Stress Analysis and Optimization of I. C. Engine Connecting Rod by Finite Element Analysis

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***Abstract*— The main idea of this study is to do analysis of connecting rod and get idea of stress producing compressive loading. And than give idea about weight reduction opportunities in connecting rod of an I.C. engine by examining two materials, AISI 1040 carbon steel and AISI 4340 alloy steel. This has entailed performing a detailed load analysis. Therefore, this study has deal with two subjects, first, static load and stress analysis of the connecting rod and second optimization for weight reduction and shape.**

In this project a static analysis is conducted on a connecting rod of a single cylinder 4- stroke petrol engine. In this project, a connecting rod for I.C. engine was designed by analytical method. On the basis of that design a physical model was modeled in Pro-E (creo parametric 2.0). Structural system of connecting rod has been analyzed using FEA. With the use of FEA von-misses stress, strain, shear stress, deformation, and weight reduction etc, were calculated for a particular loading conditions using FEA Software ANSYS WORKBENCH 14.0. The same work was done on the same design for other different materials. Compared to the former material the new material found to have less weight, stress reduction and better stiffness. After that based on results AISI 4340 alloy steel connecting rod are better than AISI 1045 carbon steel rod.

Keywords*— *ANSYS Workbench, Connecting Rod, FEA, Optimization, Static Load, Stress Analysis.

I. INTRODUCTION

Connecting rod is one of the important driving parts of petrol engine as well as diesel engine. 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 depending upon the number of cylinders in the engine. It is subjected to multiple compressive & tensile forces. Combustion in I.C. Engine produces very high load which transmits to crankshaft via connecting rod. So connecting rod is susceptible to many stresses including equivalent, shear, etc. also fatigue failure is possible because of frequent alternate loading & change of direction. Connecting rod is subjected to many millions of repetitive cyclic loadings. Therefore, durability of this component is of critical importance. It is necessary to investigate finite element modeling techniques, optimization techniques and new design to reduce the weight at the same time increase the strength of the connecting rod itself. Connecting rods are widely used in variety of engines such as, in-line engines, V-engine, opposed cylinder engines, radial engines and opposed-piston engines.

The optimization of connecting rod had already started as early year 1983 by Webster and his team. Optimization of connecting rod is to make the less time to produce the product that is stronger, lighter and less cost. The material properties are one of the major inputs to perform the FEA and optimization.

It consists of a long shank, a small end (pin end) and a big end (crank end). Pin end is connected to the piston assembly and crank end is connected to crankshaft .The cross-section of the shank may be rectangular, circular, tubular, I-section or H-section. Connecting rod is the main component of the combustion engines which main purpose are transfer the energy from the pistons to crankshafts and convert the linear, reciprocating motion of a piston into the rotary motion of a crankshaft. Forces acting on the connecting rod –

- Forces on the piston due to gas pressure and inertia of the reciprocating parts.
- Force due to inertia of the connecting or inertia bending forces.
- Force due to friction of the piston rings and of the piston.
- Forces due to friction of the piston pin bearing and crank pin bearing.

II. OBJECTIVE OF THIS PROJECT

The objective of the present work is to design and analysis of connecting rod made of AISI 1045 carbon steel and AISI 434 alloy steel. In this project, the first two forces have been considered. In this project, a connecting rod for I.C. engine is design by analytical method. Carbon steel material and alloy steel material is used to design the both connecting rods. Connecting rod was created in Creo Parametric2.0. Model is imported in ANSYS 14.0 for analysis. Analysis is done for a given load condition. In this project, load condition is gas force (compressive load), which is also known s static load. After analysis a comparison is made between AISI 1045 carbon steel connecting rod viz., AISI 4340 alloy steel connecting rod in terms of various stress, strain, total deformation, weight, shape optimization. In this project AISI 1045 carbon steel connecting rod is replaced with AISI 4340 alloy steel connecting rod.

