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A COMPARATIVE ANALYSIS OF MATERIALS FOR MANUFACTURING CONNECTING ROD

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Abstract

The connecting rod is the intermediate part between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into the rotary motion of the crank. In an IC engine maximum stressed component is connecting rod. A connecting rod act as a lever arm by transmitting motion from the piston to the crankshaft. In this, we studied the failure and strain analysis of the connecting rod beneath extraordinary loading situations by way of the usage of various materials, in order to get better material and update the same old material, which is used to make connecting rod in every engine. With the intention to give an explanation for that in regular loading circumstances, an advanced stress and deformation evaluation is completed through ANSYS. For this reason, this study targets to carry out for the deformation, and stress analysis of the connecting rod of various materials. Based on this we can get a better material for the manufacturing of connecting rod. For a good way to get the solution the geometric model of the connecting rod had been created in the software program (CATIA V5) and Dynamic analysis is carried out for determining equivalent stress, maximum and minimum principal stress, and total deformation calculated under loading conditions of compression at the big end and small end of the connecting rod.

Keywords: *Connecting Rod, Analysis of Connecting Rod, CATIA, ANSYS.*

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1. INTRODUCTION

The connecting rod is the rigid element that connects the piston to the crank, or crankshaft, in a reciprocating engine. Connecting Rods form a simple mechanism that converts reciprocating motion into rotating motion together with the crank. Connecting Rod transfers the motion of the piston to the crankshaft for the crank and functions as a lever arm. It is required to transmit compressive and tensile forces from the piston to the crankshaft for the crank. In its most common form, in an internal combustion (IC) engine, it allows pivoting on the piston end and rotation on the shaft end.

The precursor of the connecting rod is the mechanical link used by Roman watermills. The earliest known example of this has been found in the late 3rd-century Hierapolis sawmill in Roman Asia (modern Turkey) and 6th-century sawmills in Ephesus in Asia Minor (modern Turkey) and Gerasa in Roman Syria. The crank and connecting rod mechanism of these machines transformed the rotating movement of the water wheel into the linear movement of the saw blades. [1]

Connecting rods can be of two types - H-Beam or I-Beam. H-Beam can handle more stress without bending and is used in high-power engines. I-Beam is both lightweight and strong, but the material used limits its capacity to handle loads.

The objective of the present work is to design and analyse the connecting rod made of different alloy. Steel materials are used to design the connecting rod. In this project the material (forged steel) of connecting rod was replaced with beryllium alloy, titanium alloy, aluminium boron carbide and alloy steel. The connecting rod was created in CATIA software. The model is imported into ANSYS workbench 16.0 for analysis. After analysis, a comparison is made between the existing steel connecting rod and the alloys in terms of weight, deformation, stress and stiffness.

After careful consideration of the literature review, the methodology used is the same as the papers considered. So, the methodology is validated.

Following is the methodology used for finding out the results for the connecting rod.

2. Selection of Material

After careful consideration, following materials are considered for our analysis. The materials along with their mechanical properties are as follows:

BEI220H, Titanium alloy (Ti6al4V), Aluminium 6061 BORON Carbide, Alloy Steel (8620).

Table 1. Materials Selected along with their properties

S.N.	MATERIAL	DENSITY	YOUNGS MODULUS	POISSONS RATIO
1	BEI220H	1.844 g/cc	3.0375e11 Pa	0.070-0.18
2	Titanium alloy (Ti6al4V)	4429 kg/m3	1.04e11 N/mm2	0.31
3	Aluminium 6061 BORON Carbide	7.87 g/cc	200	0.29
4	Alloy Steel (8620).	7700 kg/m3	190-210	0.27-0.30

2.1 Theoretical calculation for connecting rod

Theoretical calculation for connecting rod Calculations were made by considering a 150cc Engine of Bajaj pulsar, Followed by its specifications.

Specifications Engine type = Air-cooled 4-stroke.

