Design, analysis and optimization of connecting rod of ginning machine

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***Abstract*- The connecting rod is the intermediate member between power transmitting and power receiving element. Also in some special cases like ginning machine connecting rod is used to convert the rotary motion into reciprocating motion. Sometimes the cross-section of the component gives the good or bad performance of the machine.**

The design is carried out by changing the cross-section of the connecting rod and by changing the material of connecting rod. For this purpose, after study of the various materials, SGI and EN31 are chosen for connecting rod. The proper finite element model is developed by CAD software CATIA V5. The analysis has been performed by FEA software ANSYS 14.0., so as to ensure its strength and weakness during the operation under given condition.

By optimizing the connecting rod for weight and cost reduction it is found that for new I –section connecting rod of SGI the weight reduction is 17% and cost reduction is16%. For new EN31 connecting rod the weight reduction is 13 % and there will be cost increment is 26 %. Therefore SGI is more preferable than EN31 for connecting rod.

Keywords ***– connecting rod, design optimization, analysis, CATIA.***

I. INTRODUCTION

In the cotton mill industry the ginning machine is a major constitute of the production. This machine has various mechanisms and between those the connecting rod and wrist pin are the heart of the ginning machine. There is versatile problem of failure of connecting rod between motor shaft and ginning shaft. The connecting rod is used in a machine to convert the rotary motion into reciprocating or vice versa. As wrist pin connects the connecting rod to ginning shaft it also serves all vibrations, and it fails several times reduces the productivity. While performing operation some stresses are develop in connecting rod. The major stresses induced in the connecting rod are a combination of axial and bending stresses in operation. The axial stresses are produced due to 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.

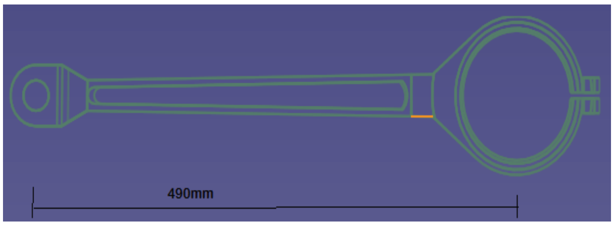

Fig.1:- Connecting rod line view

Ginning machine is used for separates seeds, hulls, and other foreign material from cotton. The ginning of cotton may be considered the second stage in textile production. After cotton has been picked in the fields, the seeds and other foreign material need to be removed before it can be spun into thread. It assembled with different components like frame, separating mesh, hub, gear box, lead screw, motor pulley, shaft pulley, cam shaft, connecting rod, wrist pin, ginning shaft. From all these components connecting rod is the heart of Ginning machine. During the survey it is observed that some ginning machines manufacturing industries uses a plus size of connecting rod i.e. the rectangular section. With this construction there are the problems arises during the working, to overcome some of its problems it needs to redesign the connecting rod with a different cross-section. Ginning machine connecting rod with I-section under design and analysis with different material with the help of FEA software is the motto of this study. For the different loading conditions Finite element analysis is done to determine maximum stress, maximum factor of safety and life of the component by using FEA software ANSYS 14.0.

II. ANALYSIS BY USING SOFTWARE

The next step after modeling is the FEA analysis of a connecting rod and wrist pin. The software used for this is ANSYS. The material given for the connecting rod is SGI.

The properties of the SGI material are given in ANSYS and the CATIA model is meshed using Quad (6 node) element type.

