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MODELING & FINITE ELEMENT ANALYSIS OF TWO WHEELER CONNECTING ROD

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ABSTRACT

Connecting rod is the vital part of an I.C.Engine. It is designed to withstand stresses from the combustion and movement of the piston. The purpose of a connection rod is to provide fluid movement between pistons and a crankshaft. When building a high performance engine, great attention is paid to the connecting rods. The most effective feature of a connecting rod is that it should be of uniform shape and lighter in weight. The main purpose of this paper is to analyse the stresses developed in connecting rod of four stroke petrol engine under static loading conditions. And then look forward for weight reduction along with material optimization. The model of the connecting rod is developed using CATIA V5 (dimensions are measured from Hero Splendor 100cc bike connecting rod) and ANSYS is used for stresses analysis by simulation (this method is also known as Finite Element Analysis by simulation). This is the cost and time effective method of analysis. Al 360 and Carbon steel are two material considered as the optimizing material.

Keywords: *ANSYS, CATIA V5, FEA, Connecting rod.*

I. INTRODUCTION

Connecting rod is a major link of an I.C.Engines which connects the piston and the crankshaft together and helps to convert the reciprocating motion of the piston into rotatory motion of the crankshaft. The main feature of the connecting rod is that it should be able to withstand the stresses from the combustion and the movement of the piston along with maintaining the uniform shape and light weight characteristics. Many research work have been carried out for material optimization, weight reduction and cost reduction. B.T. Ramesh et al [1] studied Analysis and Optimization of Connecting Rod with Different Materials. They explained that selection of connecting rod for good performance of engine is very difficult. Based on which the High Strength Carbon Fibre connecting rod was compared with connecting rod made up of Stainless Steel and Aluminium Alloy. The analysis was carried out for weight reduction and for design modification of the connecting rod in ANSYS software. PatilGajendra et al [2]studied Harmonic Analysis of Connecting Rod Using ANSYS. The material SS-304 is taken to design a connecting rod and then the harmonic analysis is carried out in ANSYS 14.0 considering loading only at single frequency during analysis. The harmonic analysis was used in this problem because of cyclic load acting on the small end of connecting rod. Mr. C.Shubham [3]studied Thermal and Structural Analysis of Connecting Rod of an I.C. Engine. Connecting rod of two wheeler was designed by analytical method and the physical design was created in CATIA V5. Thermal analysis and structural system at

IJARSE
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particular loading condition were performed on ANSYS Workbench 14.5.Two material were taken in consideration i.e. structural steel and Aluminium 360 as optimizing material. Vishwakarma Anil Kumar et al [4] worked on Study and Analysis of Connecting Rod Parameters Using ANSYS. Geometry design of a connecting rod prepared on solid work and analysis is carried out through ANSYS 16.0. The analysis of von-mises stress and strain, maximum shear stress is analysed at both the ends, one end on loading while other restrained.N. Rakesh et al [5] studied Fatigue Analysis of Composite Connecting Rod, two material are taken in consideration against carbon steel (i.e. aluminium alloys and composite material called Glare. The parametric design is prepared in Solid works 3D Modeling software and the analysis fatigue strength is carried out in ANSYS workbench. The new material is found out to be less in weight and less expensive than that of the stock material carbon steel. Wable Satish et al [6] studied Analysis of Stresses Induced in Connecting Rod of Two Wheeler Engine, the main objective of the project is the weight optimization of a connecting rod in an automobile engine. He used two material 16MnCr5 (Carbon steel) and aluminium MMC to design the connecting rod and analysed for the stresses and deformation induced in both the connecting rod.Kumar P.S. et al [7] studied Buckling Analysis and Shape Optimization of Connecting Rod using FEA, they found out that the connecting rod is subjected to various complex loads of periodic changes: power thrust from piston pin, high tensile load due to inertia and high compression load due to compression of fuel, whereas bending stress caused by the thrust and by centrifugal effects. Their investigation also includes that buckling analysis of connecting rod made up of forged steel used in SUZUKI SPRINT1.0L engine. They concluded that buckling analysis, the stresses in each loading conditions were studied and the cross-sectional area where excess material can be removed were decided.D.R. Bhandre[8] studied Experimental Analysis of Connecting Rod Hero - CBZ using FEA Software, the connecting rod used is made of SCM 415 whose dimensions are measured using Vernier calliper and screw gauge. The 3D model was developed in Creo and then imported in ANSYS work bench 13.0 to determine the stresses and strains for given loading condition. The experimental results were compared with the theoretical results. To improve the life of the connecting rod small changes in the neck radius were made. As a result the weight was optimized along with reduction in cost of the connecting rod. Prof.Shinde G.V. et al [9] studied Stress Analysis of Connecting Rod using FEA, the main motive of this paper is to analyse for the static stress developed in connecting rod. The parametric model was prepared in Pro-E 2.0 and FEA was carried out in ANSYS workbench. The load on the connecting rod were obtained as a function of crank angle. Y.T. Raviraj et al[10] studiedAnalysis of Connecting Rod Used in Two Wheeler under Static Loading by FEA, in the study connecting rod is replaced by materials ASTM A216 GR WCB and Aluminium 360. The analysis was carried out with ANSYS 15.0 by applying the pressure at the piston pin end whereas the crank end fixed. M. Sachidhanandam et al [11] studied Compression of Two Different Materials for Connecting Rod Using ANSYS, in the study the modeling of connecting rod is developed using CATIA V5/R20. They concluded that the design parameter of connecting rod with modification gives sufficient improvement in the existing results. The weight of connecting rod for forged steel is reduced as compared with carbon steel. Sharma Manoj et al [12] studied Optimization of Connecting Rod with the Help of FEA, a connecting rod of Mahindra jeep CJ-340 was considered which is made of Al360. PEEK was taken as optimizing material. The model was designed in PRO-E wildfire 4.0 and analysis was carried out in ANSYS 11.0. The parameters like von-mises stress, equivalent strain and displacement was obtained which showed reduction in weight (approx. 46.7%) and improvement in