Bore = 58 mm

Stroke = 56.4 mm

Displacement = 149.01cc

Maximum Power = 15.1ps @ 9000 rpm

Maximum Torque = 12.45 Nm @ 6500 rpm

Compression Ratio = 9.5 ± 0.5:1

Density of Petrol (C8H18) = 737.22 kg/$m3$ = 737.22× 10−9kg/ mm3

Auto ignition temperature = 280º C=536º F =553.15º K

2.2. A. Calculation of Maximum Pressure

Mass = Density x volume

= 737.22× 10−9 × 149.01× 103

= 0.1098531522 kg

= 0.11423 kg/mole

From gas equation,

PV = $m \times Rspecific \times T$

Where,

P = Gas Pressure, MPa

V = Volume

m = Mass, kg

T = Temperature, °K

$Rspecific$ = Specific gas constant

$Rspecific$ = R/M

= 8.3144/0.114228

$Rspecific$ = 72.788 Nm/kg K

P = ($m \times Rspecific \times T$)/V

P = (0.18356 x 72.788*103 x 553.15)/(149.01*103)

= 29.67 ~30 MPa

Calculation of analysis is done for maximum Pressure of 30 MPA and 15 MPA.

2.2. B. Calculation for Total Force

Total Force acting F = $FP - FI$

Where,

FP= force acting on the piston

FI= force of inertia

FP = (π/ 4) ×D 2 ×Gas pressure

Where,

D = Bore Diameter

FP = (π /4) × (58)2 ×15

= 39631.19133 N FI

= m × ω2 × r ($cos\emptyset$ + ($cos2\emptyset$)/n)

Where,

m = Mass of the reciprocating part

ω =Angular speed of crank

= (2πN)/60

= (2π9000) /60

= 942.47 rad/sec

n = length of connecting rod (l) / crank radius(r)

= (2 × $stroke$)/($stroke$/2)

= 112.8/28.2

∴ n = 4

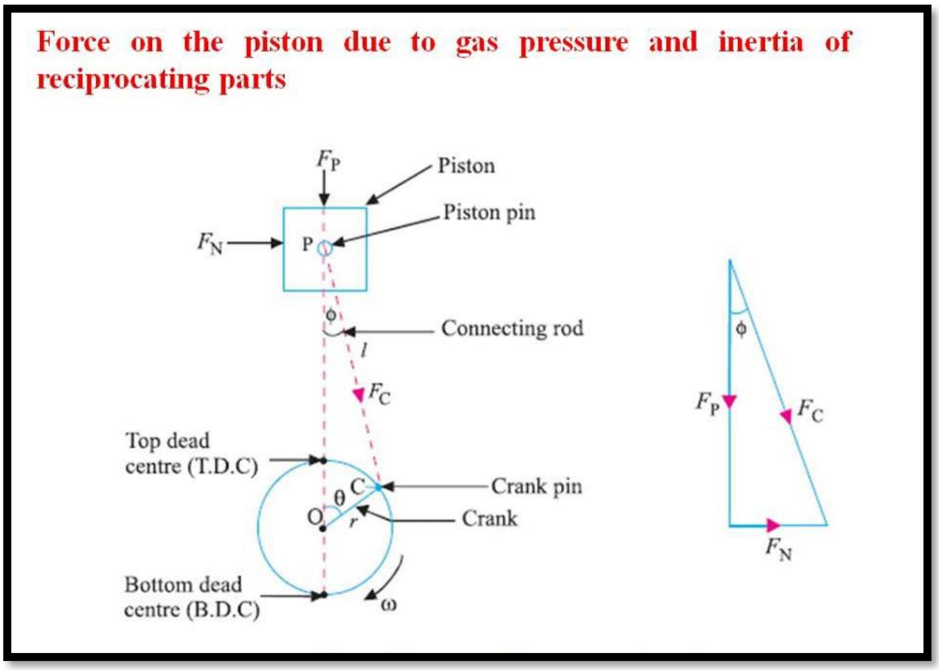

Figure 1. Force on the piston due to gas pressure and inertia of reciprocating parts

Refer to figure.1 for ∅,

The maximum gas load occurs shortly after the dead-centre position at

∅ = 3.3° cos (3.3) = 0.9983 ≅ 1

On substituting these

FI = m × ω2 × r ($cos\emptyset$ + ($cos2\emptyset$)/n)

∴FI = 0.10985 × (942.47)2× 0.0282× (1 + 1 /4)

=0.10985 ×888249.70× 0.0282 ×1.25

=3439.49 N

F = FP - FI

=39631.19133-3439.49

=36191.70133 N

3. Modelling of the Connecting rod

Connecting rod of the Bajaj pulsar 150 Four-stroke single cylinder engine is selected for the current examination. As per the dimensions, the connecting rod model is created by utilizing Catia P3 V5. The modelled version of the connecting rod is shown in the figure.