For existing connecting rod:-

The properties of SGI used are:

Density: 7.1g/cm^3

Thermal conductivity: 32 W/(m·K) ms
Tensile strength: 500 MPa
Young's modulus: 1.72x10^{5}MPa
Poisons ratio: 0.26

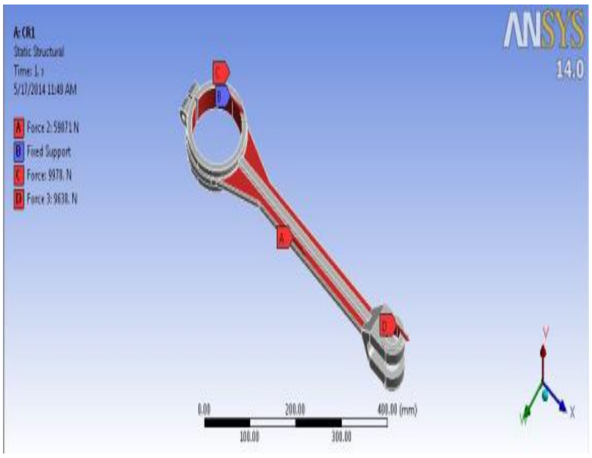

Fig.2:- Load analysis of an existing connecting rod

As per working condition of the connecting rod in ginning and pressing machine, load is applied on a connecting rod. Load at big and small end is tensile while on shank it's a compressive.

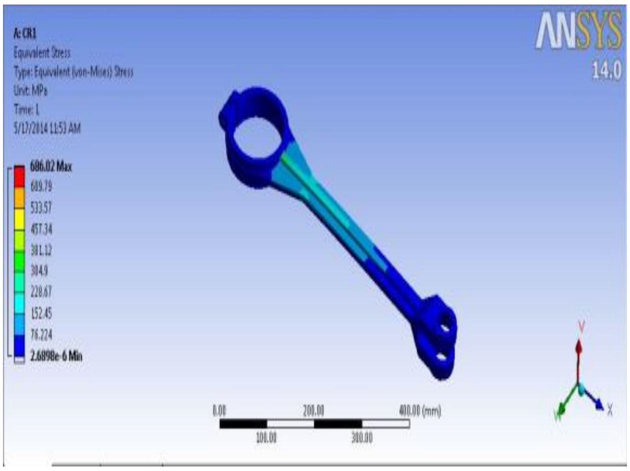

Fig.3- Stresses produce on an existing connecting rod

Above figure shows the stresses produce on the connecting rod and maximum stresses produce is at shank about 228 MPa.

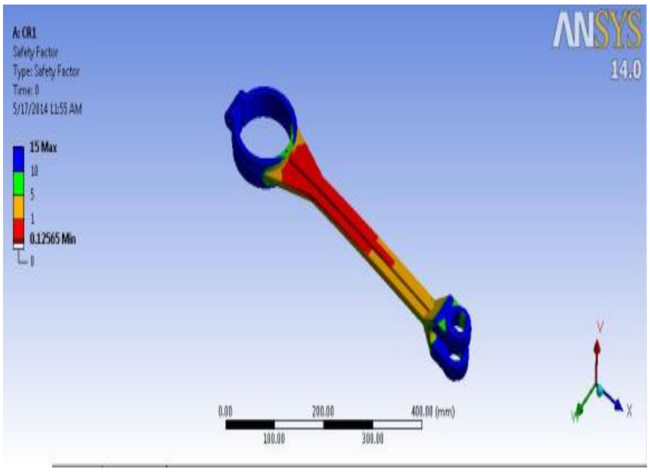

Fig.4- Factor of safety for an existing connecting rod

Maximum factor of safety found out from this analysis for this connecting rod is 15. And for the weakest part it's a 0.1256

