Cost and Weight Optimization with Stress Analysis of Connecting Rod used in Diesel Engine using FEM Approach

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ABSTRACT

An optimization study was performed on a steel forged connecting rod with a consideration for improvement in weight and production cost in that. Since the weight of the connecting rod has little influence on its total production cost, the cost and the weight were dealt with separately. Weight reduction was achieved by using an iterative design procedure. Literature survey suggests cyclic loads comprised of static tensile and compressive loads are often used for design and optimization of connecting rods. In this study weight optimization is performed under a cyclic load comprising dynamic tensile load and static compressive load as the two extreme loads. Constraints of fatigue strength, static strength, buckling resistance and manufacturability were also imposed. The fatigue strength was the most significant factor in the optimization of the connecting rod. An cost calculation for materials cost savings is also made.

Keyword : - *connecting rod, dynamic tensile load, fatigue strength*

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1. INTRODUCTION

An internal combustion engine is any engine that uses the explosive combustion of fuel to push a piston within a cylinder of engine. The piston's movement turn a crankshaft that then turn the car wheels via a chain or a drive shaft. The different types of fuel commonly used for car combustion engines are petrol, diesel, and kerosene The automobile engine connecting rod is a high volume production, critical component. It joins reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least a one connecting rod depending upon the number of cylinders in the engine. Connecting rods for automotive applications are typically manufactured by forging from either wrought steel or a powdered metal. They could also be cast. However, castings could have blow-holes which are detrimental from durability and fatigue points of view.

2. LITERATURE REVIEW

There is a very large amount of literature related to Finite Element Analysis of weight optimization of connecting rod is done. In many research publications, journals, newspaper articles, handbooks, books are available of national and international editions dealing with basic concepts of FEA analysis of connecting rod.

Ashwini Mane et al. have objective of this study is to improve the design of connecting rod of single cylinder four stroke Otto cycle engine by shape optimization. The main objective of this study is weight reduction of connecting rod and improving its performance without affecting its functionality. Stresses generated across all the locations of connecting rod evaluated using ANSYS Workbench. Static structural analysis of modified design is performed and the results compared with baseline design. They were able to achieve 14.73% weight reduction in existing connecting rod. Optimization technique used for this study is successful to achieve weight reduction by almost 15%.[1]

Pravardhan S. Shenoy et al. have done optimization performed on a steel forged connecting rod with a consideration for improvement in weight and production cost. The shank region of the connecting rod offered the greatest potential for weight reduction. The rib and the web thicknesses were reduced, while maintaining forge ability The optimized geometry is 10% lighter than the current connecting rod reduces the production cost by about 25%. As compared with a PM connecting rod, the cost saving is estimated to be about15%. [2]
Suraj Pal et al. have objective in the Design evaluation and optimization of connecting rod parameters by using finite element method is to achieve suitable design for connecting rod. That can be achieved by changing such design parameters in the existing design. The results obtained are well in agreement with the similar available existing results. The model presented here, is well safe and under permissible limit of stresses. Conclusion is based on the current work that the design parameter of connecting rod with modification gives sufficient improvement in the existing results. The weight of the connecting rod is also reduced by 0.477g. Fatigue strength is the most important driving factor for the design of connecting rod and it is found that the fatigue results are in good agreement with the existing result. The stress is found maximum at the piston end so the material is increased in the stressed portion to reduce stress. [3]
Mr. H.B.Ramani et al. have described weight reduction of internal combustion engines connecting rod by ANSYS Workbench software. The structure of connecting rod was modeled utilized Pro-E software and analysis was performed using ANSYS Workbench software. By the FEA analysis results, the crank end is suggested to be redesign based on the Shape optimization results. The optimized connecting rod is 15% lighter and predicted low maximum stress compare to initial design. it can be concluded that the weight of optimized design is up to 15% lighter and maximum stress also predicted lower than the initial design of connecting rod. [4]

3. EXPERIMENTAL PROCEDURE

The connecting rod dimensions are as follows. Which is derived after doing theoretical calculation with engine data

