Finite Element Analysis of IC Engine Connecting Rod using Different Materials for Weight Reduction

Jalak D. Doshi[1] Hardik D. Gangadia[2] Jigar A. Dave[3] Kashyap A. Vyas[4]
[1]P.G. Student [2,3]Assistant Professor
[1,2,3]Silver Oak College of Engineering & Technology, Ahmedabad

Abstract— This paper aims to utilize Finite Element Analysis, to gain insights on load distribution across the connecting rod geometry, as well as possible deformation due to structural stresses. This method significantly shortens the design cycle by reducing the number of physical tests required. Utilizing this capability, the paper compares different materials to obtain light weight connecting rod design, without affecting the structural strength.
Key words: Weight Reduction, Finite Element Analysis

I. Introduction

The connecting rod is the most relevant pats of an automotive engine. The connecting rod is subjected to an extremely complex state of loading. High compressive and tensile loads are due to the combustion and connecting rod's mass of inertia respectively. It undergoes high cyclic loads of the order of 108–109 cycles, which range from high compressive loads because of combustion, to high tensile loads because of inertia. Therefore, durability of this component is of critical importance. Usually, the worst case load is considered in the design process. Literature review suggests that investigators use maximum inertia load as one extreme load corresponding to the tensile load and compressive gas load producing maximum torque as the other extreme design load corresponding to the compressive load.

II. Problem Definition

Through research, it has been found that there is a possibility to optimize connecting rod design using different materials. Using finite element approach, critical stress regions and subsequent deformation can be identified. Alternative materials can be utilized to further reduce development cost and benefit the manufacturers.

III. Model Selection

A. Engine Specifications

To perform the thermal studies using finite element analysis, the connecting rod from the following engine is selected:

Engine type	Air cooled 4-stroke
Bore × Stroke (mm)	50×49.5
Displacement	97.2CC
Maximum Power	5.5KW@8000rpm
Maximum Torque	7.95Nm @ 5000rpm
Compression Ratio	9.0:1

Table 1: Engine Specifications

B. Connecting Rod Dimensions

Sr.no.	Parameters	Actual values
1	Length of connecting rod	122.66mm
2	Outer diameter of Big end	39.02mm
3	Inner diameter of big end	30.19mm
4	Outer diameter of small end	17.75mm
5	Inner diameter of small end	13.02mm

Table 2: Connecting Rod Dimensions

C. Material Selection

The connecting rod model is tested using four different materials having physical properties as mentioned in the table:

Sr. no	Material	Young's Modulus (GPa)	Poisson's Ratio	Density (g/cm^3)
1	Cast iron ASTM grade 20	97	0.3	7.197
2	Al 360	210	0.3	2.700
3	Stainless steel grade 304	203	0.3	7.850
4	c70 steel	211.5	0.3	7.695

Table 3: Material Properties

D. Boundary Conditions

Boundary conditions to perform structural analysis with finite element method are as mentioned below. Here the values are applied in terms of pressure both on small and big end of the connecting rod.

	Compressive Loading (MPa)	Tensile Loading (MPa)
Crank End	6.340	6.95
Piston Pin End	14.65	16.15

Table 4: Boundary Conditions

1) Analytical Calculations

During the working of the I.C.Engine, maximum gas forces generated are calculated as under:

Fg: π / 4 x D x D x pmax,

Where,
D: Diameter of the Piston head
pmax: Maximum combustion pressure
Now the diameter of the piston head is calculate as under:
D = sqrt (Engine Displacement / (Stroke x 0.7854 x no. of cycles))
= sqrt (97.2 / (4.95 x 0.7854 x 1))
= 5 cm
= 50mm
So, gas force generated in the I.C.Engine :

Fg = π / 4 x D x D x pmax

Here, assume the gas pressure inside the I.C.Engine is 69.50 Kg/cm^2, due to pressure the force generated on the connecting rod is:
= π x d x l x 69.50
= π x 3.019 x 1 x 69.50
= 659.17 Kg
= 6466.46 N

Since a connecting rod is subjected to severe load conditions including fatigue load, Thus according to Rankine formula,

Crippling load used for the connecting road calculation:

Pcr = 6466.46 N

Pcr = σcr x A / (1+a (L/kxx)2)

Where,

Pcr : Cripling load acting on connecting road

σcr : Crushing stress

A : Cross sectional area of the connecting road

a : Rankine constant, here the material of the connecting road is C70 steel, = 1/7500

L : Effective length of the connecting road, here the connecting road both end are hinged. So, the effective length is equivalent to length of the connecting road.

kxx : Radius of gyration about the x-axis.

Here the dimensions of the connecting road shown, measured from the connecting road by reverse engineering.

