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Optimization of an Epoxy Resin Two- Wheeler Connecting Rod Using CAE Tools

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***Abstract*— The main objective of the work is to carry out the weight reduction and cost optimization of connecting rod, which is achieved by changing the material of the existing connecting rod to epoxy resin. The model is developed in CATIA V5 and then imported in ANSYS workbench. The work analysis of the single cylinder four-stroke engine connecting rod is carried out using Finite Element Analysis software ANSYS WORKBENCH 9.0 and taken as a case study. The Von Mises stress, strain and total deformation determined for the same loading condition and compared with the existing results. The current work consists of two types of analysis. In the first part of the study, a static analysis is carried out for the optimization of connecting rod. The static analysis is carried out under axial load and buckling load. In the second part, a fatigue failure analysis is carried out to check the fatigue strength of the optimized connecting rod. FEA and the load analysis results, the load for the optimization study are selected. A fatigue tool is used to determine the life, stress multiaxiality, factor of safety and damage of the connecting rod.**

***Index Terms*— Connecting Rod, Epoxy resin, Factor of safety, Fatigue failure, Finite Element Analysis , Modeling, , Optimization.**

I. Introduction

This study shows the implementation of FEM software for the analysis of the strength and distortion characteristics of a connecting rod. Purpose of the connecting rod is to transfer the reciprocating motion of the piston into rotary motion of the crankshaft. The maximum stress occurs in the connecting rod near the piston end due to thrust of the piston. The tensile and compressive stresses are produced due to gas pressure, and bending stresses are produced due to centrifugal effect i.e. why the connecting rods are designed generally of I- section to provide maximum rigidity with minimum weight. The maximum stress produced near the piston end can be decreased by increasing the material near the piston end. From the point of functionality, connecting rods must have the highest possible rigidity at the lowest weight. The automobile engine connecting rod is a high volume production critical component. Every automobile body that uses an internal combustion engine requires at least one connecting rod based on the number of cylinders in the engine. To reduce the bending of the connecting rod with the cylinder axis, its length should be kept as large as possible. Reduced bending decreases the oscillatory angular motion of the connecting rod about its small end, thereby reducing the piston side thrust and enhancing the reciprocating balance of the engine. Accordingly, the current practice to reduce the overall height of the engine, the length of connecting rod has been decreased from 4 to 4.5 times the crank throw to about 3.5 times. A combination of axial and bending stresses acts on the rod in operation. The axial stresses are produced due to cylinder gas pressure (only compressive) 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. To provide maximum rigidity with minimum weight the main cross section of the connecting rod is made an I-section is made to blend smoothly into two rod ends called the small end (piston end) and big end (crank end).

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II. OBJECTIVES

In this work of study, only the static FEA of the connecting rod has been performed by the help of the design software. This work can be extended to study the effect of loads on the connecting rod under various dynamic conditions. Experimental stress analysis can also be used to calculate the stresses which will provide more reasons to compare the different values obtained. These days it is being said about vibration study of mechanical components in the detection of failure of connecting rods. Therefore, the study can be extended to the vibration analysis of the connecting rod. The study identifies fatigue strength as the most significant design factor in the process of optimization. Then the combination of finite element technique with the aspects of weight reduction is to be made to obtain the required design of connecting rod.

- To reduce weight of the existing connecting rod with desired strength
- To determine the Von Misses stresses, shear stresses, and Equivalent Alternating Stress (EAS), total deformation, fatigue life and to optimize in the existing connecting rod design
- To calculate stresses in critical areas and to evaluate if these stresses fall within 5% of critical stress value (yield)
- Stress values within 5% of yield value then design would be optimized, else if the stresses are within elastic limit fatigue life calculation would be done to evaluate the fatigue life cycle of the connecting rod

The main aim of the project is to determine the von-misses stresses, thermal stresses, principle stresses and maximal shear stress and optimize the existing connecting rod. If the existing design shows the failure, then suggest the minimum design changes in the existing connecting rod.