Table -1: connecting rod dimensions

Sr no.	Parameter	Value
1	Length o f connecting rod (L)	1 4 4 mm
2	Thickness of flange &web of the section (t)	6 mm
3	Diameter of crank pin (d_c)	3 4 . 7 6 mm
4	Length of crank pin (l_c)	4 5 . 1 8 mm
5	Diameter of piston pin (d_p)	2 5 . 5 8 mm
6	Length of crank pin (l_p)	5 1 . 5 6 mm
7	Nominal diameter of bolt (d_b)	3 2 . 3 3 mm
8	Thickness of big end cap (t_c)	3 8 . 2 7 mm

Analysis done with pressure load applied at the piston end and restrained at the crank end. The finite element analysis is carried out on existing structural steel connecting rod as well as on modified structural steel connecting rod.
The CAD model of connecting rod of existing and modified is developed in NX CAD. Analysis is carried out on these meshed models of connecting rod in ANSYS 15.0. From the analysis the equivalent stress (Von-mises stress), displacements were determined and are shown in

3.1 3D Model of connecting rod

A 3D model of connecting rod with the dimensions as in Table -1 is in Fig -1 and the design is modified by applying tapered part in the middle section.

Fig -1: 3D model of existing connecting rod

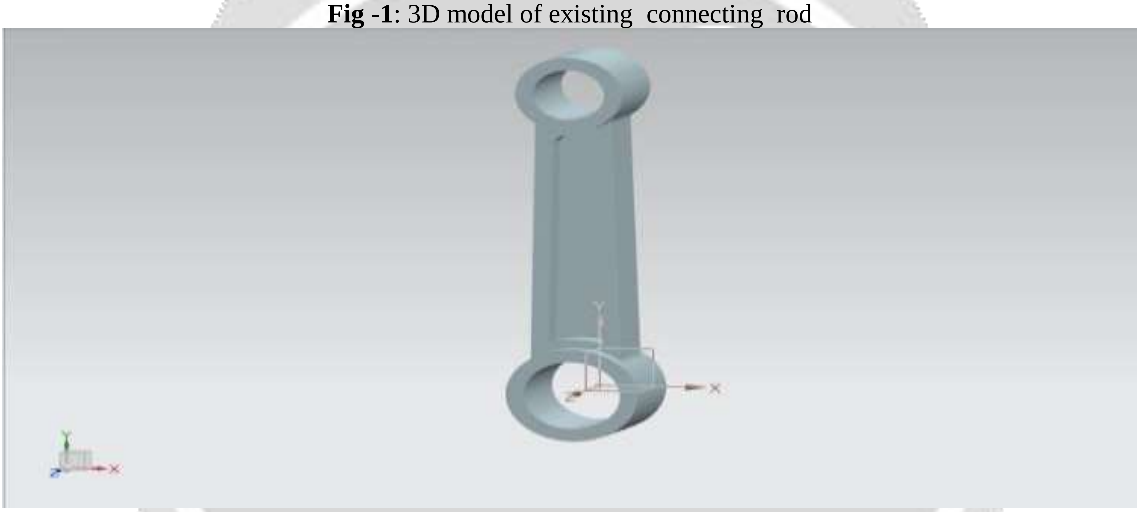

Fig -2: 3D model of modified connecting rod

3.2 Stresses generated in connecting rod

Stresses induced in connecting rod are determined from finite element method. Induced stresses are shown in below figures. Stresses generated in existing connecting rod is 29.606 MPa and in modified design is 72.005 MPa.

