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Modeling and Mechanical Behaviour Analysis of IC Engines Connecting Rod Is Made of Beryllium, Aluminium, Metallic Glass by Using FEA

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ABSTRACT: Connecting rods are practically generally used in all varieties of automobile engines. Connecting rod acting as a converting intermediate link between the piston and the crankshaft of the engine, by the reciprocating motion of the piston to the rotary motion of crankshaft. In this work existing connecting rod material are C-70 Steel, Duralumin and Carbon epoxy they are replaced by beryllium alloy, Aluminium 360 and bulk metallic glass. In this study a solid 3D model of connecting rod was developed using Pro-E software and analysis was carried out by ansys 15.0 software and useful factors like stress, Deformation were obtained. Our main objective to determine best material for connecting rod by applying finite element methodology.

KEYWORDS: Connecting Rod, FEA, Aluminium 360, Beryllium, Bulk Metallic glass.

I. INTRODUCTION

The connecting Rod is intermediate link between the piston and the crankshaft of an engine. It transmits force from piston to the crankshaft. The connecting rod converts the reciprocating motion of the piston to rotary motion of the crankshaft. Our objective is to study and compare different type of materials. Scopes of this work is to reduce the weight of connecting rod also find best composite material. Major three materials are analyzed C-70 Steel, Duralumin and Carbon Epoxy, are being developed for high-performance automotive applications. The connecting rod has been selected as the model to assess the value of these reinforced castings and to develop design and fabrication technology. While they are lighter and may offer better compressive strength and stiffness and fatigue resistance than conventional engine materials, their design still represent a major technical challenge

II. METHODOLOGY

For this work 3 types of existing materials and 3 types of modified materials are chosen for analysis. They are

Existing materials

- C-70 steel
- Duralinium
- Carbon epoxy

Modified materials

- Aluminium 360
- Beryllium alloys
- Bulk metallic glass

Modeling of the connecting rod is done in PRO-E in IGES format and imported to the Ansys work bench software for Finite Element Analysis.

Analysed result from Ansys will be compared with theoretical calculations and suitable material will be selected.

III. DESIGN OF CONNECTING ROD

A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, {or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

Mathematical Calculation for Connecting Rod;

Let

A = cross sectional area of the connecting rod.

L = length of the connecting rod.

σ_c = compressive yield stress.

W_{cr} = crippling or buckling load.

I_{xx} and I_{yy} = moment of inertia of the section about x-axis and y-axis respectively.

K_{xx} and K_{yy} = radius of gyration of the section about x-axis and y-axis respectively.

Rankine formula = $(I_{xx} = 4I_{yy})$.

Pressure calculations for 150cc Engine

Engine type air cooled 4-stroke

Bore x Stroke (mm) = 57×58.6

Displacement = 149.5 CC

Maximum Power = 13.8 bhp @ 8500 rpm

Maximum Torque = 13.4 Nm @ 6000 rpm

Compression Ratio = 9.35/1

Density of Petrol C_8H_{18} = $737.22 \text{ kg/m}^3 = 737.22 \text{E-9 kg/mm}^3$

Temperature = $60^\circ \text{F} = 288.85 \text{K}$

Mass = Density \times Volume = $737.22 \text{E-9} \times 149.5 \text{E}^3 = 0.11 \text{Kg}$

Molecular Weight of Petrol 114.228 g/mole

From Gas Equation,

$PV = Mrt$

$R = R^*/M_w = 8.3143 / 114.228 = 72.76$

$P = (0.11 \times 72.76 \times 288.85) / 149.5 \text{E}^3$

$P = 15.469 \text{ Mpa}$.

Design calculation

Thickness of flange & web of the section = t

Width of section $B = 4t$

The standard dimension of I SECTION.