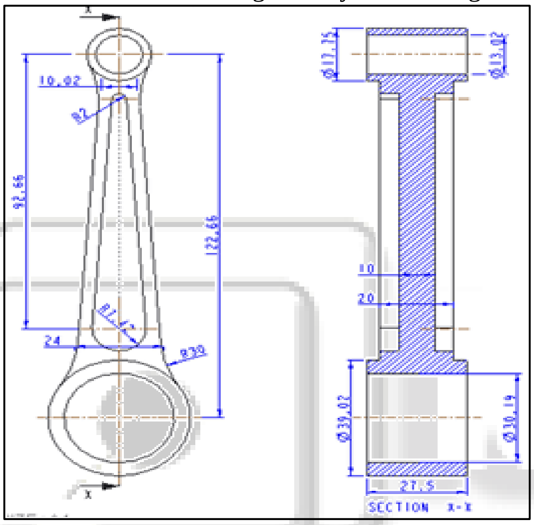

Fig. 1: Connecting rod dimensions

2) Cross section of the connecting rod:

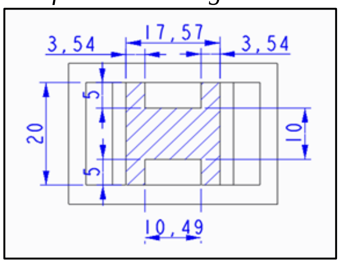

Fig. 2: Cross section of connecting rod

Cross sectional area of the above section are calculated from the modeling software:

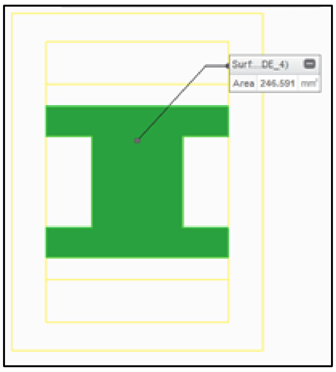

Fig. 3: Cross sectional area calculated from the software

The mass moment of inertia of the above cross sectional area is shown as under:

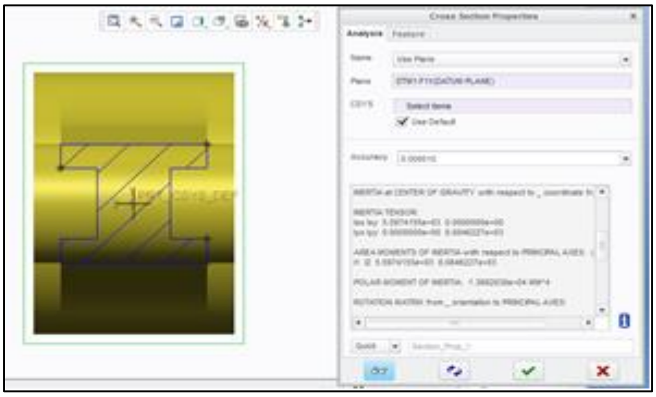

Fig. 4: Mass moment of inertia of the cross section from software

From the sketch:

Ixx = 8.0846 x 103

Iyy = 5.5974 x 103

Now from the above data, the radius of gyration is calculated as under:

kxx = Ixx/A

= 8.0846 x 103 / 246.591

= 32.785mm

kyy = Iyy / A

= 5.5974 X 103 / 246.591

= 22.699 mm

Now by applying the above data, the crushing stress generated in the connecting rod is as under:

Pcr = σcr x A / (1+1/a(L/kxx)2)

σcr = Pcr x (1+1/a(L/kxx)2) / A

= 6466.46 x (1 + 1/7500 (122.66 / 32.785)2) / 246.591

= 26.27 N/mm2

The existing connecting rod is capable to sustain a crushing stress up to 26.27 N/mm2

IV. FEA ANALYSIS

Based on the calculations and boundary conditions, the connecting rod model is imported to ANSYS environment for structural analysis. Following are the steps performed to obtain stress and deformation for the existing connecting rod design of C70 material.