IJARSE
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strength (approx. 23.76%) . Mr. Ramani[13] studied FE-Analysis of Connecting Rod of I.C. Engine by Using ANSYS for Material Optimization, the main idea of this study is to do analysis of connecting rod and get idea of stress producing during compressive and tensile loading. This study has contain by two subjects, first, load and stress analysis of the connecting rod, and second, optimization for weight reduction. This paper concluded that the connecting rod can be designed and optimized under a load range comprising compressive load as one extreme load and tensile load.

Nachimuthu A.K. [14] studied Analysis and Optimizing Connecting Rod for Weight and Cost Reduction, in this paper C70 steel is used and compared against C45 steel. The connecting rod was subjected to cyclic load composing of compressive gas load and the dynamic tensile load at different speed with various crank angle. Sushant et al[15] studiedDesign and Comparative Performance Analysis of Two Wheeler Connecting Rod Using Two Different Materials Namely Carbon 70 Steel and Aluminium 7068 by Finite Element Analysis. In this paper the design was made by analytical method and then the physical model is prepared in pro-e wildfire 5.0. And the structural system of the designed connecting is analysed with the help of FEA. The von-mises stresses and strain, shear stress and bending stress were analysed under particular loading condition using ANSYS workbench 14.0.S. Khan et al [16] studied Modeling and Analysis of Connecting Rod of Two Wheeler (Hero Splendor). The main objective of study was to explore weight reduction opportunities for a production forged steel connecting rod by using finite element analysis method. This was entailed by performing a detailed load analysis. The CAD model was analysed in ANSYS, FEMFAT and OPTISTRUCT. Sayeed et al [17] studied Design, Fabrication and Analysis of a Connecting Rod with Aluminium Alloys and Carbon Fibre. Broken connecting rod of LML Freedom is considered. In the study, the connecting rod is prepared in Pro/Engineer, forces are calculated, analysis is done on the connecting rod using materials aluminium 6061, aluminium 7075, aluminium 2014 carbon fibre 280 gsm bidirectional, and analysis is also done for the assembly of piston, connecting rod and crankshaft. Performed well. Then prototype of the connecting rod is made using direct machining for aluminium alloy and hand layup method for carbon fibre connecting rod. The connecting rod were successfully tested in ideal condition and also by changing gears at regular interval of time of the bike and three of the rods performed to the level of expectation as they should have performed. Gotiwale Deepak G. et al [18] studied Design of Connecting Rod for Light Weight Using C70S6 Material. The paper is completely based on an over view design of connecting rod for its weight reduction. The fatigue testing was carried out for failure or its life cycles and then analysed with the FEA for tensile and compressive loading for both small end and big end keeping one end restrained while other under loading. Kumar Amit et al [19] studied Dynamic Analysis of Bajaj Pulsar 150cc Connecting Rod Using ANSYS 14.0. In this study the connecting rod was modulate and simulated for the dynamic analysis by using CATIA software for modelling-design of connecting rod and ANSYS 14.0 for dynamic analysis. Available high strengthen alloy (i.e. 20CrMo, 30CrMo, 42CrMo) is used for the connecting rod of Bajaj pulsar 150cc for the weight reduction to reduce moment of inertia. B. Anusha et al [20] studied Modeling and Analysis of Two Wheeler Connecting Rod by Using ANSYS. In this paper a static analysis is conducted on a connecting rod of a single cylinder 4 stroke engine (Hero Splendor). The design was formulated in PRO/E and the simulation was carried out in ANSYS workbench at particular loading condition. L. Krishna et al [21] studied Design and Analysis of Connecting Rod Using Forged Steel. The analysis of CAD mode is carried out in ANSYS Workbench for von-