III. DIMENSIONS OF BOTH CONNECTING RODS

S. no.	Parameter (mm)
1	Thickness of the connecting rod (t) = 3 mm
2	Width of the section (B = 4t) = 12 mm
3	Height of the section(H = 5t) = 15 mm
4	Height at the big end (H_1) = 18 mm
5	Height at the small end (H_2) = 13 mm
6	Inner diameter of the small end = 14 mm
7	Outer diameter of the small end = 28 mm
8	Inner diameter of the big end = 22 mm
9	Outer diameter of the big end = 48 mm
10	Length of small end = 28 mm
11	Length of big end = 28 mm

Table 1. Dimensions of connecting rod

IV DRAWING OF CONNECTING ROD

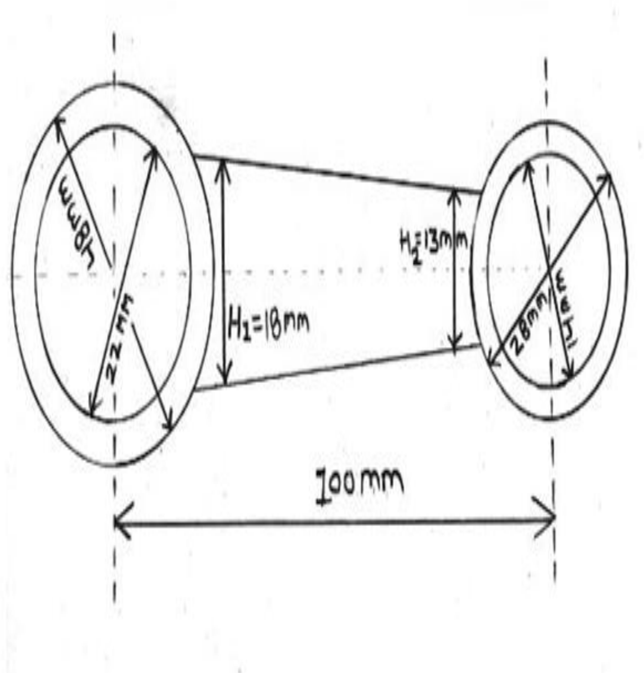

Fig. 1 2D drawing of connecting rod

V. MODELING OF BOTH CONNECTING RODS

According to these dimensions, Connecting Rod has been modeled with the help of creo parametric 2.0. The modeled connecting rod is as shown in figure 2.0. In this analysis two materials are used.

1. AISI 1045 carbon steel.
2. AISI 4340 alloy steel.

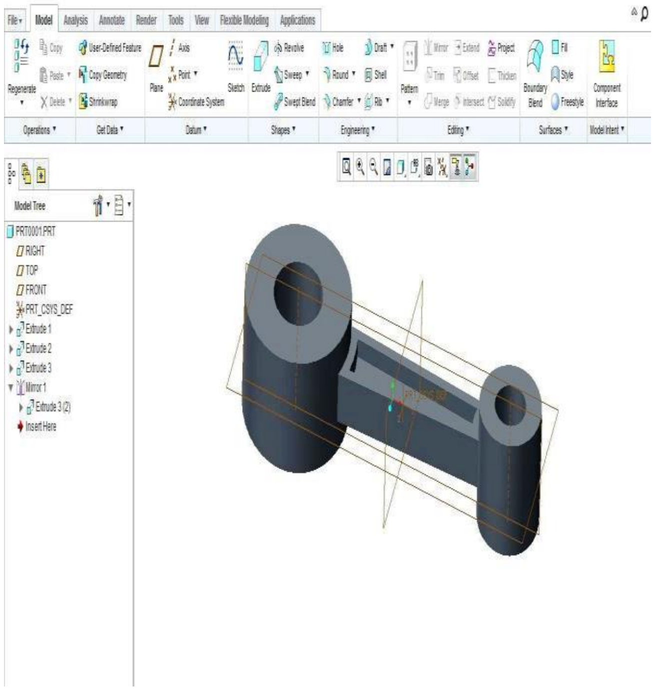

Fig.2 modeling of connecting rod

Table 2. Mechanical properties of AISI 1045 carbon steel –

Mechanical properties	AISI 1045 carbon steel
Density(Kg/mm^3)	7.87×10^{-6}
Modulus of elasticity(Gpa)	200
Poisson ratio	.29
Compressive Yield strength(Mpa)	415
Ultimate tensile strength(Mpa)	565
Shear modulus(GPa)	77.519

Table 3. Material properties of AISI 4340 alloy steel –

Mechanical properties	AISI 4340 alloy steel
Density(Kg/mm^3)	7.85×10^{-6}
Modulus of elasticity(Gpa)	210
Poisson ratio	.28
Yield strength(Mpa)	470
Ultimate tensile strength(Mpa)	745

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VI. ANALYSIS AND OPTIMIZATION OF CONNECTING RODS

In this project stress analysis and optimization is done using ANSYS 14.0

A. Meshing - For meshing of the model, element size was taken 1 mm. No. of elements were 36590 and no. of nodes were 62586. Mesh model of both connecting rods has shown in figure 3.

