ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

Stress Analysis of I.C.Engine Connecting Rod by FEM

Vivek. C. Pathade, Bhumeshwar Patle, Ajay N. Ingale

Abstract— The automobile engine connecting rod is a high volume production critical component. Every vehicle that uses an internal combustion engine requires at least one connecting rod .From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight. The major stress induced in the connecting rod is a combination of axial and bending stresses in operation. The axial stresses are produced due to cylinder gas pressure (compressive only) and the inertia force arising in account of reciprocating action (both tensile as well as compressive), where as bending stresses are caused due to the centrifugal effects. The result of which is, the maximum stresses are developed at the fillet section of the big and the small end. Hence, the paper deals with the stress analysis of connecting rod by Finite Element Method using Pro/E Wildfire 4.0 and ANSYS WORKBENCH 11.0 Software.

Index Terms— **Connecting Rod, failure of Connecting Rod, tensile stresses, compressive stresses, Big End fillet section, Small End fillet section , Finite Element Analysis.**

I. INTRODUCTION

The connecting rods subjected to a complex state of loading. It undergoes high cyclic loads of the order of 10^8 to 10^9 cycles, which range from high compressive loads due to combustion, to high tensile loads due to inertia. Therefore, durability of this component is of critical importance. Due to these factors, the connecting rod has been the topic of research for different aspects such as production technology, materials, performance simulation, fatigue etc. For the current study, it was necessary to investigate finite element modeling techniques, optimization techniques, developments in production technology, new materials, fatigue modeling and manufacturing cost analysis. Webster *et al.* (1983) performed three dimensional finite element analysis of a high-speed diesel engine connecting rod. For this analysis they used the maximum compressive load which was measured experimentally, and the maximum tensile load which is essentially the inertia load of the piston assembly mass. The load distributions on the piston pin end and crank end were determined experimentally. They modeled the connecting rod cap separately, and also modeled the bolt pretension using beam elements and multi point constraint equations. Sarihan and Song (1990), for the optimization of the wrist pin end, used a fatigue load cycle consisting of compressive gas load corresponding to maximum torque and tensile load corresponding to maximum inertia load. Evidently, they used the maximum loads in the whole operating range of the engine. To design for fatigue, modified Goodman equation with alternating octahedral shear stress and mean octahedral shear stress was used. For optimization, they generated an approximate design surface, and performed optimization of this design surface. The objective and constraint functions were updated to obtain precise values. This process was repeated till convergence was achieved. They also included constraints to avoid fretting fatigue. The mean and the alternating components of the stress were calculated using maximum and minimum values of octahedral shear stress. Their exercise reduced the connecting rod weight by nearly 27%.

Pai (1996) presented an approach to optimize shape of connecting rod subjected to a load cycle, consisting of the inertia load deducted from gas load as one extreme and peak inertia load exerted by the piston assembly mass as the other extreme, with fatigue life constraint. Fatigue life defined as the sum of the crack initiation and crack growth lives, was obtained using fracture mechanics principles. The approach used finite element routine to first calculate the displacements and stresses in the rod; these were then used in a separate routine to calculate the total life. The stresses and the life were used in an optimization routine to evaluate the objective function and constraints. The new search direction was determined using finite difference approximation with design sensitivity analysis. The author was able to reduce the weight by 28%, when compared with the original component.

Sonsino and Esper (1994) have discussed the fatigue design of sintered connecting rods. They did not perform optimization of the connecting rod. They performed preliminary FEA followed by production of a prototype. Fatigue tests and experimental stress analysis were performed on this prototype based on the results of which they proposed a final shape. In order to verify that design was sufficient for fatigue, they computed the allowable stress amplitude at critical locations, taking the ratio, the stress concentrations and statistical safety factors into account and ensure that maximum stress amplitudes were below the allowable stress amplitude.

For their optimization study, Serag *et al.* (1989) developed approximate mathematical formulae to define connecting rod weight and cost as objective functions and also the constraints. The optimization was achieved using a Geometric Programming technique. Constraints were imposed on the compression stress, the bearing pressure at the crank and the piston pin ends. Fatigue was not addressed. The cost function was expressed in some exponential form with the geometric parameters. Athavale and Sajan pawar (1991) modeled the inertia load in their finite element model. Interface software was developed to apply the acceleration load to elements on the connecting rod depending upon their location, since acceleration varies in magnitude and direction