IJARSE
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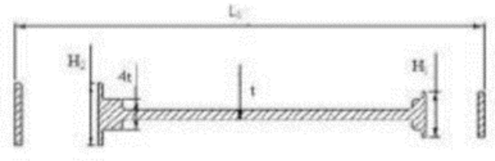
ISSN (P) 2319 - 8346

mises stress, and strain, deformation. Factor of safety and weight reduction. Fatigue analysis was done for life time analysis. As a result the modified forged rod steel has improved no of life cycles. Malleshwara G. Naga [22] studied Design Optimization and Analysis of a Connecting Rod Using ANSYS. The main aim of the paper was to explore for the weight reduction opportunities in the connecting rod of the I.C engine by examining the connecting rod with various materials (i.e. genetic steel, aluminium, titanium and cast iron) which was entitled by detail load analysis. The static load was considered for the analysis and the design optimization was carried to minimize the deflection. The design optimization was done by considering the theory pressure is inversely proportional to that of area. To increase the area of the connecting rod the fillet radius value were changed. M.N. Mohammed et al [23] studied Failure Analysis of a Fractured Connecting Rod. The main motive of this paper is to analyse for the failure of the connecting rod. The failure analysis was carried by FEA software and MSC patran software. Under tension loading and compressive loading the von-mises stress was calculated and compared.Shaari M.S. et al[24] studiedDesign of Connecting Rod of An Internal Combustion Engine: A Topology Optimization Approach. The main objectives of this paper were to develop structural modeling, finite element analysis of the model and the optimization of the connecting rod for robust design. The structure of connecting rod was designed, utilizing SOLIDWORKS software. Finite element modeling and analysis were performed using MSC/PATRAN and MSC/NASTRAN software. Linear static analysis was carried out to obtain the stress/strain state results.



II. BASIC EQUATIONS USED

H1 –Height of Big end connected to crankshaft

H- Height of Small end connected to piston*Fig 1: Design parameter of con rod.*

Ls- I section length

L - Pitch length

L1- Total length

t - Thickness

Required design parameters are taken from Hero Splendor 100cc two wheeler form the manufacture "HERO MOTOR" and the specifications are as follows:

Table 1: Engine Specifications

Hero Splendor	
Type of engine	Single cylinder, four stroke, air cooled, petrol engine.
Maximum power out put	5.5 kW (7.5 ps)@8000 rpm.
Maximum torque	7.95 Nm@8000 rpm
Compression ratio	9:1
Bore x Stroke	50 x 49.5
Displacement	97.2 cc.

IJARSE
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A connecting rod is critical machine member which is subjected to compressive and tensile forces. The compressive forces acting on the connecting rod are higher than that of the tensile force. To withstand the enormous compressive forces the cross-section of the connecting rod is designed so that it withstands the force and the Rankine formula taken in consideration while designing a connecting rod.

Rankine's Gordon formula:

$$F\ about\ x - axis\ = \frac{\sigma c\ A}{(1 + a\ (1/Kxx)2\ )} \qquad (1)$$

To find thePressure of HERO HONDA 100 cc engine the following entity are considered:-