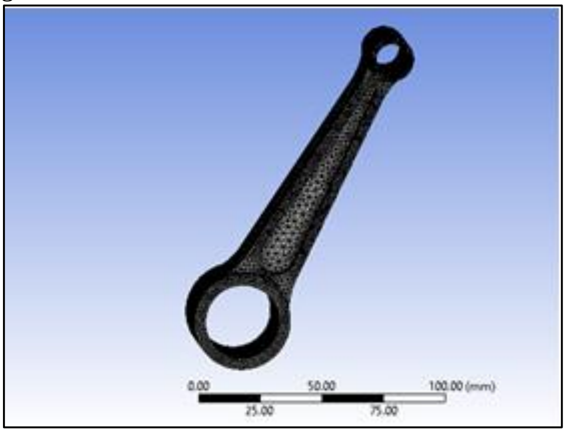

Fig. 5: Meshing applied on connecting rod model

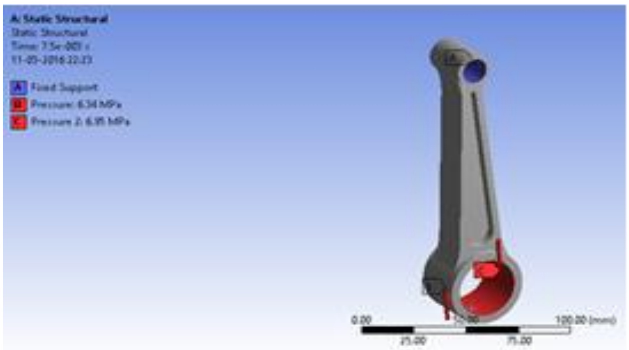

Fig. 6: Pressure boundary applied at big end

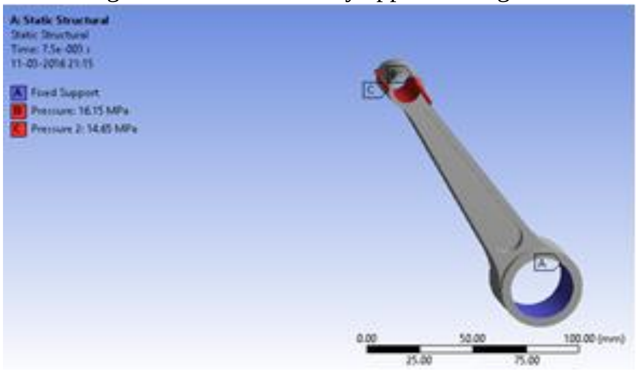

Fig. 7: Pressure boundary applied at small end

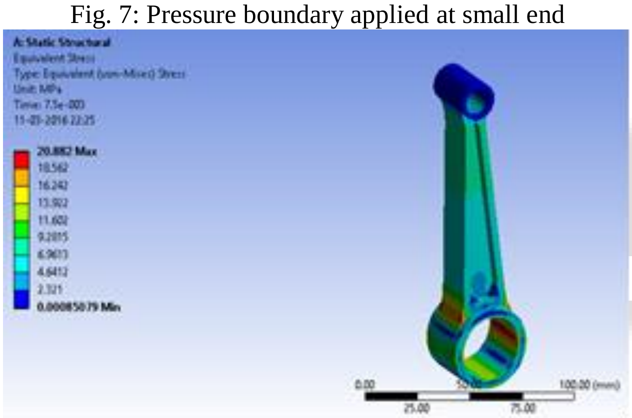

Fig. 8: Equivalent stress for big end loading condition

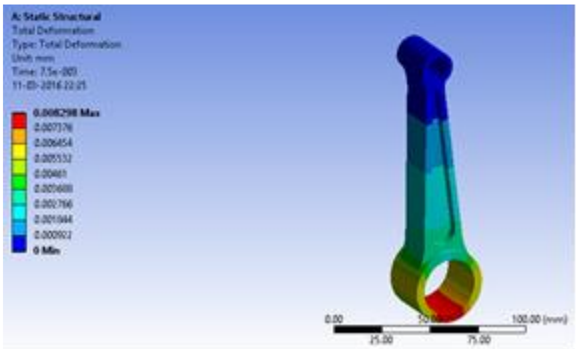

Fig. 9: Total deformation for big end loading condition

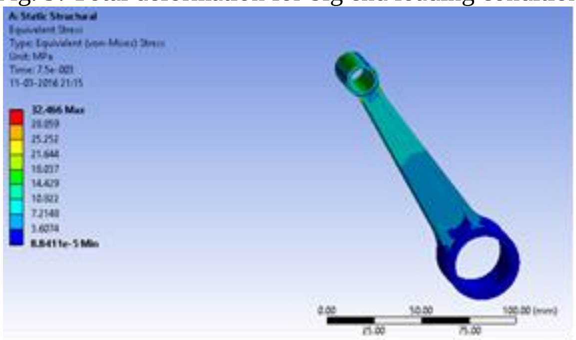

Fig. 10: Equivalent stress for small end loading condition

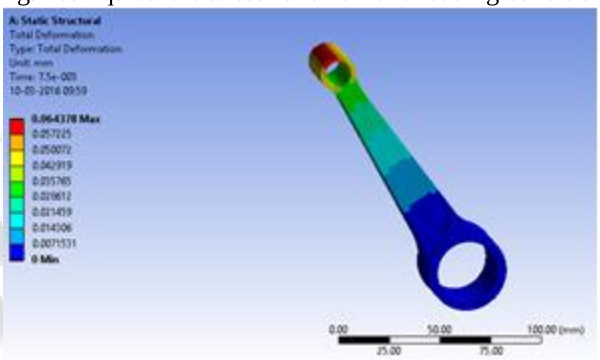

Fig. 11: Total deformation for small end loading condition

Similar analyses are conducted for alternative materials and the stress and deformation values were computed to compare the behaviour of connecting rod made up of different materials.