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

with location on the connecting rod. They fixed the ends of the connecting rod, to determine the deflection and stresses. This, however, may not be representative of the pin joints that exist in the connecting rod. The results of the detailed analysis were not discussed, rather, only the modeling technique was discussed. The connecting rod was separately analyzed for the tensile load due to the piston assembly mass (piston inertia), and for the compressive load due to the gas pressure. The effect of inertia load due to the connecting rod, mentioned above, was analyzed separately. In a published SAE case study (1997), a replacement connecting rod with 14% weight savings was designed by removing material from areas that showed high factor of safety. Factor of safety with respect to fatigue strength was obtained by performing FEA with applied loads including bolt tightening load, piston pin interference load, compressive gas load and tensile inertia load. The study lays down certain guidelines regarding the use of the fatigue limit of the material and its reduction by a certain factor to account for the as-forged surface. The study also indicates that buckling and bending stiffness are important design factors that must be taken into account during the design process. On the basis of the stress and strain measurements performed on the connecting rod, close agreement was found with loads predicted by inertia theory. The study also concludes that stresses due to bending loads are substantial and should always be taken into account during any design exercise.

II. Problem Formulation

For the analysis of I.C. Engine connecting rod the most critical area is considered and accordingly the two dimensional model of connecting rod is formed. The different dimensions of the connecting rod are shown in the figure (1) below. Three loads, 69kg, 85kg and 99kg were applied at one end i.e, small end and the big end is kept fixed. The stresses calculated theoretically and found out numerically by FEM.
Model thickness (h) = 6mm

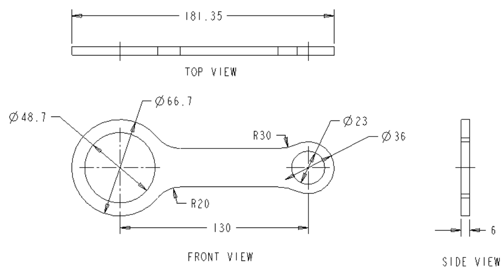

Fig.1. Orthographic view of specimen connecting rod for analysis

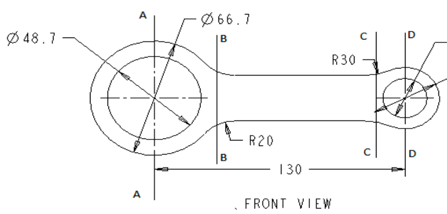

Fig.2. Four different sections considered for analysis. Sec A-A, Sec B-B, Sec C-C, Sec D-D.

III. Finite Element Analysis Of I.C.Engine Connecting Rod

For the finite element analysis three different loads i.e., 69kg= 677N, 85kg= 834N, 99kg= 971N are used. . For the analysis triangular plate element with six degrees of freedom per node is considered. The analysis is carried out using *Pro*/E Wildfire 4.0 and ANSYS WORKBENCH 11.0 software. The normal load is applied at the small end of connecting rod keeping big end fixed.