III. STEPS IN MODELING OF CONNECTING ROD

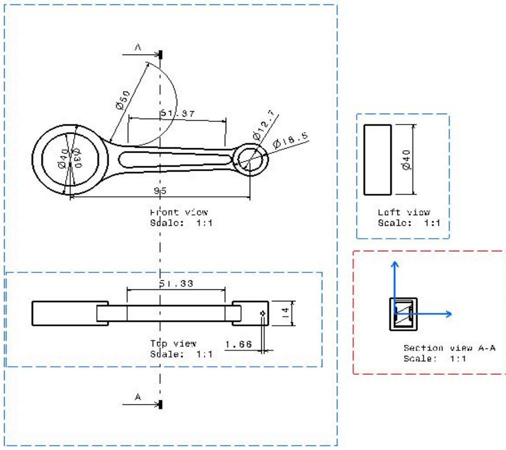

Fig 1:- 2D drawing of connecting rod in CATIA V

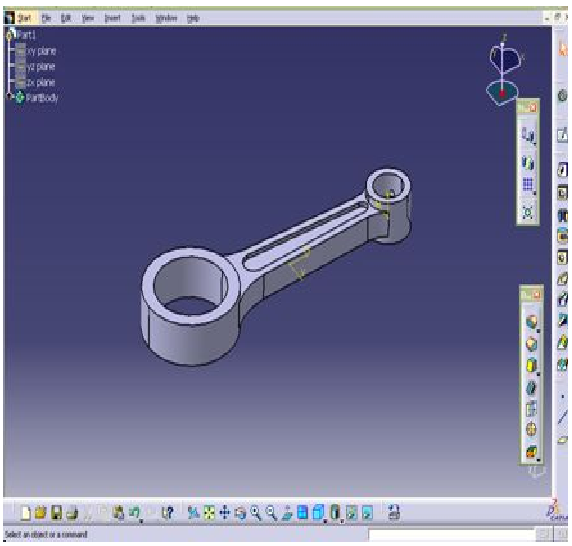

Fig 2: - Final Solid Model of Connecting Rod (CAD model in CATIA V5)

IV. RESULT OF FINITE ELEMENT ANALYSIS: FEA RESULTS FOR AXIAL LOAD (4319N)

In this study four finite element models are analyzed. FEA for both tensile and compressive loads are conducted. Two cases are analyzed for each case, one with load applied at the crank end and restrained at the piston pin end, and the other with load applied at the piston pin end and restrained at the crank end. In this analysis, the axial load was 4319 N (Gas Force) in both tension and compression. Finally the comparisons are done for optimization purpose. The pressure constants for 4319 N are as follows used for applying Boundary Condition: Fig. 4 shows the contours of equivalent Von Mises stress. The maximum stress found to be maximum at the piston pin end and minimum at the crank end. The shear stress is maximum on one side of piston end and minimum at the other side as shown in fig. 5. The elastic strain and deformation are at the maximum at the piston end and minimum at the crank end are shown in fig.6 & fig.7. The colors show the contour of stresses, strain, deformation and other results in the connecting rod. Red color shows the maximum stress, strain and deformation and blue color shows the minimum

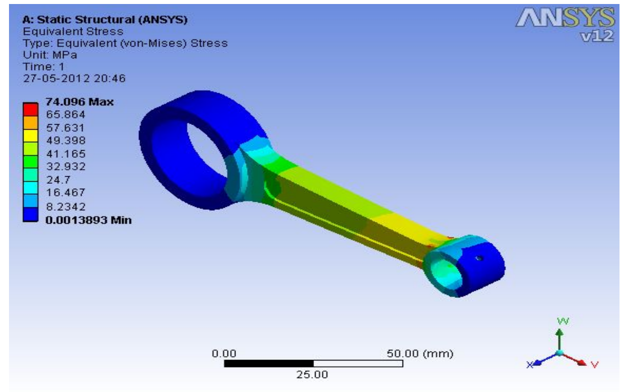

Fig. 3:- Equivalent (Von-Mises) Stress (for load =4319N)

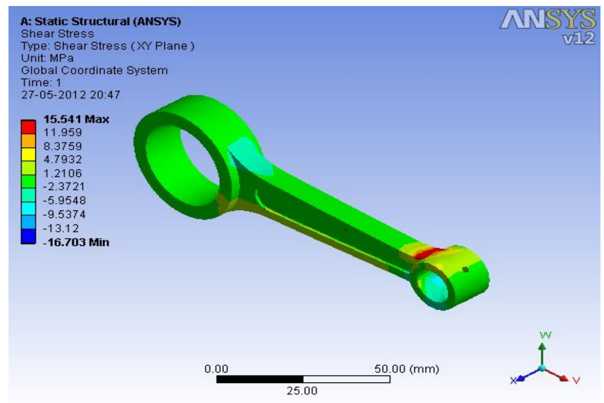

Fig. 4:- Shear Stress (for load =4319N)

