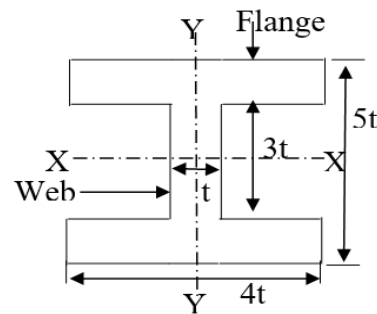In general, cross section of connecting rod shown in Fig. (3).

Fig. 3: I Section for connecting rod

Let,
t : Thickness of flange and web of the section
B : Width of the section B = 4t
H : Height of the section H = 5t
A : Area of the section A = 11t
Ixx : Moment of inertia about x axis Ixx= $34.91t^4$
Iyy : Moment of inertia about y axis Iyy= $10.91t^4$
Therefore, Ixx/Iyy= 3.2
A : cross-sectional area of connecting rod
Ixx and Iyy = Moment of inertia of the section about X-axis and Y-axis respectively, and Kxx and Kyy = Radius of gyration of the section about X- axis and Y-axis respectively
The connecting rod specifications:
Diameter of Piston (d) = 68.3 mm
Mass of piston 0.7kg
Length of Connecting rod (2L) = 144 mm
Stroke Length (L) = 72 mm
Speed (n) = 3000 R.P.M
Maximum Explosion = 37.20 Bar

$$A = (5t \times 4t) - (3t \times 3t) = 11t^2(8)$$

$$K = \sqrt{\frac{1}{A}} = 1.78t(9)$$
Crank radius r

$$r = \frac{strokofpiston}{2} = \frac{L}{2}(10)$$

$$ń = \frac{lenghtofconnectingrod}{crackradius}(11)$$

Angular Speed (ω)

$$\omega = \frac{2\pi N}{60} \quad (12)$$

Inertia forces of reciprocating parts (F)

$$F = \frac{WrV^2}{gr}cos\theta \pm cos2\frac{cos2\theta}{\acute{n}} \quad (13)$$

$$Wr = mg \quad (14)$$

Crank Velocity (V)

$$V = r \times \omega \quad (15)$$

Now, Inertia forces, from equation.

$$F = \frac{1000\times19.62\times(11.30)^2}{9.81\times36} \mp \frac{cos2\theta}{4} \quad (16)$$

$$Fc = Fp - Fj = Fp - F \quad (17)$$

$$Fc = \frac{fcA}{1+K(\frac{1}{K})^2} \quad (18)$$

III. FINITE ELEMENT ANALYSIS OF CONNECTING ROD

Cero PTC software's medium considering following notes in order to calculate stress which was exerted on corresponding parts in modeled connecting rod:

1. X, Y, Z translations of all the node on this surface are set to zero if the connecting rod is in tension. Similarly, when the connecting rod is under axial compressive load, 120° of contact surface area is totally restrained.

2. For static analysis keeping the small end fixed and apply the load at bigger end. Three different compression load of amount -173.4,- 4342.1N,-17305.3N, and tensile load288.95 N,7236.8N, 28842.1N,the value of these forces was calculated using equation (13), as show in Fig, (4).
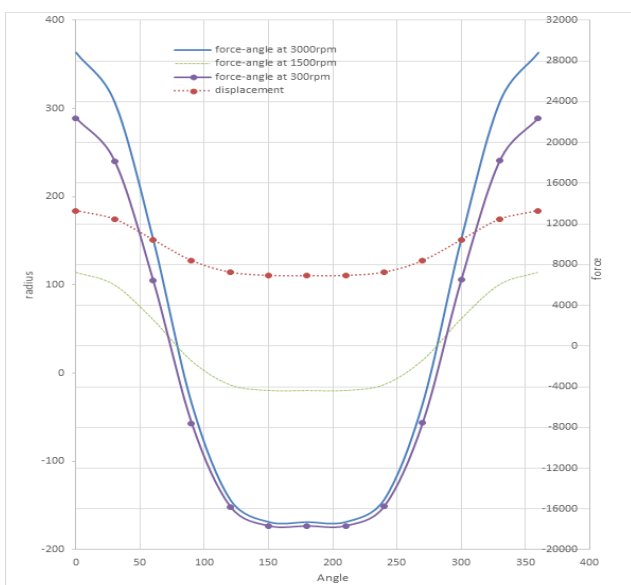

Fig. 4: Shows tensile and compressive forces acting on a connecting rod with respect to crank angle.

IV. RESULT AND DISCUSSION

Solid modeling tool shown in Fig.(1), is developing by Cero PTC software and initial design of any mechanical components and analyses by using Finite Element Technique. Due to the connecting rod involves surfaces and several merging radii, a classical study into this complicated problem has limitations and hence a finite element analysis is more appropriate to study the effect of combined loads due to gas pressure and inertia of reciprocating and oscillating parts of an engine. In this connecting rod, before finalization of element size, tetrahedral element with various element lengths for meshing as show in Fig.(5). From FEA, the results received, there is large margin of material removal from small end area, big end area, and area connecting to small end the of connecting rod.
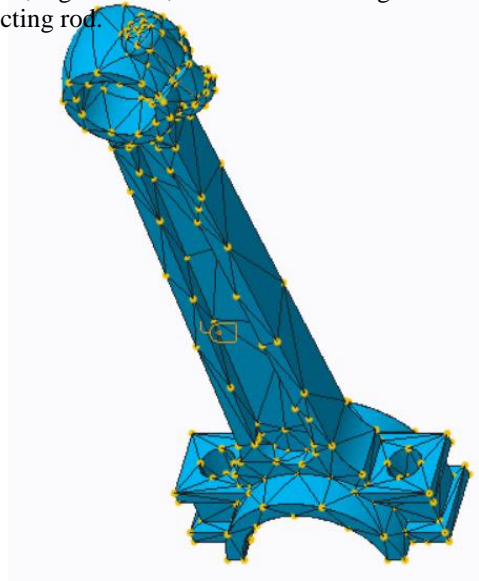