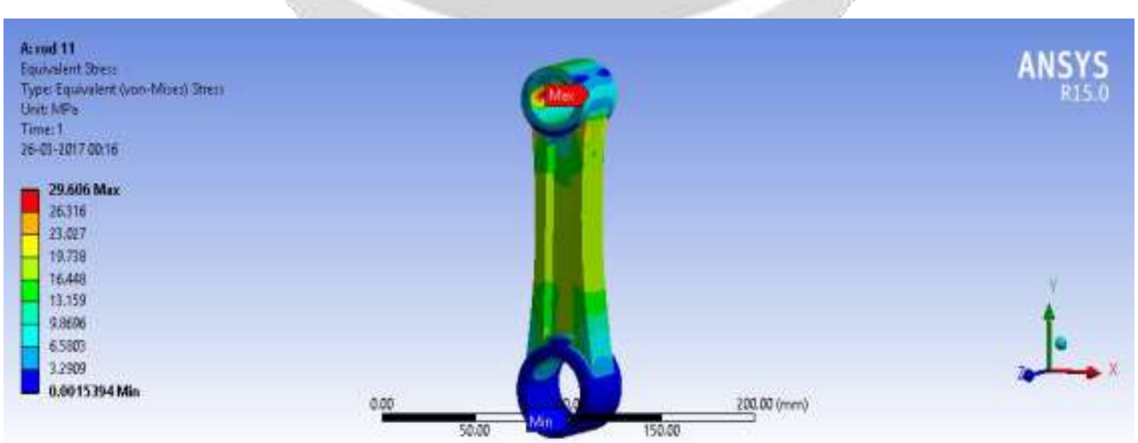

Fig 3: Von-mises stress in existing connecting rod

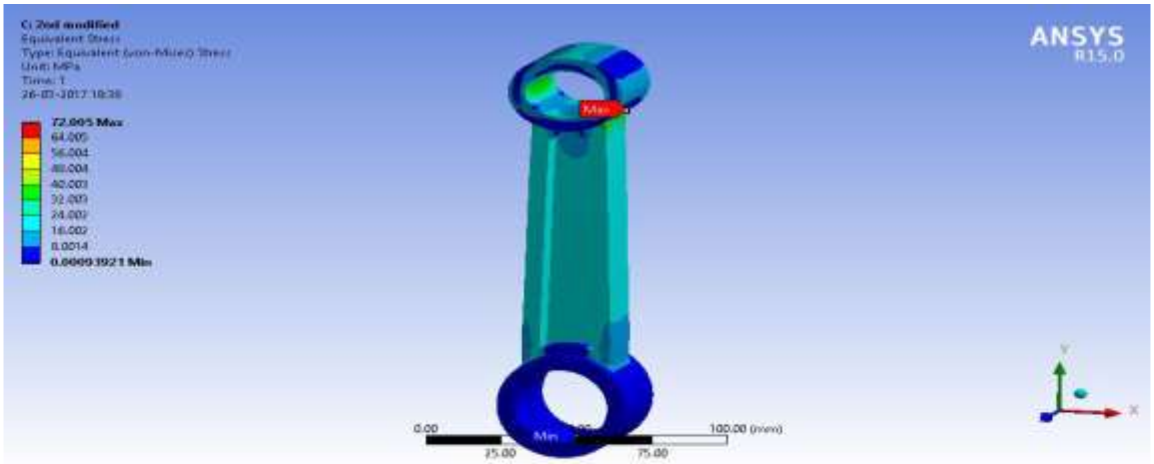

Fig -4: Von-mises stress in modified connecting rod

3.3 Total deformation in connecting rod

Deformation of connecting rod is determined from finite element method. Deformation Of connecting rod is shown in below figures. Deformation of existing connecting rod is 1.31×10^{-2} mm and in modified it is 1.52×10^{-2} mm