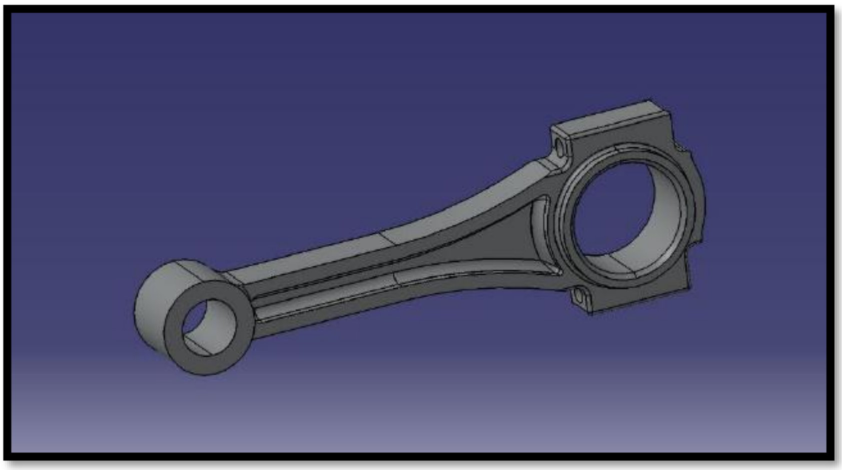

Figure 2. CAD model of Connecting Rod

Initially the inner and outer ends i.e., the piston end and the crank end diameter are drawn. Draw smaller holes of connecting rod on bog end diameter side. Then the small end and the big end diameter circles are padded respectively. After completion of padding of both big and small the stem of the connecting rod is created. The constructed stem is padded. After finishing the padding, the stem pocket is applied to one side of the stem, mirror extent pocket is given in order to pocket the other side of the stem. Edge fillets are assigned at the desired locations. Thus, the required connecting rod is modelled using Catia P3 V5 software.

4. ANALYSIS OF CONNECTING ROD IN ANSYS

The basic idea of the Finite Element Method is to find the solution to complicated problems in a relatively easy way. The Finite Element Method has been a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis of automotive, aircraft, building, defence, and missile and bridge structures to the field of analysis of dynamics, stability, fracture mechanics, heat flux, fluid flow, magnetic flux, seepage, and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modelled with relative ease. To do the ANSYS we have chosen the workbench of 16 version. Then importing the saved connecting rod model to the workbench by saving it as a part file, as it is easy to import easily for doing meshing and further process. Then go to static structural and insert the data and type of material used for analysis. Go to engineering data and give the density, Poisson's ratio and young's module values. Next, go to geometry and import the part file of connecting which was saved before in Catia P3 V5 software. Then double-click on the model now the actual workbench window opens.

4.1 Mesh

Meshing is an important part of the engineering simulation process where complex geometries are divided into small and simple elements. It influences the convergence, accuracy and speed of the simulation. It helps in the Finite Element Analysis of a continuous body. For this case, Automatic mesh gives fewer numb nodes and elements. With the assistance of Hex-Dominant mesh, it gives a greater number of nodes yet a smaller number of elements; because of this the complexities to tackle the problem will rise. The Tetrahedron mesh method gives proper mesh results as shown in figures 3 & 4. Choosing the Tetrahedron method with picking improved sizing of mesh, we got the maximum number of nodes = 55772 and elements = 37833.