Fig. 5: Meshing of connecting rod

FEA is performed and the stress, displacement distribution is as shown in Fig. (6) and Fig. (7).
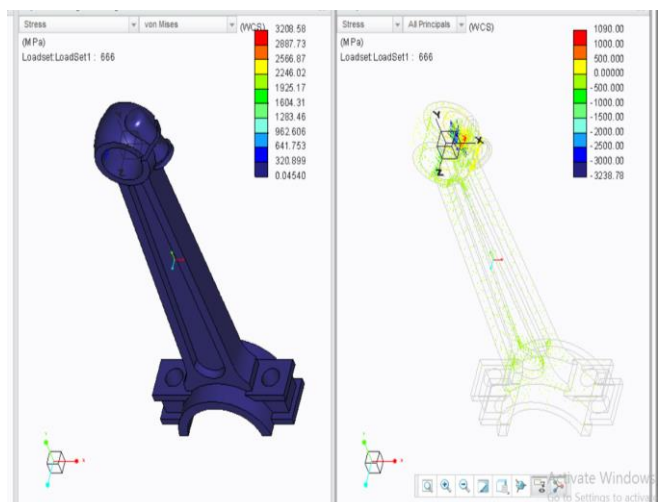

Fig. 6: Von Mises stresses with Crank end fixed and static compression load 17305N at piston pin end at 3000rpm.
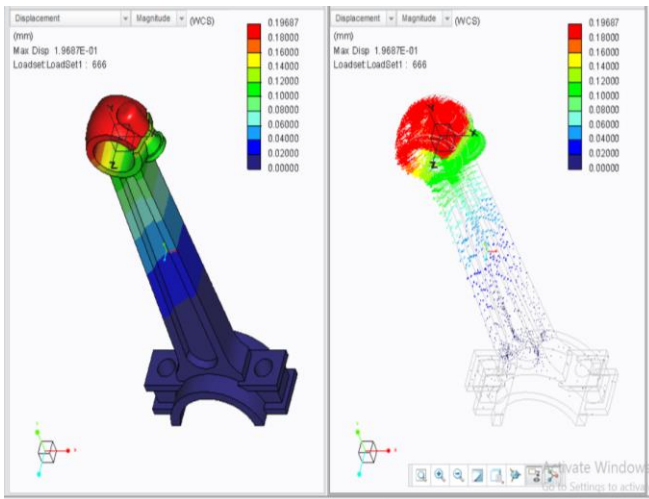
Fig. 7: Displacement with Crank end fixed and static compression load 17305N at piston pin end at 3000rpm.

As shown in Fig. (4) The maximum pressure force is 28842.13 (N) and it occurs at 3000 RPM rotational. And the maximum tensile force is 173.373 (N) and it occurs at 300 RPM rotational speed. For calculating stresses, a compression load 17305N the Cero PTC software was used.

V. CONCLUSION

The 3D modeled of connecting rod was done first, and corrections were made in the problematic area. After that load analysis was performed using Cero PTC software.

The following conclusion results of this study

- There is large margin of material removal from big end area, small end area and area connecting to small end the of connecting as a result from FEA analysis.

Table 2: Stresses at Various Speeds

Speed(rpm)	300	1500	3000
Tensile force(N)	288.9543	7236.816317	28842.13
Compression force(N)	-173.373	-4342.090033	-17305.3

- The result of stresses at various speeds was shown in table 2.

REFERENCES

[1] P. S. Shenoy and A. Fatemi, (2006, February).Dynamic analysis of loads and stresses in connecting rods. Journal of Mechanical Engineering Science. Vol. 220, pp 615-624.

[2] M. Ranjbarkohan, M. R. Asadi and B. N. Dardashti. (2011, August). Stress analysis of connecting rod of nissan Z24 engine by the finite elements method. Aust. J. Basic and Appl. Sci.5(12), pp. 2084-2089.

[3] B.Kuldeep, L.R. Arun and F.Mohammed. (2013, June). Analysis and optimization of connecting rod using alfa SiC composites. International Journal of Innovative Research in Science, Engineering and Technology, 2(6), pp. 2480- 2487.

[4] A. D. Dantale and A. J.Keche. (2014). Fatigue life validation and analysis of connecting rod. International Journal of Hybrid Information Technology. 7(6). pp. 423-432.

[5] F. Desil, K. Jagtap. And A. Deshpande. (2014, July).Numerical and experimental analysis of connecting fod. International Journal of Emerging Engineering Research and Technology. 2(4,) pp 242-249.

[6] N. U. Thakare, N. D. Bhusale, R. P. Shinde, M. M. Patil (2015,April).Finte element analysis of connecting rod using ansys. International Journal of Advances in Science Engineering and Technology, 3(2), pp 82-87.

AUTHOR'S PROFILE

Nuha H. J. Al Hasan, was born in Basrah, Iraq, on April 18 1981, She was graduated from the department of engineering material, university of basrah, college of engineering in 2003 and student of Ms.cand ph.d in mechanical engineering at university of basrah, college of engineering in Iraq. Her areas of interest are material selection design, corrosion, powder metallurgy related topics. Her publications, in the field of corrosion heat treatment in the different journal in Iraq.