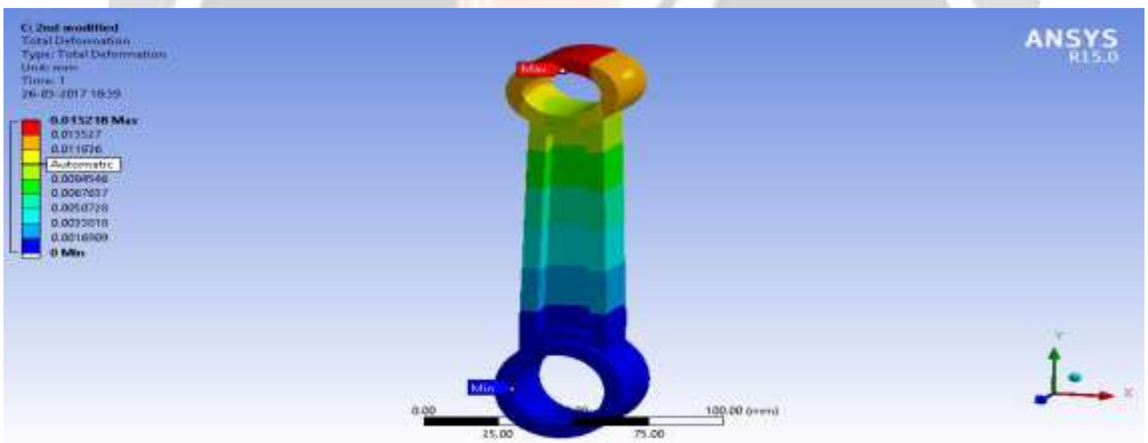

Fig -5: Total deformation in existing connecting rod

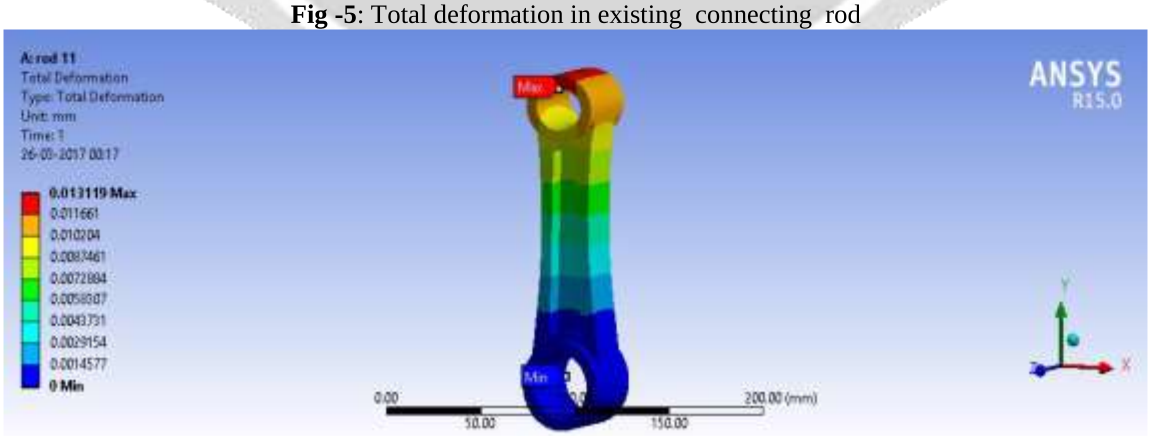

Fig -6: Total deformation in modified connecting rod

3.4 Comparison of FEA results for stresses & deformation

Table -2: Comparison of FEA results for existing and modified design

Parameter	Existing design	Modified design
Equivalent (von-Mises) Stress	29.606MPa	72.005 MPa
Total deformation	1.31×10^{-2} mm	1.52×10^{-2} mm

3.6 Weight comparison for existing design and modified design

Existing design has a weight of 7.9461 kg and modified design has a weight 7.0589 kg

Table -3: Weight comparison for existing and modified design

Parameter	Existing design	Modified design
Weight	7.9461 kg	7.0589 kg

4. COST CALCULATION

Here only the cost for material is described all other costs like processing cost , equipment cost and tooling cost will vary according to the material cost. Cost per piece is as described below

Cost for existing design
= 7.9461kg × 55Rs/kg
= 437.035Rs

Cost for modified design
= 7.0589kg × 55Rs/kg
= 388.2395Rs

According to this if this per piece saving cost is 48.796Rs and if it is calculated on annual basis with daily production of 500 piece the total cost saving will be 8783280Rs.

5. CONCLUSION

As per FEM analysis of different design of connecting rod and from observation table of results of stress analysis in modified design is suitable for connecting rod with given space and loading condition. Compare to original design stress analysis, equivalent von misses stress is increasing but within yielding limit of material and comparatively deformation is also less affected by optimizing design. We achieve weight loss of 0.08kg in optimised design and fatigue life is also not affected compare to exiting design. weight reduced by 11.18%. Modified design 2 has a cost saving per year 8783280 Rs which is also 11.17% of the existing one

6. REFERENCES

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