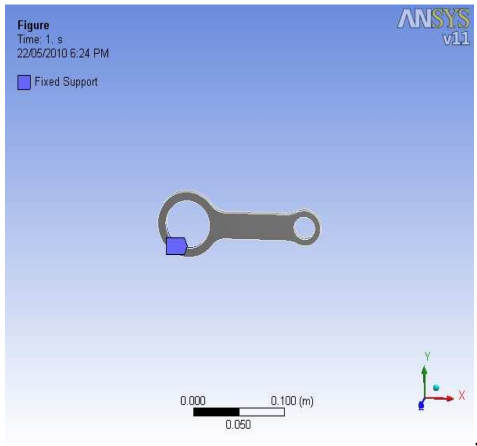

Fig.3. Connecting Rod under Load

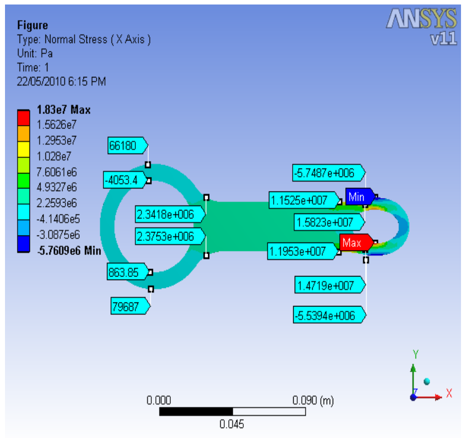

Fig.4. Normal stress at 677N

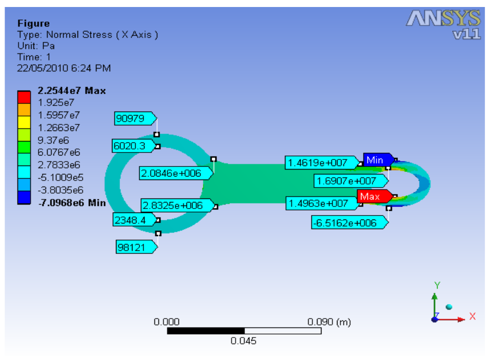

Fig.5 Normal Stress at 834N

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

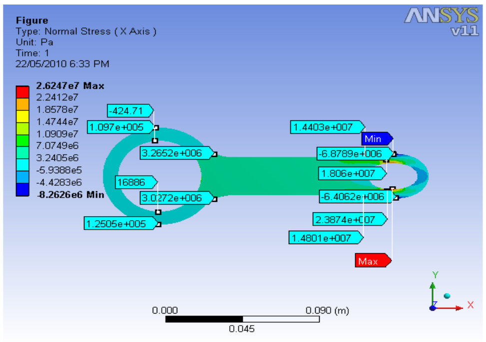

Fig.6 Normal Stress at 971N

TABLE I: Calculations for Finding Maximum Principal Stress Theoretically

Stresses along section A-A

$\sigma = P/(b-d)*t$

For P = 677N (69kg)

$\sigma = 677/(66-48)*6$

$= 6.2675 N/mm^2$

For P = 834N (85kg)

$\sigma = 7.720 N/mm^2$

For P = 971N (99kg)

$\sigma = 8.9925 N/mm^2$

Stresses along section B-B

For P = 677N (69kg)

$\sigma = 3.13 N/mm^2$

For P = 834N (85kg)

$\sigma = 3.86 N/mm^2$

For P = 971N (99kg)

$\sigma = 4.49 N/mm^2$

Stresses along section C-C

For P = 677N (69kg)

$\sigma = 3.7605 N/mm^2$

For P = 834N (85kg)

$\sigma = 4.6325 N/mm^2$

For P = 971N (99kg)

$\sigma = 5.3955 N/mm^2$

Stresses along section D-D

For P = 677N (69kg)

$\sigma = 17.35 N/mm^2$

For P = 834N (85kg)

$\sigma = 21.38 N/mm^2$

For P = 971N (99kg)

$\sigma = 24.90 N/mm^2$

IV. Comparison Of Results

The connecting rod is analyzed by two methods i.e.,

i) Theoretical method.

ii) Numerical method (Finite Element Analysis).

The results obtained by the above two methods are compared at two critical areas of the connecting rod or two different sections of connecting rod where the connecting rod is likely to fail. The two areas or sections of connecting rod where results are compared are:

i) Sec D-D at the Small End.

ii) Sec B-B at the root of Big End.

TABLE II: Observation Table-Comparison

LOAD, P (N)	COMPUTED VALUES OF TENSILE STRESSES(MPa)			
	FOR SECTION B-B		FOR SECTION D-D	
	THE	FEA	THE	FEA
677	3.13	2.37	17.35	15.82
834	3.86	2.832	21.38	19.25
971	4.49	3.265	24.90	23.87

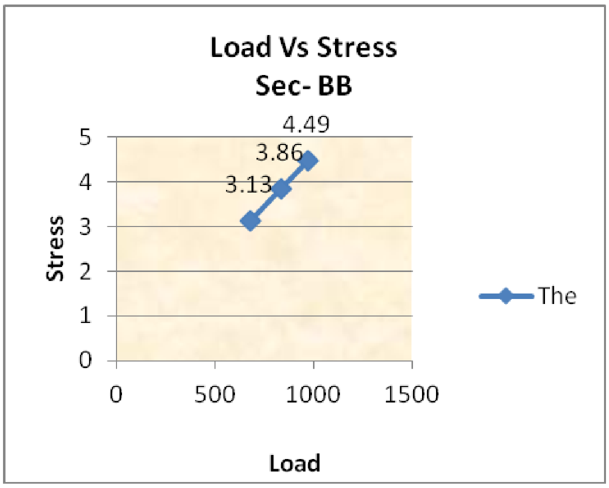

Fig.7.Graph between Load & Stress

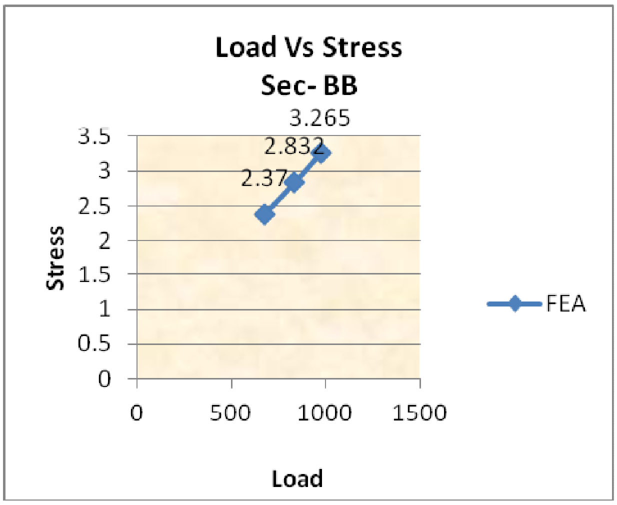

Fig.8.Graph between Load & Stress(Sec-BB)