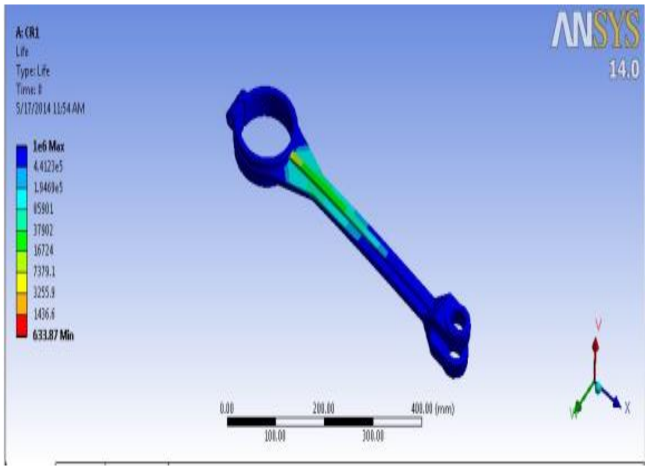

Fig.5- Life of a existing connecting rod in terms of no of cycles

By using fatigue tool, life of the connecting rod is found out. It ranges from 633 to 10^6 cycles.

For new designed connecting rod:-

Similar to existing rod, the new designed rod is also analyze by using ANSYS. As the working condition of the connecting rod in ginning machine is same as existing connecting rod, hence the load is applied is same as an existing connecting rod.

For SGI

Load at big and small end is tensile while on shank it's a compressive.

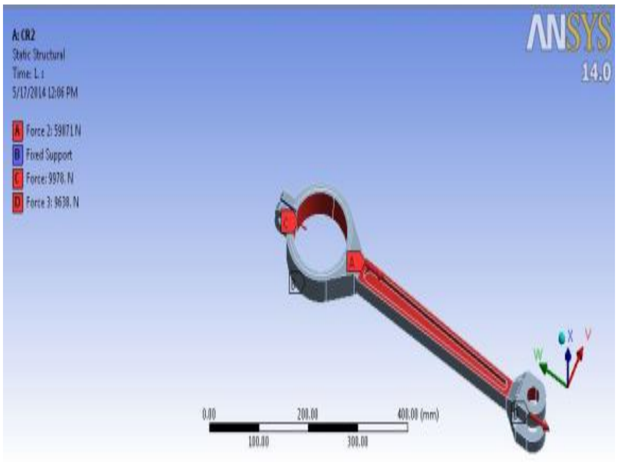

Fig.6:- Load analysis of new connecting rod

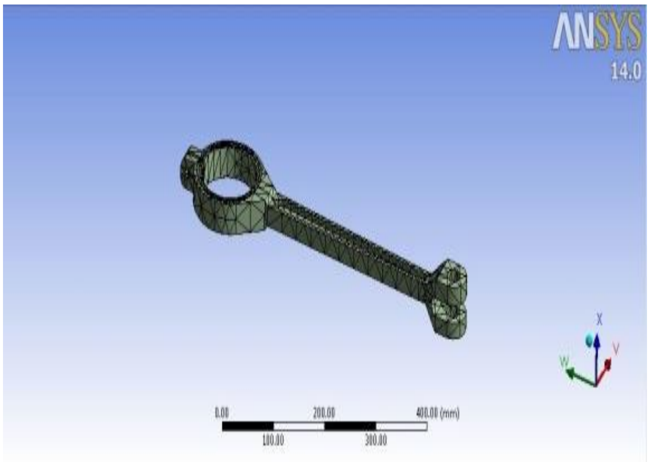

Fig.7- Meshing of new connecting rod

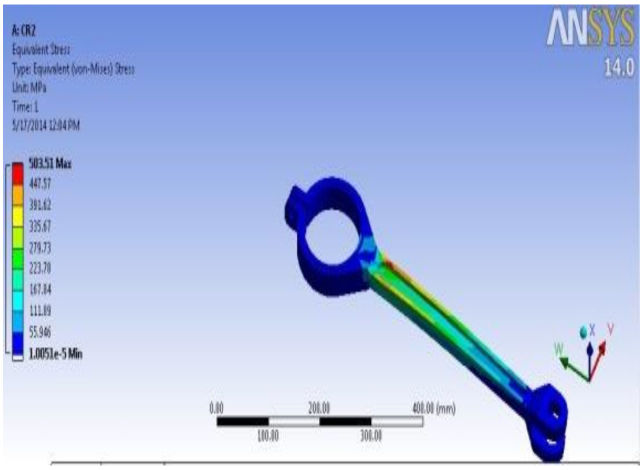

Fig.8- Stresses produce on new SGI connecting rod

Above figure shows the stresses produce on the connecting rod. Stresses produce ranges 1.005x10^{-6} to 503MPa. And maximum stress is at shank about 503 MPa.