Height of section $H = 5t$

Area of section $A = 2(4t \times t) + (3t \times t)$

$A = 11t^2$

MI of section about x axis:

$I_{YY} = 2 \times \frac{1}{12} t (4t)^3 + \frac{1}{12} (3t) t^3 = 131 \frac{1}{12} t^4 = 3.2$

Length of connecting rod (L) = 2 times the stroke

$L = 117.2 \text{ mm}$

Buckling load = maximum gas force \times F.O.S = 37663 N

σ_c = compressive yield stress = 415 Mpa

$K_{xx} = I_{xx}/A = 1.78t = 0.0002$

• By substituting σ_c , A , a , L , K_{XX} on WB then

$4565t^4 - 37663t^2 - 81639.46 = 0$

• By solving the above equation

$t^2 = 10.03, t = 3.167 \text{ mm}, t = 3.2 \text{ mm}$

• Width of section $B = 4t = 12.8 \text{ mm}$

• Height of section $H = 5t = 16 \text{ mm}$

- Area $A = 11t^2 = 112.64\text{mm}^2$
- Height at the big end (crank end) = $H_2 = 1.1H$ to $1.25H$
- $H_2 = 17.6\text{ mm}$

IV. MODIFIED MATERIAL MODEL

Reason for selecting alternate materials:

A hybrid composite is the mixture of different composite layers. Bulk metallic glass is efficient in storing the greater amount of energy has high strength, stiffness and low weight. On the contrary, it has low impact strength and in the case of contact with a metal. A good combination of the material properties and cost is obtained with glass fibers. Research has indicated that the results of E-glass are found with good characteristics for storing strain energy. Material is specified as an orthotropic in nature with all other data then material is assigned to the model.

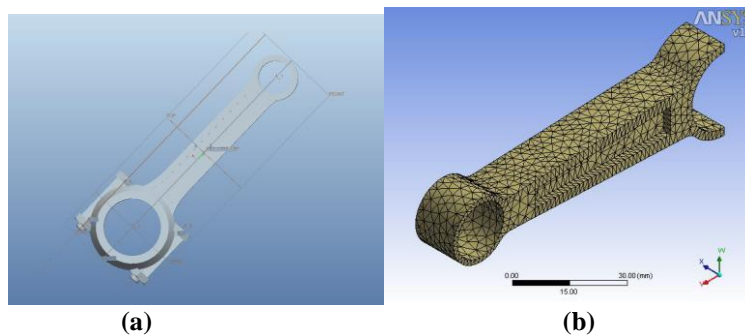


Figure 1. (a) Assembly of Modified Connecting Rod, (b) And their meshed model

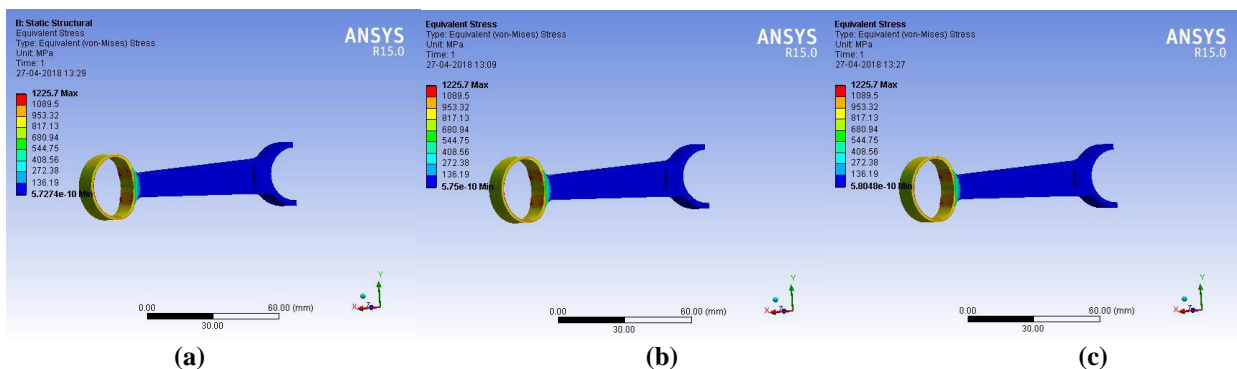
Assembly of connecting rod consists of cover, stud, Distance Piece, Nut, these parts are assembled one by one with suitable constraints.

V. RESULTS ANN DISCUSSIONS

Analysing of meshed model is done by ansys workbench software by applying FEA approaches.

The following figures shows the deformation respective to the applied load to six different types of selected materials.