Density of Petrol (C8H18) = 737.22kg/m^3 = 737.22E-9 kg/mm^3

Molecular Weight of Petrol (M_w) = 114.228 g/mole

Temperature = 60^{0}F

Mass = Density × Volume = 737.22E-9×97.2E3 = 0.07165 Kg

From Gas Equation*:*

$$PV\ = Mrt \qquad (2)$$

$$r\ =\ R/Mw\ =\ 8.3143\ E3/114228E\ -3\ \ =\ 72.786 \qquad (3)$$

Where,

R is universal gas constant = 8.314E3,

Mw is molecular weight of petrol,

III. RESULT AND DISCUSSION

The properties of the optimizing material and the design parameter of connecting rod is given in Table 2 and Table 3 respectively. The 3D model of the existing cast iron connecting rod and optimised connecting with Al 360 and carbon steel is prepared in CATIA v5. The analysis is carried out in ANSYS Workbench 12.0.3D design of cast iron connecting rod is prepared as per the parameters measured from the specimen with the help of Vernier calliper, inner-diameter calliper and outer- diameter calliper. For the optimised connecting rod with Al 360 and carbon steel the thickness is considered to be the same as per the analytical calculation using Rankine formula. Hence, one design is prepared by optimising the parameters within the limits (taking in consideration pressure is inversely proportional to area). The 3D design of specimen connecting rod is presented in Fig 2: and the 3D design of the optimised connecting rod is shown in Fig 3:The comparison of FEA analysed parameters are presented in the Table 5 and the weight of the connecting rod is presented in Table 4:

Table 2: Properties of the materials.

Properties of materials	Cast iron	Carbon steel	Aluminium 360
Young's modulus (E)	170 GPa	210 GPa	71 GPa
Poisson's ratio	0.3	0.3	0.33
Density	7196 Kg/m^3	7833 Kg/m^3	2630 Kg/m^3
Tensile strength	200 MPa	485 MPa	300MPa

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Table 3: Connecting rod parameters.

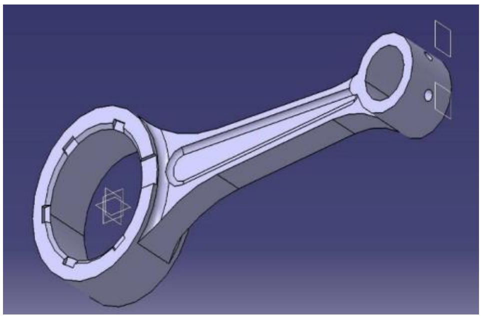

Fig 2: 3D model of existing connecting rod

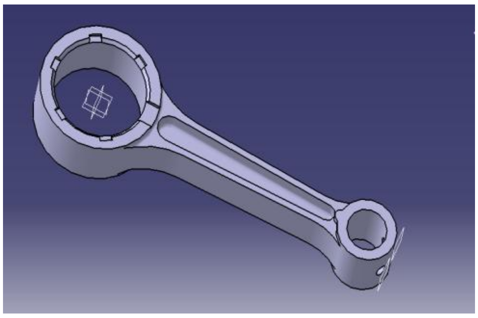

Fig 3: 3D model of optimized connecting rod

3.1. Finite Element Analysis

ANSYS workbench 12.0 is used for analysis of the stress like von-mises stress, maximum principle stress, shear stress, equivalent elastic strain and total deformation. Finite element analysis (FEA) is also referred as finite element method (FEM) is a numerical method for solving engineering and mathematical physics. A large problem is subdivided into smaller, simpler parts that are called finite elements.The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses vibrational methods from the calculus of variations to approximate a solution by minimizing an associated error function.The method yields approximate values of the unknowns at discrete number of points over the domain.

The first step of the analysis is creating the mesh model of the structure system and then load and boundary condition are fixed. Pressure of 15.5 MPA is applied to the small end keeping big end fixed and then the FEA analysis on the structure system is carried out for von-mises stress, maximum principle stress, shear stress, equivalent elastic strain and total deformation

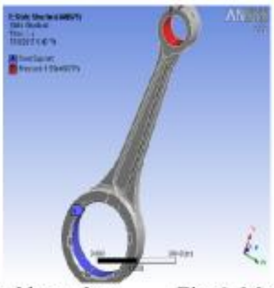

Fig 4: Mesh model of Fig 5: Load and boundary Fig 6: Mesh model of Fig 7: Load and boundary