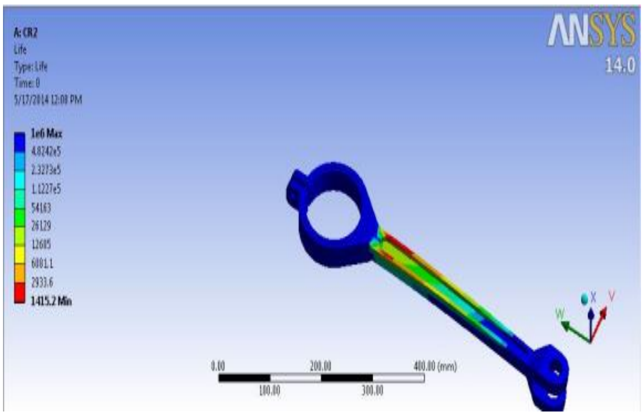

Fig.9:- Life of a new connecting rod of SGI in terms of no of cycles

By using fatigue tool, life of the connecting rod is found out. It ranges from 1415 to 10^6 cycles.

For EN-31

The properties of EN-31 used are:

Density: 7.81g/cm^3
Thermal conductivity: 46.6 W/(m·K) ms
Tensile strength: 750 MPa

Young's modulus: 2.15x10^5MPa
Poisons ratio: 0.28

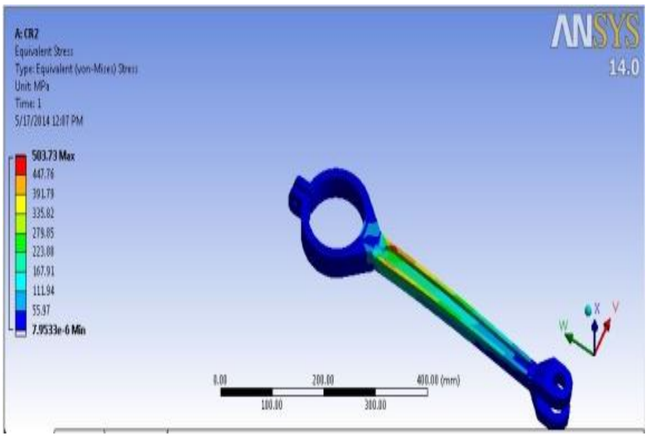

Fig.10:- Stresses produce on new connecting rod for En31

Above figure shows the stresses produce on the connecting rod. Stresses produce ranges $7.95x10^{-6}$ to 503MPa. And maximum stress is at shank about 503 MPa.

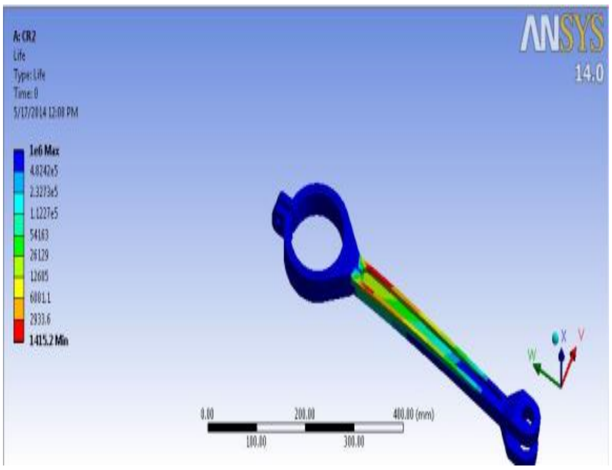

Fig.11- Life of a existing connecting rod in terms of no of cycles

By using fatigue tool, life of the connecting rod is found out. It ranges from 1415 to 10^6 cycles.