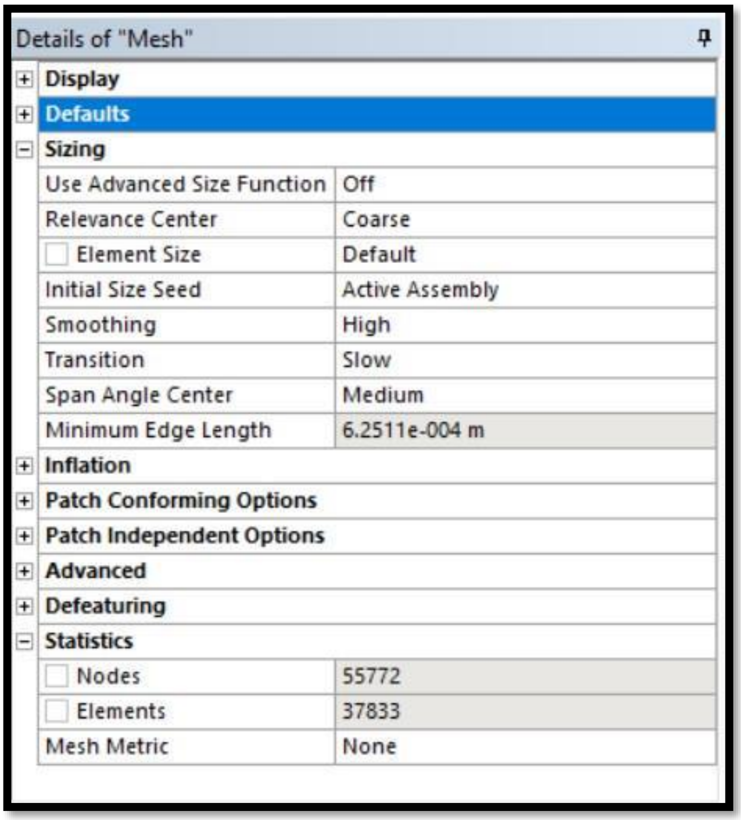

Figure 3. Mesh Details of the model in Ansys

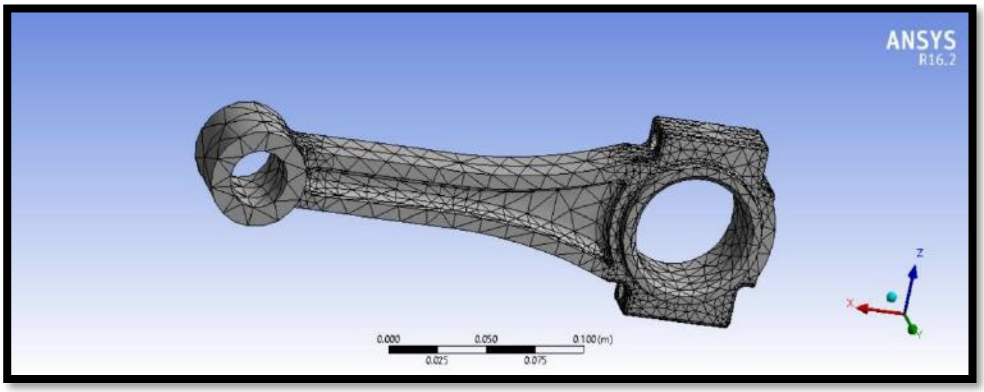

Figure 4. Mesh Result of the Connecting Rod

4.2 Loading condition

In figure 5 we have given fixed support to the big end or crankshaft side end of the connecting rod and put a force of 36191.7 N is similar to 36192 N on the Small end or Piston side end of the connecting rod in the direction of the big end which is a compressive type of load. Figure 6 shows a similar loading condition at the big end.

