A Review on Comparison of Connecting Rod Made by 3D Printing Method

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***Abstract*: Connecting rod is the intermediate link between the piston and crank. It is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rod are manufactured using carbon steel but in recent days aluminum alloys are finding its application in connecting rod. In this work connecting rod material is replaced by aluminium based composite material reinforced with silicon carbide and fly ash. And it describes the modelling and analysis of connecting rod. Compared to former material to the new material found to have less weight.**

***Keywords*: connecting rod, 3d printing method**

1. Introduction

The connecting rod automotive should be lighter and should consume less fuel and at the same time they should provide comfort and safety to passenger that unfortunately leads to increase the weight of the vehicle. This tendency in vehicle construction led the invention and implementation of quite new materials which are light and meet the design requirement. Lighter connecting rod helps to decrees lead caused by forces of inertia in engine as it does not require big balancing weight of crank shaft.

Application of MMCs enables safety increase and advances that leads to effective use of fuel and to obtained high engine power. By carrying out these modifications to engine element will result in effective reduction of weight, increase of durability of particular part will lead to decrees the overall engine weight, improvement in its traction parameter, economy and ecological conditions such as emission of harmful substances into atmosphere. So we are interested in design and analysis of connecting rod for IC engine by using ALFA Sic composite. A composite material is made from two or more constituents materials with significantly different physical or chemical properties that, when combine produce a material which characteristics different from the individual components. The composite material may be preferred for many reasons such as stronger, lighter, less expensive when compared to the traditional material. In this project AL360 connecting rod is replaced by ALFA Sic composite connecting rod. Aluminum based fly ash and silicon carbide is found to have working factor of safety is nearer to therotical factor of safety.

A. *Why we use fly ash*

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) are an advanced materials resulting from a combination of two or more materials in which tailored properties are realized. MMCs possess significantly improved properties including high specific strength, damping capacity and good wear resistance compared to unreinforced alloys.

In the last few years' considerable development has occurred in the potential use of metal matrix composites for automotive applications. Considerable trails have been done on the use of metal matrix composites like aluminium-silicon carbide composites for connecting rods, brake rotors, drive shafts and several other components. However, cost still remains a major barrier in designing aluminium composite components for wider applications in automotive industries. The bulk density of the fly ash particles was found to be 2.42 g/cm^3. Al - fly ash (ALFA) composites were produced by stir casting route successfully. There was a uniform distribution of fly ash particles in the matrix phase. It clearly that there were no voids and discontinuities in the composite; there was a good interfacial bonding between the fly ash particles and matrix phase. The density of the composites decreases with increasing the percentages of fly ash particulates. With 10% fly ash, the density of composite decreased to 2.422 g/cm3 compared to the density of the alloy 2.680 g/cm3. The measured densities were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing fly ash content. This can be attributed to the increase in porosity with fly ash content. From the EDX analysis of ALFA composites shows that no oxygen peaks were observed in the matrix area, confirming that the fabricated composite did not contain any additional contamination from the atmosphere. This might be due to a shield of argon gas was maintained during the mechanical stirring while reinforcement addition. The hardness of the composites increased with increasing the amount fly ash than the base alloy. Enhanced mechanical properties were observed with increasing amount of fly ash under compression.

Higher compression strength values were observed for the aspect ratio

(Ho/Do) =1.0 than 1.5 aspect ratio.

B. Need of Composites & Benefits

In comparison to common materials used today such as metal and wood, composites can provide a distinct advantage. The primary advantage in composites is the light weight, relative stiffness and strength properties. In transportation, less weight equates to more fuel savings and improved acceleration. In sporting equipment, lightweight composites allow for longer drives in golf, faster swings in tennis, and straighter shots in archery. While in wind energy, the less a blade weighs the more power the turbine can produce. Rubber tiers replacing wooden wheels; bright nylon or polyester dress materials becoming more popular than cotton; tennis rackets made of lighter materials being preferred over the old, heavy wooden one. Composite materials are generally costlier as compared to conventional materials, but still their use is becoming increasingly popular because of their significant properties.

C. Objective

To find all Design parameters of connecting rod according to machine design approach (Analytical method) for existing material (A360) & New material (ALFASIC) composite. To find stiffness of connecting rod according to machine design approach for existing material (A360) & new material (ALFASIC) composite. To find weight of connecting rod according to machine design approach for existing material (A360) & New material (ALFASIC) composite. Compare all coming results for existing material & new material. After that Validate all theoretical result with the software analysis result using ANSYS 16.0 software I found the new ALFASIC composite material have low weight and less Area as compared to Aluminum cast alloy A360 IC Engine connecting rod.

2. Methodology

For project I have selected which connecting rod used in 180cc bike in IC Engine. Assuming BAJAJ PULSER 180cc bike specification as like cc, Compression ratio, Type of Engine, Power, Torque, Bore dia., Stroke length, According to that all specifications. First find out the total mass of air-fuel mixture which is coming inside the cylinder during suction stroke. After that following step are applied by taking reference of Author Book & Recent Research Paper

- To calculate force acting on piston. And maximum inertia force on the piston.
- To calculate Net load on the piston.
- By using Rankin's-Gordon formula, to find the I section thickness, width, height for both material.
- To calculate Small end & Big end of connecting rod. And According to All dimension we make 2D drawing preparation by using Auto-cad software. That model Convert 2D model into 3D model by using Solid work 16.0 version software for both material model. (Aluminum cast alloy A360) & ALFASIC composite AL 6061) Import both model Solid works 16.0 to ANYSIS 16.0 for analysis purpose. (IGES le extension)
- Compare all result whatever coming from analytical method & software method.