III OPTIMIZATION STATEMENT

Objective of the optimization task was to minimize the mass of the connecting rod under the effect of a load and material change corresponding to1440 rev/min. This requires some of the dimensions in the existing connecting rod to be maintained. These dimensions are discussed in detail.
Mathematically stated, the optimization statement would appear as follows:
Objective: Minimize Mass and Cost
Subject to:

- Tensile load = dynamic tensile load corresponding to 1440 rev/min.
- Maximum stress < Allowable stress.
- Equivalent stress amplitude < Allowable stress amplitude (for 106 cycles).
- Manufacturing constraints.
- Buckling load > Factor of safety (Recommended, 3 to 6).

IV WEIGHT REDUCTION

For cost reduction, weight reduction is the better technique. Also reduction in weight of the element affects on other parameters of the machines like efficiency and vibrations etc.
Mass of existing connecting rod is 4.5 kg

Mass of new SGI connecting rod,
m_1 = Mass of Big end + Mass of Shank + Mass of Small end + Mass of Bolt flange

$= [\pi/4(0.135)^2 - \pi/4(0.110)^2 x \ 0.04 \ x \ 7100]+[11(0.006)^2 x \ 0.357x \ 7100] + [\pi/4(0.065)^2 - \pi/4(0.026)^2 x0.062x \ 7100] + 0.1$

= 1.38+ 1.00 + 1.22 + 0.1

= 3.7 kg

So, the reduction in weight = $\frac{4.5-3.7}{4.5}$

= 0.17 i.e. 17%

Mass of new EN31 connecting rod,
m_1 = Mass of Big end + Mass of Shank + Mass of Small end + Mass of Bolt flange

$= [\pi/4(0.135)^2 - \pi/4(0.110)^2 x \ 0.04 \ x \ 7800]+[11(0.006)^2 x \ 0.357x \ 7800] + [\pi/4(0.065)^2 - \pi/4(0.026)^2 x0.062x \ 7800] + 0.1$

= 1.5+ 1.0 + 1.3 + 0.1

= 3.9 kg

So, the reduction in weight = $\frac{4.5-3.9}{4.5}$ = 0.13 i.e. 13 %

V. COST REDUCTION

For every application, there is a limiting cost beyond which the designer cannot go. When this limit is exceeded, the designer has to consider other alternative materials. In cost analysis there are two factors, namely, cost of material and the cost of processing the material into finished goods. It is likely that the cost of material might be low, but the processing may involve costly manufacturing operations. The cost of connecting rod manufactured from

EN-31 and by changing cross-section is estimated. For a fracture split able steel connecting rod, one can expect similar machining steps as for a casting connecting rod. As a result, it is a reasonable approximation to carry the machining costs from casting of the SGI and EN-31.

During the optimization of the connecting rod, the material is change from the existing SGI to EN-31. In perspective of the above discussion, this change in material brings down the production cost of the optimized connecting rod by about 14%, in comparison to the cost of the existing connecting rod. It should be noted that the cost has not been optimized; rather, it has been reduced. From this, it is clear that one important requirement to reduce machining cost is to select the proper material by studying its material properties. For cost reduction, the weight reduction is the better technique.