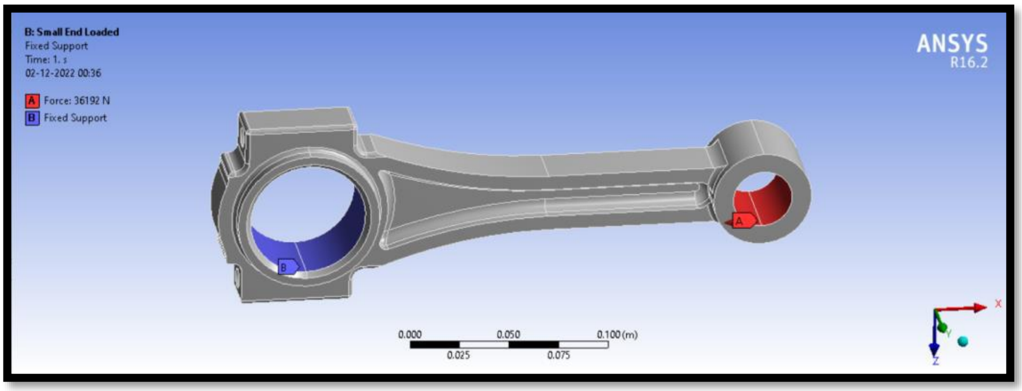

Figure 5. Loading on the Small End of Connecting Rod

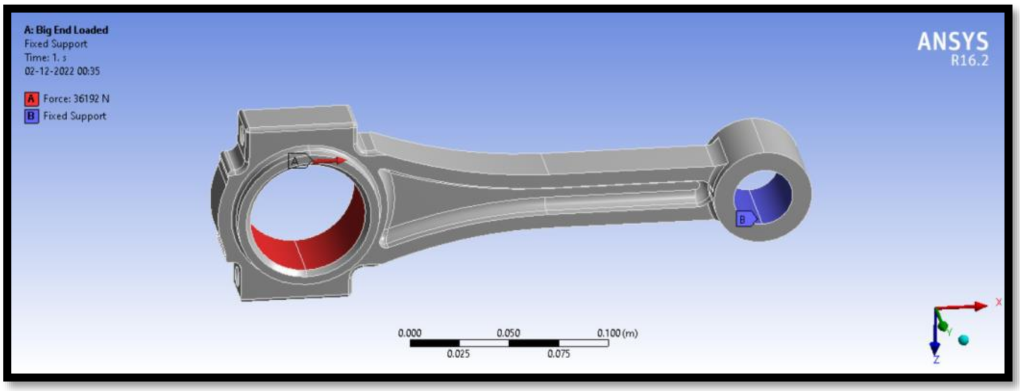

Figure 6. Loading on the Big End of Connecting Rod

5. RESULTS

The summary of the analysis can be seen as shown in the Table 2:

Table 2. Result Table Summary

Materials / Mech. Properties			BEI220H	Titanium alloy (Ti6al4V)	Aluminium 6061 BORON Carbide	Alloy Steel (8620)
Small end loaded	Total Deformation (m)	Maximum	5.82E-05	1.69E-04	8.78E-02	8.36E-02
		Minimum	0	0	0	0
	Equivalent Stress (Pa)	Maximum	2.12E+08	2.03E+08	2.04E+08	2.04E+08
		Minimum	2962.8	6022.2	5627.4	5627.5
	Maximum Principal Stress (Pa)	Maximum	7.02E+07	7.22E+07	7.20E+07	7.20E+07
		Minimum	-1.66E+07	-1.79E+07	-1.75E+07	-1.75E+07
	Minimum Principal Stress (Pa)	Maximum	9.26E+06	1.50E+07	1.48E+07	1.48E+07
		Minimum	-2.19E+08	-2.12E+08	-2.13E+08	-2.13E+08
Big end loaded	Total Deformation (m)	Maximum	6.58E-05	1.94E-04	0.10057	9.58E-02
		Minimum	0	0	0	0
	Equivalent Stress (Pa)	Maximum	1.32E+08	1.28E+08	1.29E+08	1.29E+08
		Minimum	39097	81318	76931	76931
	Maximum Principal Stress (Pa)	Maximum	4.97E+07	5.66E+07	5.58E+07	5.58E+07
		Minimum	-1.27E+07	-1.87E+07	-1.72E+07	-1.72E+07
	Minimum Principal Stress (Pa)	Maximum	4.48E+06	1.18E+07	1.11E+07	1.11E+07
		Minimum	-1.39E+08	-1.42E+08	-1.42E+08	-1.42E+08
Density	kg/m3		1844	4429	7870	7700
Volume	m^3		0.0002486	0.0002486	0.0002486	0.0002486
Mass	Mass = Density*volume		0.4584184	1.1010494	1.956482	1.91422
Weight = Mass * 9.81 N			4.497084504	10.80129461	19.19308842	18.7784982
Stiffness = Weight/deformation (N/m)		Small end loaded	77317.31834	64053.22074	218.6100554	224.5828882
		Big end loaded	6.84E+04	5.58E+04	1.91E+02	1.96E+02

From the above table we can plot the weight of the connecting rod. The graph is as shown in Figure 7.