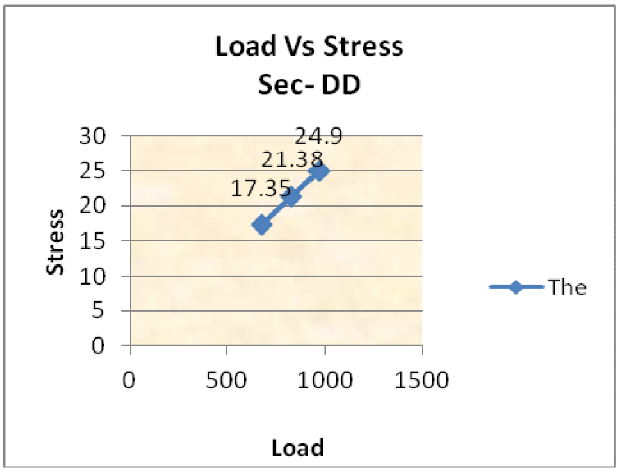

Fig.9.Graph between Load & Stress (Sec-DD)

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

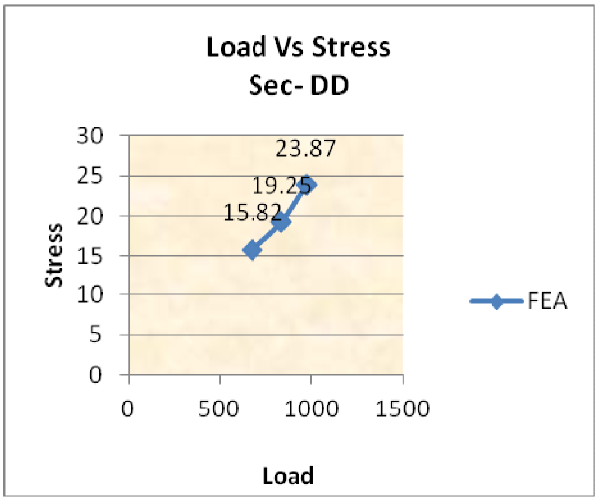

Fig.10.Graph between Load & Stress (Sec-DD)

V. DISCUSSION AND CONCLUSION

From the theoretical and Finite Element Analysis it is found that

i) The stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end.

ii) Therefore, the chances of failure of the connecting rod may be at fillet section of both end.

REFERENCES

[1] 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.

[2] 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.

[3] 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.

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

[5] 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.

[6] 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 Split Steel Connecting Rods," SAE Technical Paper Series, Paper No. 2003-01-1309.

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

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

[9] 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.

[10] 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.

AUTHOR BIOGRAPHY

Vivek Charandas Pathade Presently working in Datta Meghe Institute Of Engineering, Technology And Research, Sawangi(M), Wardha Deptt. Of Mechanical Engg. Duration: 20/06/2011 till date. Designation: Assistant Professor (Regular)

Publications:

1) Evaluation of Thermal Stresses of Solar Parabolic Trough Collector by FEM for Solar Power Plant.

2) National Conference on Recend Trends and Challenges in Mechanical Engineering. Department of Mechanical Engineering, Kavikulguru Institute of technology and Science, Ramtek, Dist: Nagpur

Projects-

P.G.- Stress and Buckling Analysis Of I.C.Engine Connecting Rod by FEM and Photoelasticity.

U.G- Assembly Modelling and Virtual Assembly Of Economizer.

Membership- I.E.I. Membership No. :- AM097721-5

B. K. Patle Pursuing PhD from NIT Raurkela, Orisa Presently working in RSR Runghta College of Engineering and Technology Bhilai Dist- Durg, (C.G.) India Deptt. Of Mechanical Engg. Duration: 11/07/2009 till date Designation: Assistant Professor (Regular)

Publications:

4 papers has been published in international conference and 1 in national conference.

Projects-

PhD research topic- Navigation of automobile robot in complex environment by using AI techniques.

P.G:

Finite element analysis of solar parabolic plate collector.

U.G.-

Design and fabrication of heat exchanger.

Ajay Ingale Working as Assistant Professor in Datta Meghe Institute of Engineering, Technology and Research, Sawangi (Meghe), Wardha (Maharashtra, INDIA). Completed Master of Technology in Thermal Engineering in 2009.

Publications

Papers in International Conferences -2,

Papers in National Conferences - 2