For cost reduction,

Cost of existing SGI connecting rod is

Cost of Casting – 69 Rs./Kg

Machining cost - 75 Rs./kg

(Facing + boring + drilling)

Total cost = 69x4.5 +75x4.5 = 310.5 + 337.5 = Rs. 648 for 1436 life cycle

Therefore, Total cost/cycle = 648/1436 = 0.4512

For new SGI connecting rod

Cost of existing SGI connecting rod is

Cost of Casting – 69 Rs./Kg

Machining cost _ 75 Rs./kg

(Facing + boring + drilling)

Total cost = 69x3.7 +75x3.7 = 255.3 + 277.5 = Rs. 532.8 for 1415 life cycle

Therefore, Total cost/cycle = 532.8/1415 = 0.3765

Cost saving for single connecting rod = 648-532.8 = Rs. 115.2 /-

Therefore,

Cost saving $= \frac{0.4512-0.3765}{0.4515}$

= 0.16 i.e. 16%

For new En31 connecting rod

Cost of existing SGI connecting rod is

Cost of Casting – 120 Rs./Kg

Machining cost - 88 Rs./kg

(Facing + boring + drilling)

Total cost = 120x3.9 +88x3.9 = 468 + 343.2

= Rs. 811.2 (for 1415-life cycle)

Therefore,

Total cost/cycle = 811.2/1415

= 0.57Rs./cycle

Cost change for single connecting rod =811 – 648

= Rs. 163 /-

Therefore,

Cost increment $= \frac{0.57-0.4512}{0.4515}$

= 0.26 i.e. % 26

From above calculations it is found that for new I –section connecting rod of SGI there will be cost reduction is 16%. And for new I –section connecting rod of EN31 there will be cost increment of 26 %.

VI. RESULT

From the analysis of the connecting rod and wrist pin the results are found out like below

For connecting rod

Table no.1:- Comparison for connecting rod from ANSYS data

Type of connecting rod	Equivalent Stresses (MPa)	Life of connecting rod (no. of cycles)	Factor of safety
Existing	$2.68x10^{-6}$ – 686	1436- 10^{6}	0.125-15
New SGI	$2.68x10^{-6}$ – 503	1415- 10^{6}	0.01- 15
New En31	$7.95x10^{-6}$ - 503	1415 - 10^{6}	0.711-15

From above table it is observed that equivalent stresses changes as design and material changes with its factor of safety. Also the life of new SGI and new En31 is same.

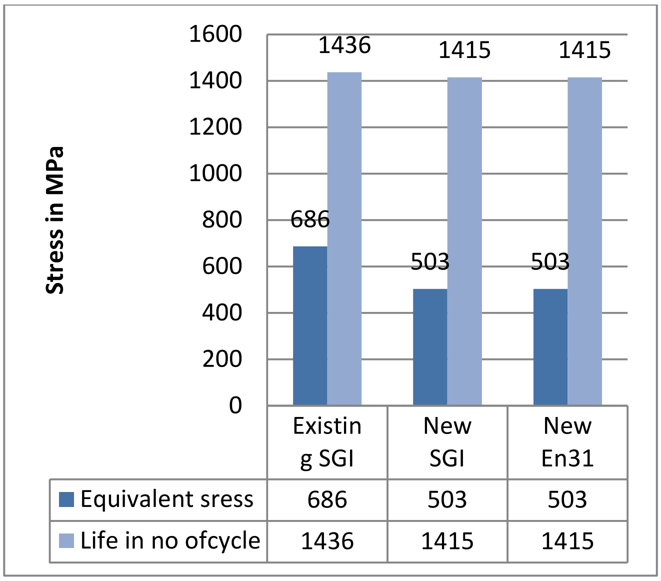

Fig.12- Stress & life relation for connecting rod of different material.

From this comparison it is found that, existing SGI have more life but more stresses compared with new design.

Table no.02:- Comparison for Weight reduction of connecting rod

Type of connecting rod	Weight of connecting rod in kg	Variation in weight w.r.t. existing rod in kg	% Reduction
Existing SGI	4.58	- --	- ---
New SGI	3.7	0.88(Decrease)	17
New EN31	3.9	0.68(Decrease)	13

From above table it is cleared that weight of the existing rod is more than the new designed rod for same and new materials for different cross section.