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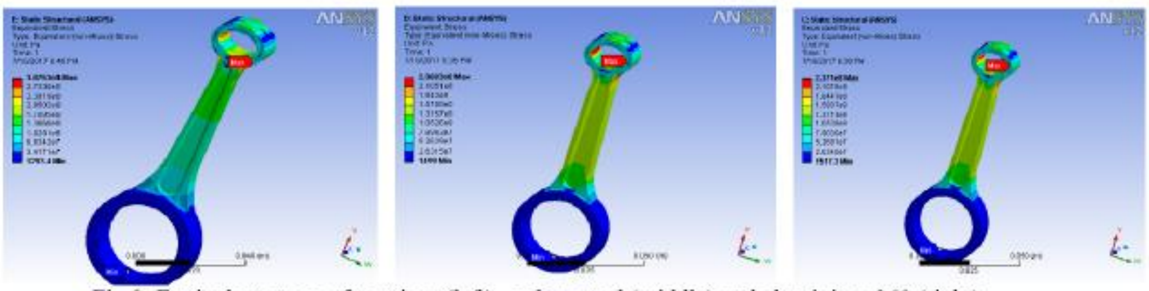

Fig 8: Equivalent stress of cast iron (left), carbon steel (middle) and aluminium 360 (right).

IJARSE
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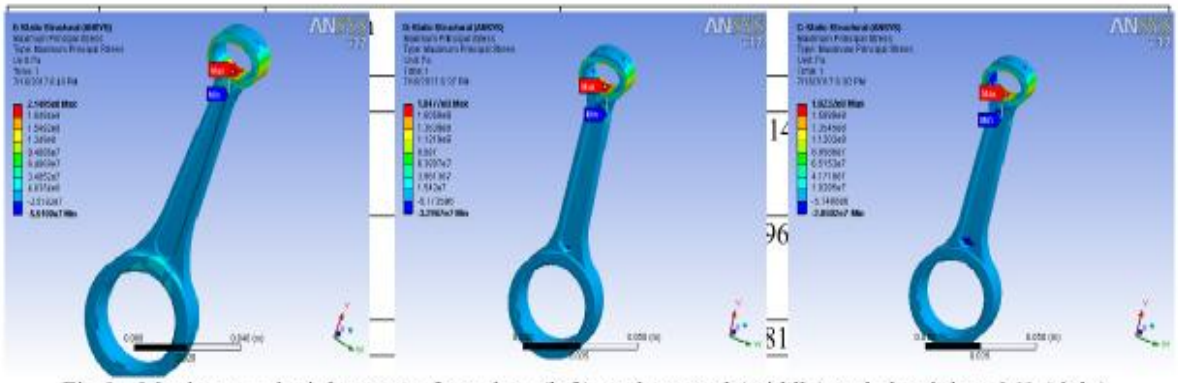

Fig 8:- Maximum principle stress of cast iron (left), carbon steel (middle) and aluminium 360 (right).

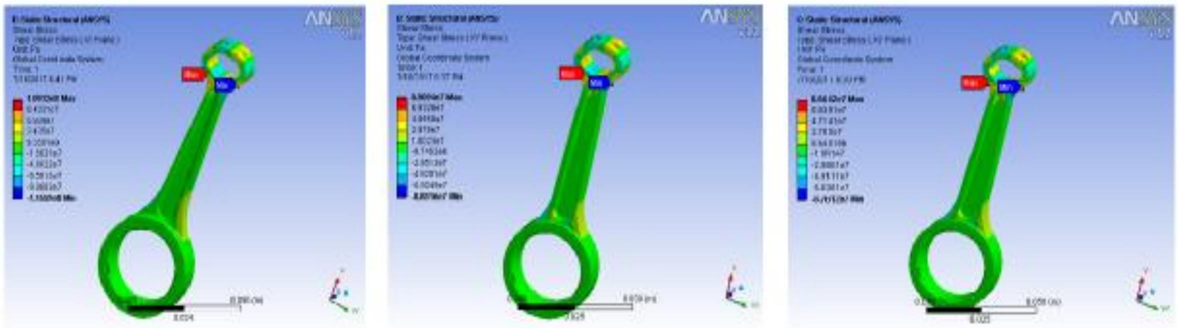

Fig 9:- Shear stress of cast iron (left), carbon steel (middle) and aluminium 360 (right).