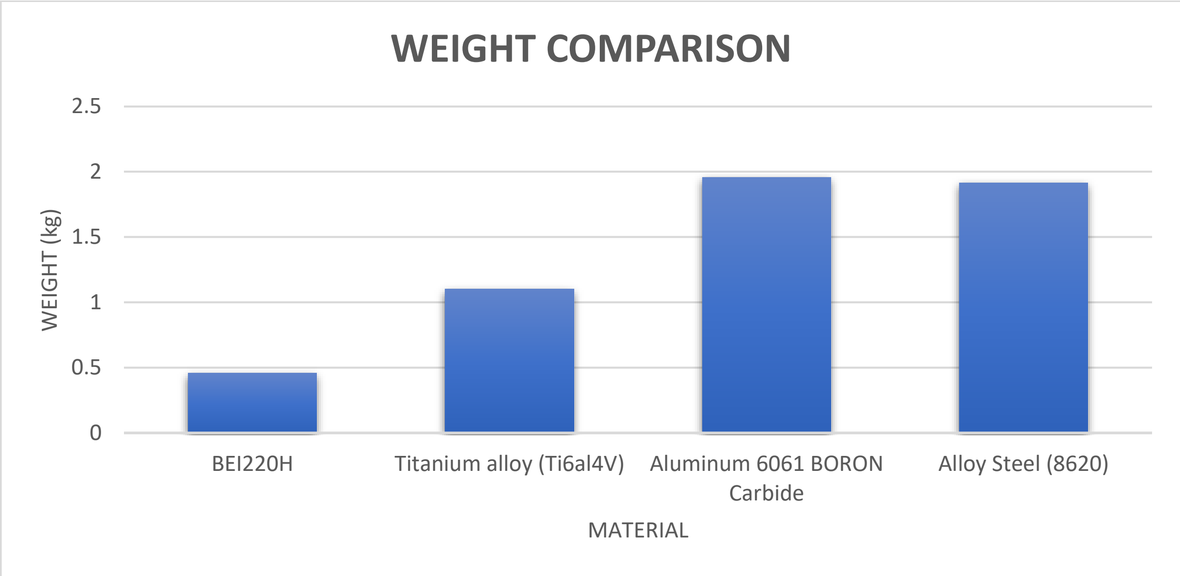

Figure 7. Weight Comparison Graph.

6. CONCLUSIONS AND RECOMMENDATIONS

In automotive industries, to achieve reduced fuel consumption as well as greenhouse gas emission is a current issue of utmost importance. To reduce automobile weight and improve fuel efficiency, the auto industry has dramatically increased the use of aluminium in light vehicles in recent years. Aluminium alloy-based metal matrix composites (MMCs) with ceramic particulate reinforcement have shown great promise for such applications. These materials have a lower density and higher thermal conductivity as compared to conventionally used ones. Weight reduction of up to 50 – 60 percent in the systems. Moreover, the potential of these advanced materials has performed better under severe service conditions like higher speed, higher load etc. The objective of the present work is to design and analysis of connecting rods made of various other alternative Alloys. The connecting rod is designed using steel materials. In this project, the material (Forged steel) of connecting rod was replaced with various Alloys such as Beryllium alloy, Titanium alloy, Aluminium Boron Carbide and Alloy Steel. The connecting rod was created in CATIA. The model is imported in ANSYS 16.2 for analysis. After analysis, a comparison is made between existing steel connecting rods and these Alloys in terms of weight, stiffness, deformation and stress. The present work aimed at evaluating alternate materials for connecting rods with lesser stresses and lighter weight. This work found alternate material for minimizing stresses in connecting rods. FEA analysis was performed using ANSYS WORKBENCH 16.2 software for determining deformation and stresses.

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