Deformation of model under 26700 N load:



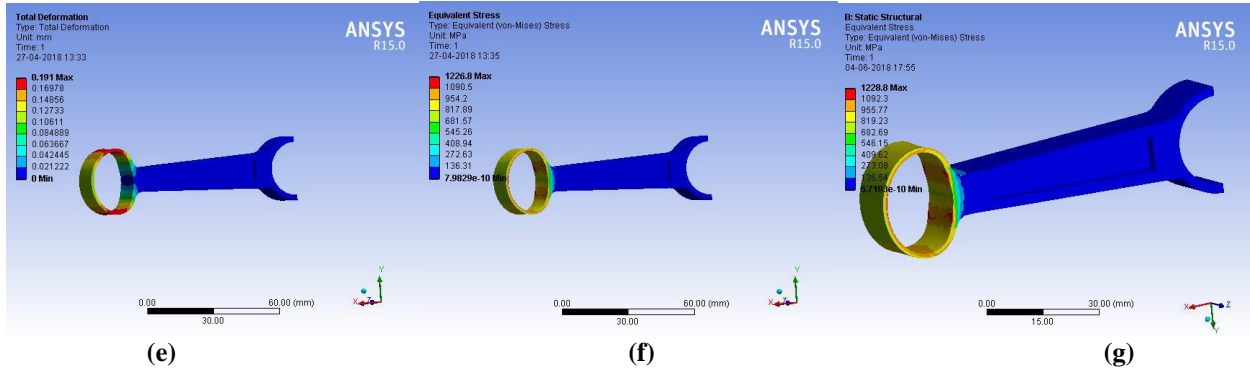


Figure 2. shows the analysis results for Deformation of connecting rod, Existing materials {(a),(b),(c)} and modified materials {(d),(e),(f)} under load. (a) C-70 STEEL, (b) DURALUMIN, (c) CARBON EPOXY, (d) Aluminium 360, (e) Beryllium, (f) Bulk Metallic Glass.

TABLE 1. Stress and Deformation comparison of existing and modified materials

MATERIALS	MATERIAL NAME	STRESS [Mpa]	DEFORMATION [mm]
EXISTING	C-70 Steel	1225.4	0.070111
	Duralumin	1225.64	0.18762
	Carbon Epoxy	1225.7	0.1903
MODIFIED	Aluminium 360	1226.8	0.191
	Beryllium	1226.2	0.10285
	Bulk Metallic Glass	1228.8	0.06667

Graphical Comparisons Between modified and existing models:

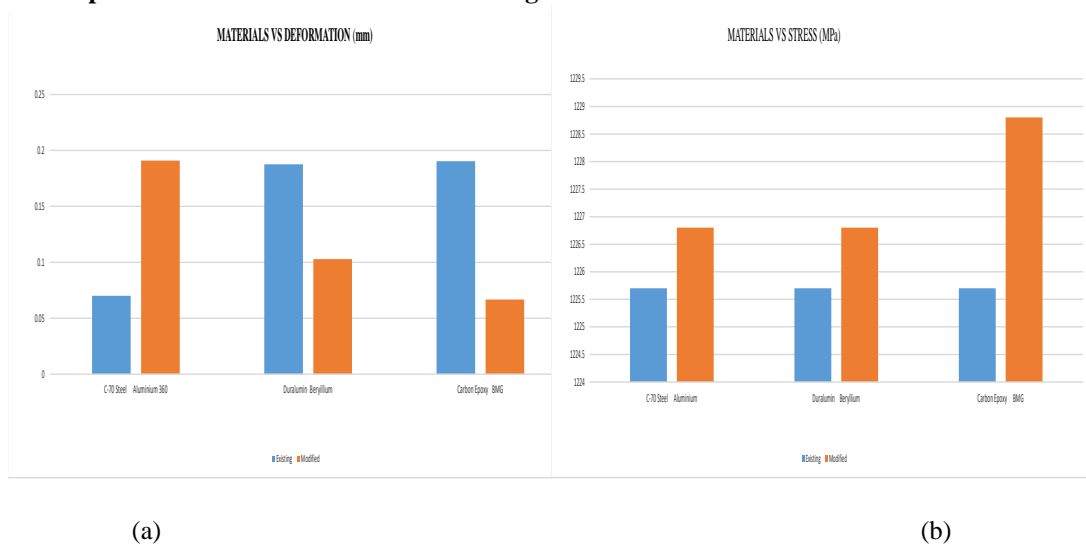


Figure 3: Graphical comparison of existing and modified: (a) Material vs. Deformation, (b) materials vs. Stress