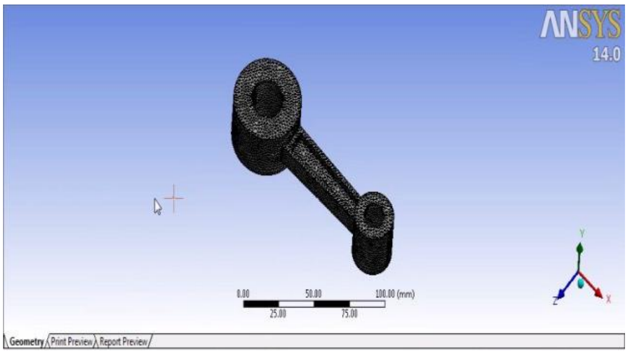

Fig.3 mesh model

B. Load and boundary condition - Analysis is done with the gas force of 6185 N (compressive load),which is also known as static load applied at the piston end of the connecting rod and fixed at the crank end of the connecting rod. It is shown in Fig.4

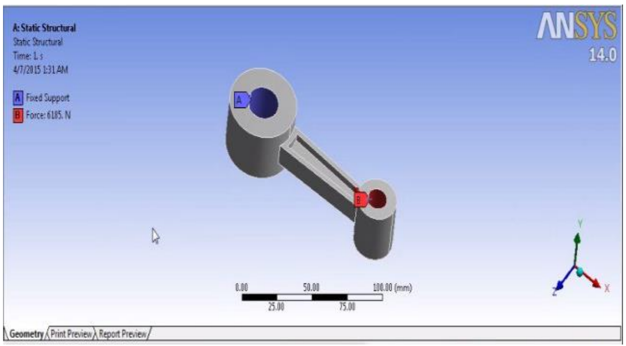

Fig.4

VII. RESULT AND DISCUSSION

A. AISI 1045 carbon steel connecting rod –

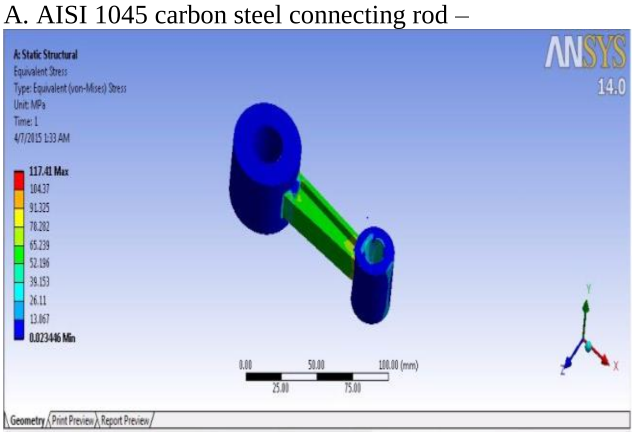

Fig.5 equivalent stress

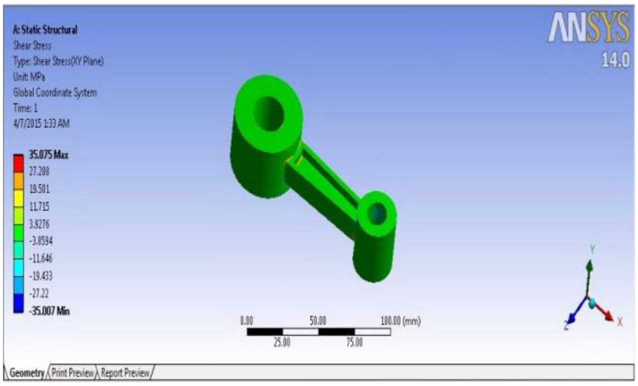

Fig.6 shear stress

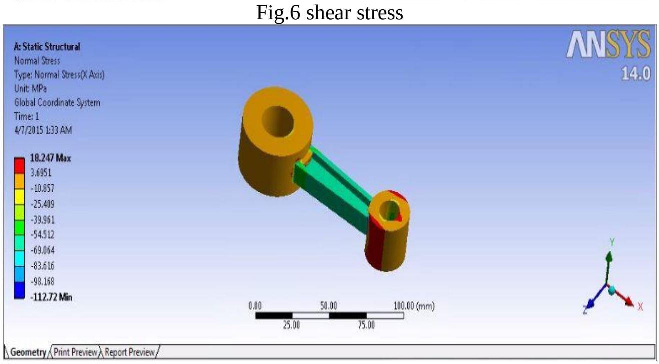

Fig.7 Normal stress