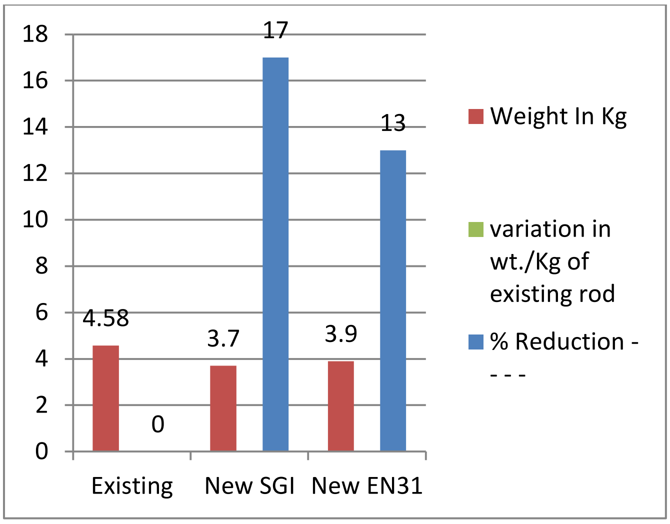

Fig.13:- weight comparison for connecting rod

From this graph it is found that, existing SGI have more weight than new SGI and new En31 connecting rod.

Table no.03:- Comparison for cost reduction of connecting rod

Type of connecting rod	Cost of connecting rod in Rs.	Cost of connecting rod in Rs./cycle	Variation in cost w.r.t. existing rod	% saving
Existing	648	0.4515	- --	- ---
New SGI	532.8	0.37	115(saving)	16
New En31	811.2	0.57	163(increase)	26(increase)

From above comparisons it is found that for new I –section connecting rod of SGI cost reduction is Rs.115 for new SGI rod whereas it increases for En31.

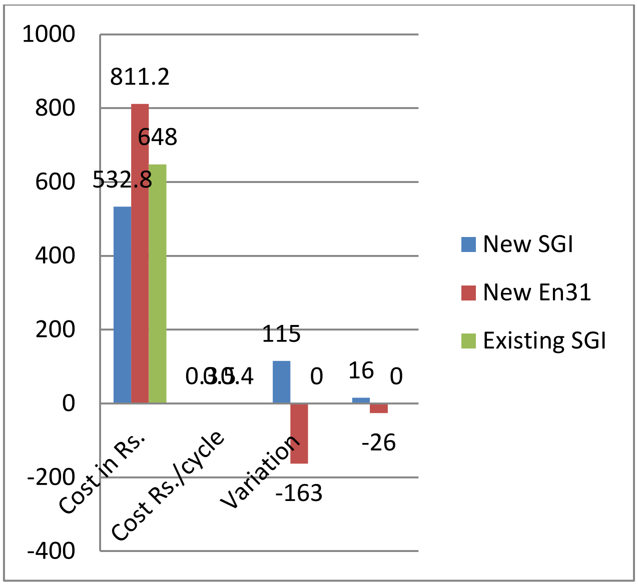

Fig.14:-Cost comparison

VII. CONCLUSION

It has been observed that by adopting I- Section connecting rod is more suitable than rectangular cross-section. The shank of the connecting rod having uniformly distributed load and the I-section can sustain more load variations than old design. There is considerable difference in the structural behavior of the connecting rod between axial fatigue loading and service operating condition. There are also differences in the analytical results obtained from fatigue loading and the results from software ANSYS.
Optimization performed to reduce weight and manufacturing cost. Cost is reduced by changing the cross-section of the connecting rod. While reducing the weight, the static strength, fatigue strength, and the buckling load factor were taken into account. Fatigue strength is the most significant factor (design driving factor) in the optimization of this connecting rod. The optimized geometry is 17% lighter whereas cost saving is 16% with SGI material. In spite of that higher life cycle En31 connecting rod is not preferable since it increases the cost of the component. So, it is conclude that the SGI new designed rod is the optimized rod.

ACKNOWLEDGMENTS

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