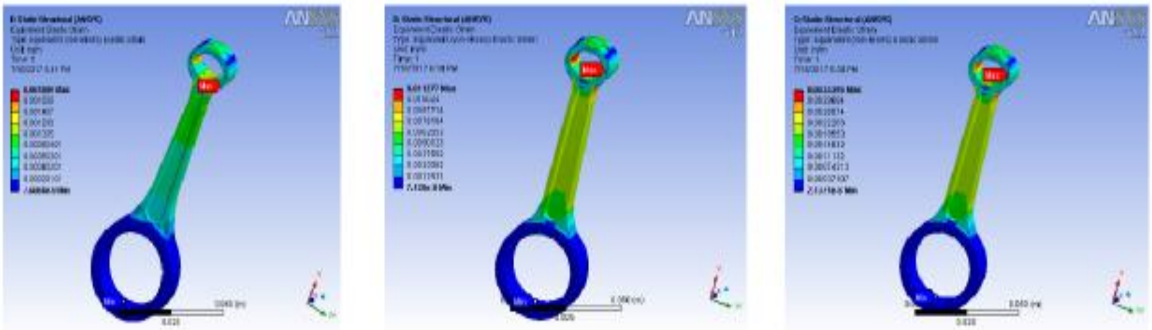

Fig 10:- Equivalent elastic strain of cast iron (left), carbon steel (middle) and aluminium 360 (right).

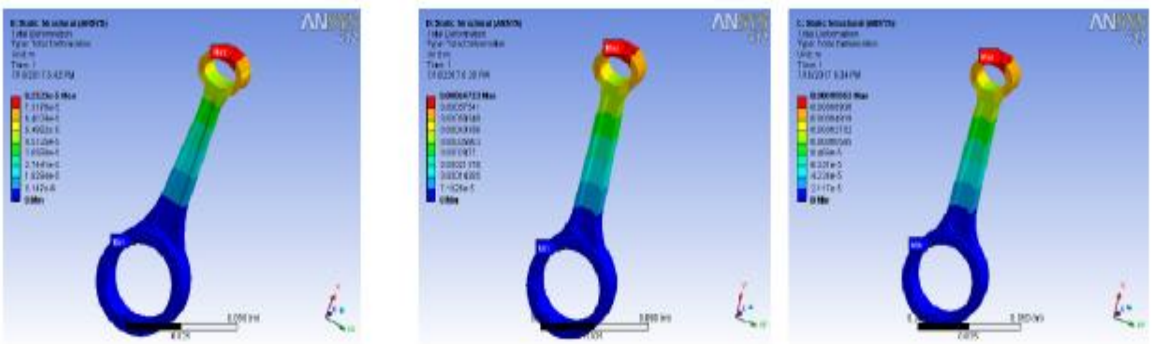

Fig 11:- Total deformation of cast iron (left), carbon steel (middle) and aluminium 360 (right).

IJARSE
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ISSN (P) 2319 - 8346

Table 4: Weight of the connecting rod.

Material	Conrod weight(Kg)
Cast iron	0.12056
Carbon steel	0.13123
Al 360	0.04189

Table 5: comparisons of the analysis result

Sr.No	Analysis	Cast iron		Carbon steel		Al 360	
		Max	Min	Max	Min	Max	Min
1	Equivalent (von-mises) stress	307.53	0.001293	236.83	0.001499	237.1	0.0015173
2	Maximum principle stress	214.95	-55.199	184.77	-32.967	182.32	-28.582
3	Shear stress	109.32	-115.59	89.094	-88.816	85.642	-87.612
4	Equivalent (von-mises) elastic strain	1.809E-9	7.6084E-15	1.1277E-8	7.138E-14	3.3395E-9	2.137E-14
5	Shear elastic strain	1.672E-9	-1.7679E-9	1.1031E-8	-1.0996E-8	3.2085E-9	-3.2824E-9
6	Total deformation	8.2323E-5	0	0.0006473 3	0	0.0001905 3	0

IV. CONCLUSION

Al 360 has been proven to meet the requirement so wisely over carbon steel and cast iron. All the three material definitely have fulfilled the requirements but Al 360 is a bit outstanding in case of stress as well as weight reduction is achieved over cast iron and carbon steel. While comparing cast iron connecting rod with the Al 360 rod, we get the maximum von-mises stress developed in cast iron is 307.53 MPa and in Al connecting rod is 237.1MPa in response to fixed load at small end of 15.5 MPa. In percentage there is reduction of equivalent stress of about 23%. And in context of weight there is reduction of about 35% in weigh of optimised aluminium 360 connecting rod than that of the cast iron connecting rod. As Aluminium have shown reduction in overall weight than that of cast iron connecting rod. This means lesser weight of the connecting will require lesser piston pressure, lesser piston pressure will burn lesser fuel. Directly or indirectly increased fuel economy is achieved when we use light weight connecting rod. Also the weight of the connecting rod will have impact on the cost of the connecting rod. Lighter connecting rod will have lesser price than that of heavy connecting rod material.

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IJARSE
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