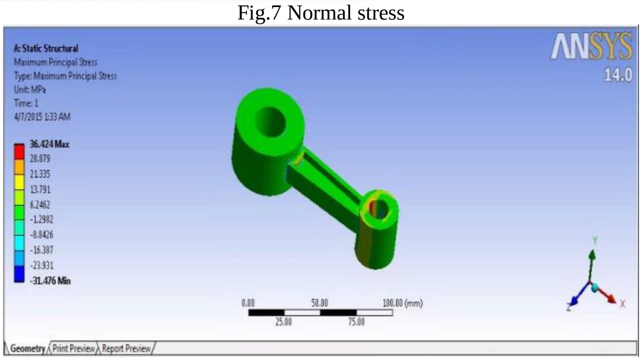

Fig.8 Maximum Principal Stress

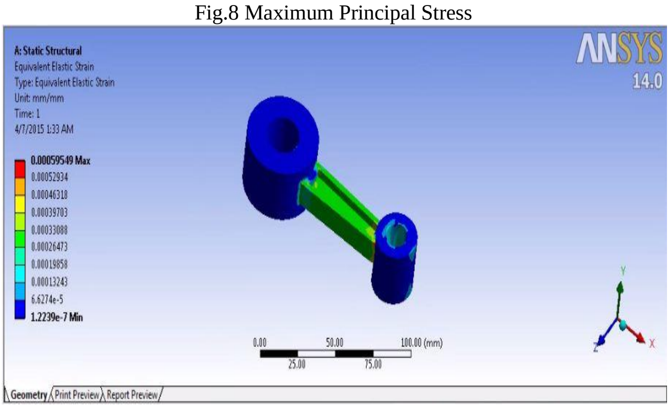

Fig.8 Elastic Strain

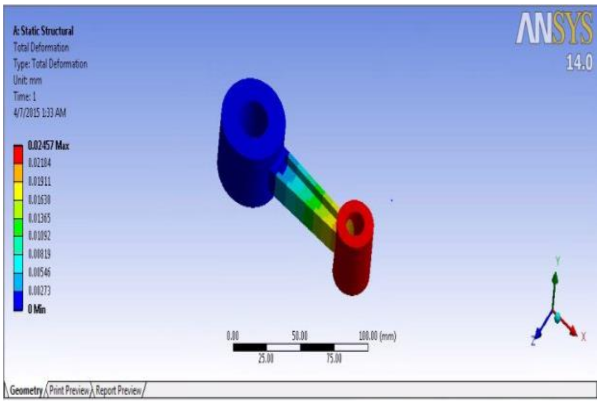

Fig.9 total deformation

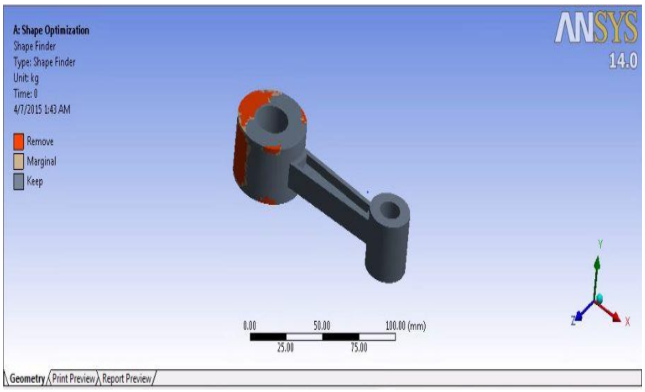

Fig.10 shape optimization

B. AISI 4340 alloy steel connecting rod-

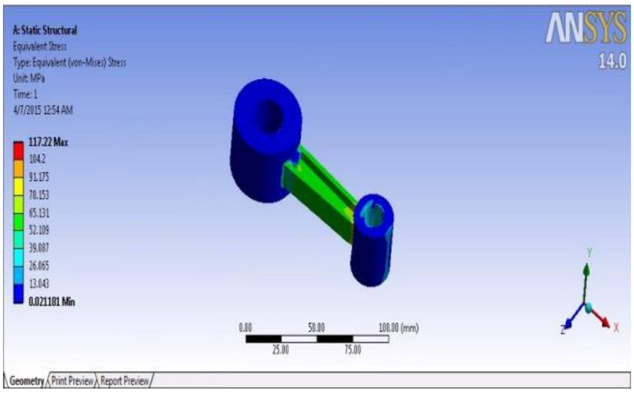

Fig.11 equivalent stress

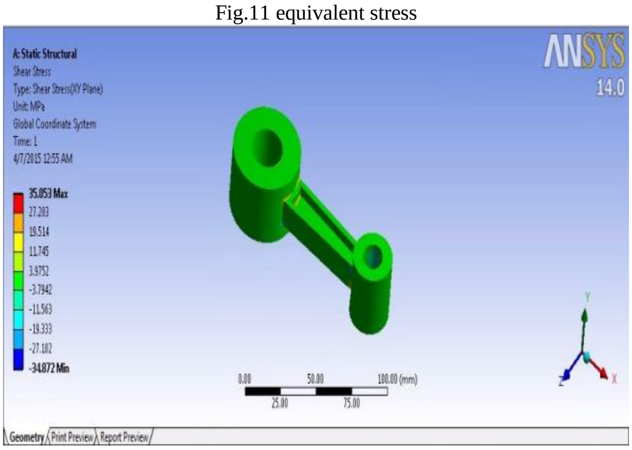

Fig.12 shear stress

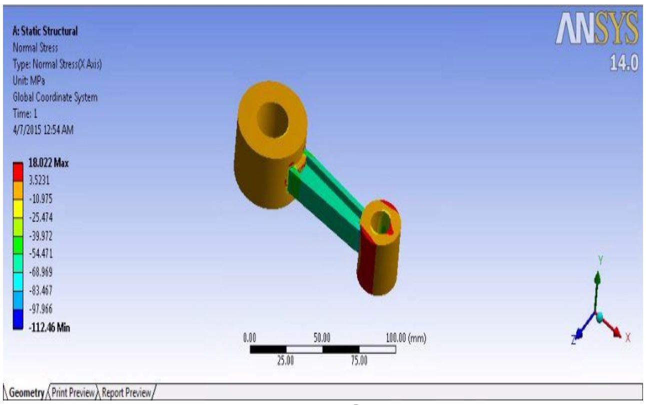

Fig.13 Normal stress

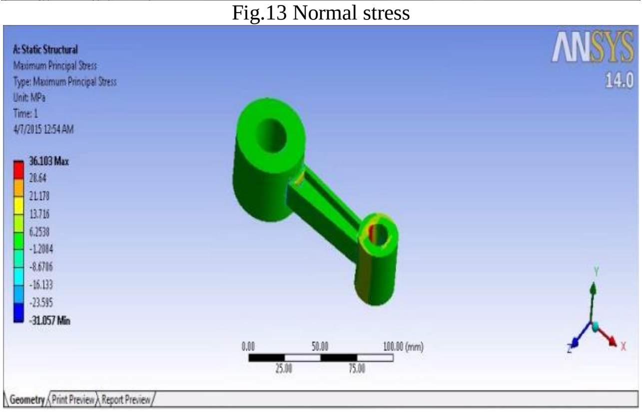

Fig.14 Maximum Principal Stress

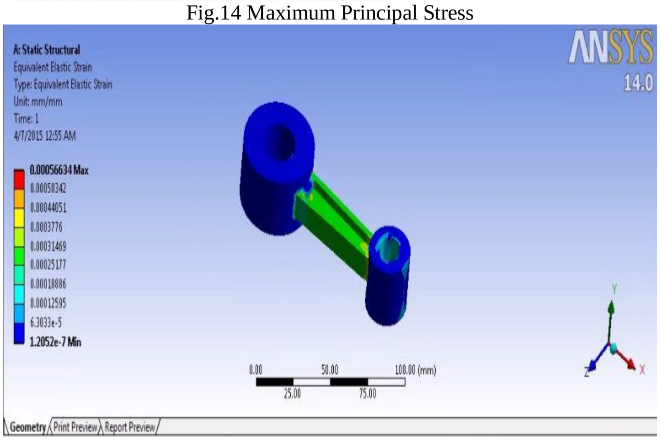