STRESS STRAIN CURVE FOR EXISTING MATERIALS

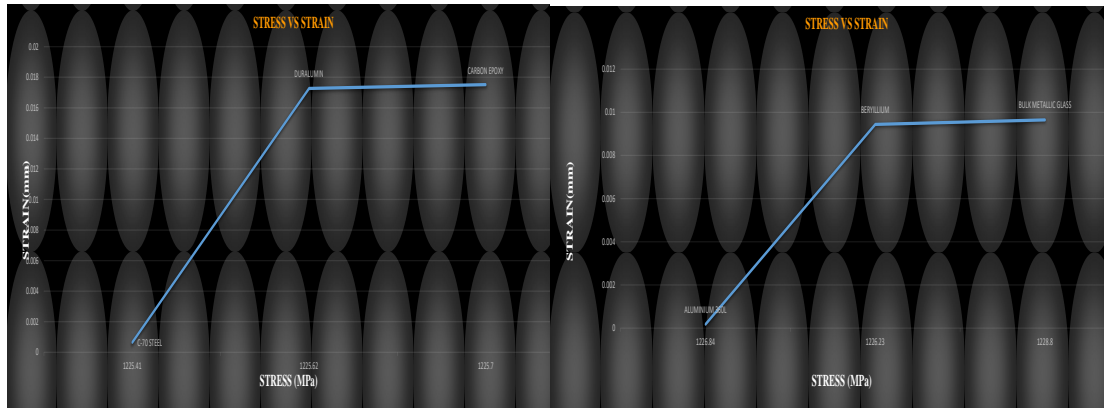


Figure 4: Stress vs. strain comparison of materials: (a) Existing, (b) Modified.

Discussions:

Now days the Connecting rod are made up of Duralumin, C-70 steel, and Carbon epoxy Material which expands enormously due to generation of heat in the piston. This will affect clearance volume and insufficient clearance can cause the piston size in the cylinder. The ultimate aim is to reduce the expansion and to analyze the various characteristics of Connecting rod like stress, deformation, density, and Young’s modules and poissons ratio. For analysis of connecting rod model the ANSYS software is used. The structural analysis on the connecting rod is done by changing different materials under same loading conditions and same dimensions of the connecting rod. The theory of von- mises Theory is used for calculating the stress induced in the connecting rod when it is in heavy loaded conditions. For the current manufacturing condition, it was necessary to investigate finite element modeling techniques, optimization techniques, and developments in new materials, fatigue modeling, and material cost analysis for connecting rod which are made by large volume production. Due to its large volume production, it is only logical that optimization of the connecting rod for its material cost will result in large-scale savings

Table 2. Overall Result comparisons of existing and modified materials and their Properties:

Material	Materials Name	Density kg/mm ³	Young’s modulus N/mm ²	Poisson ratio	STRESS [MPa]	DEFORMATION [mm]
Existing	C-70 Steel	7.85 *10 ⁻⁶	2*10 ⁵	0.3	1225.4	0.070111
	Duralumin	2.77*10 ⁻⁶	7.1*10 ⁴	0.3	1225.64	0.18762
	Carbon Epoxy	1.60*10 ⁻⁶	7*10 ⁴	0.3	1225.7	0.1903
Modified	Aluminium360	2.63 *10 ⁻⁶	7.0*10 ⁵	0.33	1226.8	0.191
	Beryllium	8.36*10 ⁻⁶	4.0*10 ⁴	0.33	1226.2	0.10285
	Bulk Metallic Glass	1.81*10 ⁻⁶	26.8*10 ⁴	0.33	1228.8	0.06667

VI. CONCLUSION

The following conclusions can be drawn from this study:

- For Design modified connecting rod Bulk metallic glass is best among the other two composite material (Aluminium360, Beryllium alloys).
- Compared to existing material it has high ultimate stress and low deformation value.
- Material cost is low as compared to existing model.



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