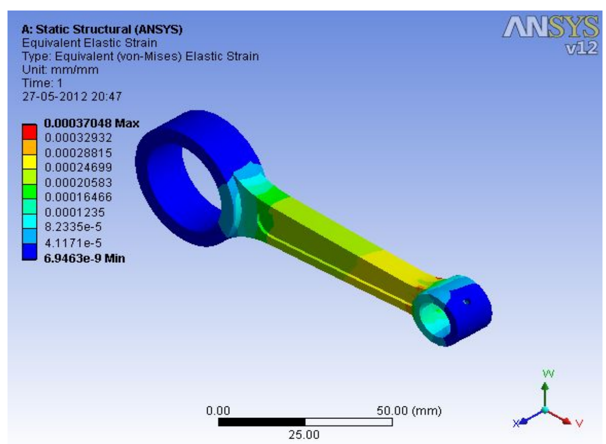

Fig. 5:- Equivalent Elastic strain (for load =4319N)

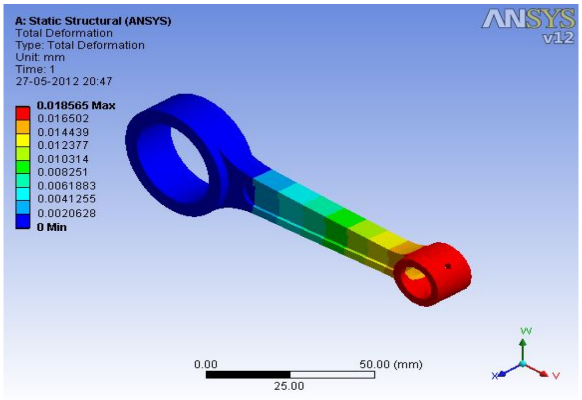

Fig.6:- Total deformation (for load =4319N)

The maximum stress is found to be 74.096 MPa near the piston pin end. The maximum shear stress found to be 15.541 MPa which is less than the existing result. The maximum strain found to be 3.7 *10^-4. So, connecting rod results are in good agreement with the existing results. The same results are studied for the buckling load also. The fatigue analysis consists of following terms in results. The maximum factor of safety reported is 15.

V. OPTIMIZATION STATEMENTS

Objective of the optimization task was to minimize the mass of the connecting rod under the effect of a load range comprising the two extreme loads, the peak compressive gas load, such that the maximum, minimum, and the equivalent stress amplitude are within the limits of the allowable stresses. The production cost of the connecting rod was also to be minimized. Furthermore, the buckling load factor under the peak gas load has to be permissible. Mathematically, the optimization statement would appear as follows:

Objective**:** Minimize (Mass and Cost), subjected to:

- Compressive load = peak compressive gas load
- Maximum stress < Allowable stress
- Side constraints (Component dimensions)
- Manufacturing constraints
- Buckling load > Factor of safety x the maximum gas load (Recommended FOS, 3 to 6)

6. RESULT COMPARISONS (FOR STATIC ANALYSIS)

Sr. no.	Parameters	Existing result for axial load (4319N)	FEA result for axial load(4319N)
1.	Equivalent von-Misses stress	76.22Mpa	74.096Mpa
2.	Shear stress	16.44MPa	15.541Mpa
3.	Elastic strain	3.8e-4 mm/mm	3.7e-4 mm/mm
4.	Total deformation	_	0.018565mm

Table 1:- Result Comparisons for static analysis

RESULT COMPARISON (FOR FATIGUE ANALYSIS)

S.No.	Parameter	Existing result for axial load(4319N)		FEA results for axial load (4319N)	
		Min.	Max.	Min.	Max.
1	Life	1e6	1e6	1e6	1e6
2	Safety factor	1.13	15	1.634	15
3	Biaxiality indication	-1.0	0.97	-0.99	0.876
4	Damage	1000	1000	1000	1000

Table 2:- Result Comparisons for fatigue analysis

WEIGHT OPTIMIZATION

Name	Original	Optimized	Weight reduction
weight	0.13kg	0.127kg	0.003kg

Table 3:- Weight Optimization

CONCLUSION

Finite Element analysis of the connecting rod of a two-wheeler motorbike has been done using FEA tool ANSYS Workbench. From the results obtained from FE analysis, many discussions have been made. 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.

- On the basis of the current work, it is concluded that the weight parameter of connecting rod with modification gives sufficient improvement in the existing results.
- The weight of the connecting rod is also reduced by 0.003 kg. Thereby, reduces inertia force.
- 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 results.
- The stress is found maximum at the piston end. This can be reduced by increasing the material near the piston end.

FUTURE SCOPE

Dynamic analysis can also be performed for the same design of the connecting rod. The connecting rod can be designed and optimized under the tensile load, compressive load, and maximum gas pressure corresponding to the 360^0 crank angle at the maximum engine speed. Composite and heterogeneous material can be used to provide the maximum rigidity with minimum weight.

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