Fig.15 Elastic Strain

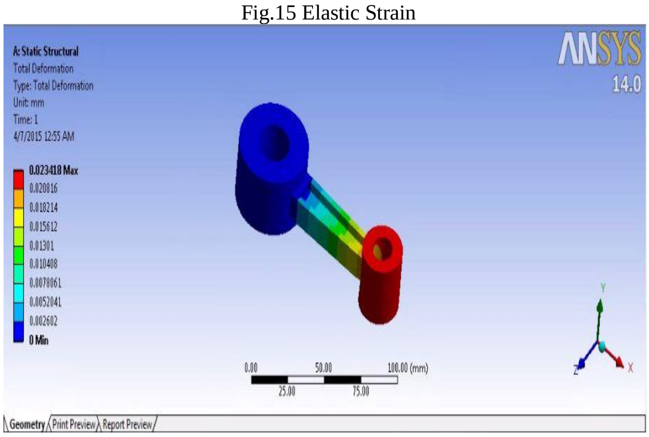

Fig.16 Total deformation

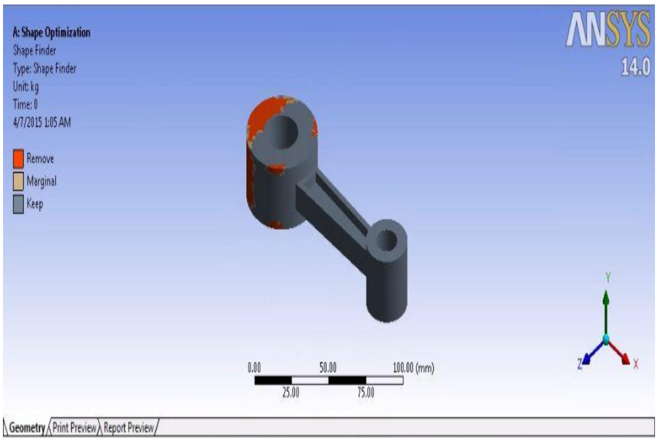

Fig.17 shape optimization

C. stress, total deformation and elastic values –

parameters	AISI 1045 carbon steel		AISI 4340 alloy steel	
	min	max	min	max
Equivalent stress (MPa)	2.3446e-002	117.41	2.1181e-002	117.22
Shear stress(MPa)	-35.007	35.075	-34.872	35.053
Normal stress(MPa)	-112.72	18.247	-112.46	18.022
Max. principal stress (MPa)	-31.476	36.424	-31.057	36.103
Total deformation(mm)	0	.02457	0	.023418
Elastic strain	1.2239e-007	.00059549	1.2052e-7	.00056634

Table 4

D. comparison of stress parameters reduction –

Maximum equivalent stress for AISI 1045 carbon steel –
= 117.41 MPa
Maximum equivalent stress for AISI 4340 alloy steel –
= 117.22 MPa
% reduction in equivalent stress –
= .16 %

E. Weight of AISI 1045 carbon steel connecting rod –

The volume of the connecting rod used is 59875 mm3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume × density

$= 59875 \text{ kg} \times 7.87 \times 10^{-6} \text{kg/mm}^3$

.4712 kg

F. Weight of AISI 4340 alloy steel connecting rod –

The volume of the connecting rod used is 59875 mm3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume × density