V. RESULTS

Material	Von-Mises Stress Big End MPa	Von-Mises Stress Small End (MPa)	Deformation Big End (mm)	Deformation Small End (mm)	Weight (Kg)
C.I. ASTM grade 20	21.06	32.60	0.0180	0.0135	0.2963
Al 360	20.59	32.29	0.0245	0.0184	0.1112
Stainless steel grade 304	20.79	32.40	0.0082	0.0064	0.3232
C70 steel	20.88	32.46	0.0082	0.0062	0.3168

Table 5: Result Comparison

VI. CONCLUSION

Based on the analyses conducted on the existing connecting rod design, it is observed that stresses and deformation values remain within permissible ranges for small and big ends. Hence, it is possible to reduce the weight of the CR with the methodology adopted here. Aluminum 360 is found to be the best material for reducing the connecting rod weight by 64%.

The methodology presented here opens up new avenues for carrying out research work on improving the engine performance further. Following are the key areas that can be considered as a good candidate for future work.

– Performing fatigue analysis on the optimized design of the connecting rod and evaluating the available useful life.
– Utilizing different materials and identify further weight reduction opportunities
– Using the methodology for other IC engine components to improve overall performance of the engine

- Evaluating various engine test cases for dynamic analysis

REFERENCES

[1] Dynamic Analysis Of Loads and Stresses in Connecting Rods, P S Shenoy and A Fatemi, Journal of Mechanical Engineering Science Vol. 220, 2005

[2] Analysis of Connecting Rod Using Analytical and Finite Element Method, N.P.Doshi, N.K.Ingole, International Journal of Modern Engineering Research Vol.3 Issue 1, Jan-Feb 2013

[3] FEA Analysis Of Geometric Parameters Of Connecting Rod Big End, Sanjay B Chikalthankar, V M Nandedkar, Surendra Prasad Baratam, International Journal of Engineering Science and Technology, Vol.4, Issue 04, 2012

[4] Fatigue Analysis of Connecting Rod Using Finite Element Analysis to Explore Weight and Cost Reduction Opportunities for a Production of Forged Steel Connecting Rod, Ambrish Tiwari, Jeetendra Kumar Tiwari, Sharad Kumar Chandrakar, International Journal of Advanced Mechanical Engineering, Vol.4, Issue 7, 2014

[5] Stress Analysis of I.C.Engine Connecting Rod by FEM, Vivek. C. Pathade, Bhumeshwar Patle, Ajay N. Ingale, International Journal of Engineering and Innovative Technology, Vol. 1, Issue 3, 2012

[6] Design And Finite Element Analysis Of Aluminium-6351 Connecting Rod, Priyank D. Toliya, Ravi C. Trivedi, Prof. Nikhil J. Chotai, International Journal of Engineering Research & Technology, Vol. 2 Issue 5, May – 2013

[7] Design and Comparative Performance Analysis of Two Wheeler Connecting Rod Using Two Different Materials Namely Carbon 70 Steel and Aluminum 7068 by Finite Element Analysis, Sushant, Victor Gambhir, International journal of research in aeronautical and mechanical engineering, Vol. 2, Issue 6, June- 2014

[8] Design & Shape Optimization of Connecting Rod using FEA: A Review, Shweta Ambadas Naik, International Journal of Engineering and Technical Research, Volume-2, Issue-8, August 2014

[9] Design and Optimization Of Connecting Rod for 4 – Stroke Petrol Engine by Using Finite Element Analysis, S. Aishwarya and E. V. V. Ramanamurthy, ARPN Journal of Engineering and Applied Sciences, Vol. 10, No. 11, June 2015

[10] Design of Connecting Rod for Light Weight Using C70S6 Material, Deepak G. Gotiwale and Shailesh D. Ambekar, International Journal of Advanced Science, Engineering and Technology, Vol 3, Issue3, 2014

[11] Shape Optimal Design of an Engine Connecting Rod, Y. M.Yoo, E. J. Haug, K. K. Choi, Journal of Mechanisms, Transmissions, and Automation in Design, ASME, Vol. 106/415, September 1984

[12] Design and Comparative Analysis of Connecting Rod using Finite Element Method, Shahrukh Shamim, International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 9, September- 2014