$= 59875 \text{ kg} \times 7.85 \times 10^{-6} \text{kg/mm}^3$

= .47 kg

G. Comparison of weight reduction for both connecting rods –

Net difference = .4712 - .4700

= .0012 kg

% reduction in weight = .25 %

H. Stiffness for AISI 1045 carbon steel rod –

Weight of the connecting rod = .4712 kg

Deformation = 0.02457 mm

Stiffness = weight / deformation

Stiffness =

= 19.17 kg/mm

I. Stiffness for AISI 4340 alloy steel rod –

Weight of the connecting rod = .4700 kg

Deformation = 0.023418 mm

Stiffness = weight / deformation

Stiffness =

= 20.07 kg/mm

J. Results of Shape Optimization –

Materials	Original Mass	Optimized Mass	Weight reduction
AISI 1045 carbon steel	4.7232e-035 kg	3.7242e-035 kg	21.14%
AISI 4340 alloy steel	4.7232e-035 kg	3.7237e-035 kg	21.16%

Table 5

VIII. CONCLUSSION –

The structural analysis and shape optimization on the connecting rod using two materials AISI 1045 Carbon steel and AISI 1045 alloy steel has been done and comparing both connecting rods results and is concluded that –

1. The maximum stresses occurred in static structural analysis are less than the yield strength of material. Hence the design is safe.
2. Maximum stresses occurred at the piston end of the connecting rod and minimum stresses occurred at crank end of connecting rod.
3. By comparing the stresses values for both materials, it is slightly less for AISI 4340 alloy steel than AISI 1045 carbon steel.
4. The AISI 4340 alloy steel connecting rod is comparatively much stiffer than the AISI 1045 carbon steel connecting rod.
5. Weight can be reduced by changing the material of the current AISI 1045 carbon steel connecting rod to AISI 4340 alloy steel.
6. By using AISI 4340 alloy steel instead of AISI 1045 carbon steel can reduce weight up to .25%
7. According to shape finder tool, AISI4340 alloy steel connecting rod is lighter than the AISI 1045 carbon steel connecting rod.

By observing the results, we can conclude that AISI 4340 alloy steel connecting rod is better than AISI 1045 carbon steel connecting rod.

IX. REFERENCES –

1. ANNA ULATOWSKA (2008), "Shape Optimization of the Connecting Rod".
2. Bhandari V. B., "*Design of Machine Elements*," Tata McGraw-Hill, Third Edition 2010.
3. Manufacturing Engineering and Technology by Kalpakjian.
4. Amstead, B, H, Ostwald P, F, Begeman M, L, (ed) 1987 "Manufacturing process" John Wiley Publication Singapore.
5. K. Sudershn Kumar, Dr. k. Tirupathi Reddy, Syed Altaf Hussan "Modeling and analysis of two Wheeler connecting rod", International Journal of Modern Engineering Research, Vol -2, Issue- 5, Sep-Oct-2012.
6. Anil Kumar, Kamaldeep Grover, Balvinder budina "optimization of connecting rod parameters using CAE tools", International Journal of Latest Trends in Engineering and Technology, Vol- 1, Issue- 3 , Sep2012.
7. Suraj Pal, Sunil Kumar, "Design Evaluation and Optimization of Connecting Rod Parameters Using FEM", International Journal of Engineering and Management Research, Vol- 2, Issue- 6, Dec 2012.
8. Vivek.c.pathade, Bhumeshwar Patle, Ajay N. Ingale "Stress Analysis of I.C. Engine Connecting Rod by FEM", International Journal of Engineering and Innovative Technology, Vol-1, Issue-3, March2012.
9. Dr S B jaju, P G Chakra, "Modeling and Optimization of Connecting rod of Four Stroke Single Cylinder Engine for Optimization of cost and material".
10. Singh R (2013) "Stress Analysis of orthotropic and isotropic Connecting Rod using Finite Element Method". IJMERR, Vol.2 No. 2.
11. R.J.yang, D.L Dewhirst "Shape optimization of connecting rod pin end using a generic model original research article" Finite element in analysis and design vol 11,issue 3 july 1992,page 257-264.
12. FEM analysis of connecting rod by R.Vozenilek,C.Scholz (The Technical University ofLiberec,Halkova)
13. ANSYS WORKBENCH 14.0 Reference Manual.
14. Creo parametric 2.0 Reference Manual.