A. Design of connecting rod

The Connecting Rod consist of an eye at the small end to accommodate the piston pin a long shank & a big end opening split into two parts to accommodate the crank pin. The construction of connecting rod is illustrated. The connecting rod of an IC engine is made by drop forging process & the outer surfaces are left unfinished. The connecting rod is subjected to the Z force of gas pressure & the inertia force of the reciprocating part. It is one the most heavily stressed Part of the IC engine Aluminum & Aluminum alloy are used for connecting rods of automobile engines. The length of the connecting rod is an important consideration when the connecting rod is short as compared to the crank radius It has greater angular swing resulting in greater side thrust on the piston in high speed engine rod to the crank radius (L/r) is generally four or less than four.

Most of the connecting rods in High-Speed engines have an I-Section. It reduces the weight & inertia forces. It is also easy for forging. Most rods have a ri e-drilled hole through all the length from the small end to the big end to carry the lubricating oil to the piston pin bearing. In low-speed engines circular cross section is used [20].

Taking 180cc engine configuration to calculating connecting rod of I section [24]

Displacement -178.60 cc

Maximum power -16.8 BHP @ 8500 rpm

Maximum Torque - 14.2 N-m @ 6500 rpm

Engine Description - 4-stroke, Petrol Engine, Air cooled, single cylinder

Bore Diameter - 63.5 mm

Stroke length - 56.4 mm

From standard for high speed application I section of connecting Rod are used and According to design Data book the following empirical relation with related to Thickness (t) in mm [20].

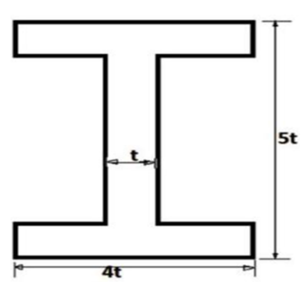


Fig. 1. I Section

Thickness of flange and web of the section = (t) mm

Width of the section B = 4t

Total height of I section H = 5t
Area of I section A= 11 t2
Moment of inertia about X axis and Y axis Ratio is Ixx/Iyy= 3.2
Length of the connecting Rod (L) = 2 times of stroke of the = 56.4 x 2 = 112.8 mm Kxx & Kyy Radius of gyration of the section about x-x and y-y axis respectively (Kxx) 2 =Ixx/A
Kxx= 1.78 t [20]
Pressure calculation for connecting rod following are the consideration used [4]

Compression ratio = 9.35/1
Density of petrol at 274 k is 737.22 x 10 9 g/cc
Molecular weight m(petrol)= 114.228 g/mole
Ideal gas constant R = 8.3143 j/mol*k

Mass of the Air Fuel Mixture in the cylinder [4]
Density of petrol x volume of the cylinder =737.22 x 10 9x 178.60 x103 =0.13 Kg
R specific = R/Mass [4]
=8.314/0.13
=63.95
Pressure on connecting Rod [4][8]
P=m x R specific c x T/V
Where,
M= mass of air fuel mixture in the cylinder
R specific = Ideal gas constant specific
T= temperature in Kelvin
V= volume of cylinder
=0.13 x 103 x 63.95 x 274/178.60 x103
=12.75 Mpa
Fp = Force acting on piston [4] [8]
Gas pressure x Area of cylinder Fp=40378.25 N
Maximum inertia load on the piston [4] [8]
Fi= m x!2 x r (1+1/n)
Where,
M= mass of air fuel mixture =0.13 Kg
!=angular velocity (2 N=60) = 890.11 Radian/sec
R= crank radius = (Stroke length /2)=56.4/2= 28.2 mm= 0.0282 m
N=ratio of length of connecting rod to crank radius = (112.8/28.2)=4

Putting all this value in given formulae
We get Maximum inertia load on the piston
Fi = 3604 N [Maximum inertia load on the piston]

Net load on piston [8]
=Force acting on piston -Maximum inertia load on the piston-F = Fp {Fi
=40378.25-3604
=36774.25 N
F= 36774.25 N [Net load on piston]
By using Rankine's-Gordon formula to and the thickness of I section [20] [21]

W = (x A)/ (1+ a (l/Kxx) ^2)
Where
W =buckling load in N
A= Area of I section = 11t2
= Material Yield stress in N=mm^2

Connecting rod Small End Calculation:
Force on piston (Fp) = 40378.25 N
Fp= Projected area x Bearing pressure [20], [21]

The all allowable bearing pressure for the piston pin push is usually taken from 12.5 to 16 MPA and (l/d) ratio for the piston pin Bush is taken from 1.5 to 2 it made of phosphor bronze bush of 3 mm thickness
Fp= dp x lp x pb
Where,
Fp {force on piston N
dp {diameter of piston pin, mm
pb {permissible bearing pressure piston pin, N/mm2 40378.25= dp x 1.5dp x 16
dp= 41.01 mm (Inside Diameter)
lp= 1.5 dp
lp=61.52 mm
dpo= dp+2tb+2tm [12]
Where
Thickness of bush (tb) = 2 to 5 mm
Marginal thickness (tm) = 5 to 10 mm
dpo=41.01+ (2x2) + (2x5)
dpo=55.01 mm (Outside Diameter)

Connecting rod Big End calculation:
Fp=dc x lc x pc
Where,
dc- Diameter of Big End bearing, mm
lc { Length of crank pin, mm
pc- Permissible Bearing pressure crank pin, N/mm2

The all allowable bearing pressure for the piston pin push is usually taken from 5 to 10 MPA and (l/d) ratio for the piston pin Bush is taken from 1.25 to 1.5 it made of bronze or steel material with thin lining (1 mm or less)
40378.25= dc x 1.5dc x 10
dc = 51.88 mm 52 mm (Inside Diameter)
lc =1.5 dc
=1.5 x 51.88 = 77.82 mm
dco = dc + 2tb + 2tm + 2tmb
Where,
Thickness of bush (tb) = 3 to 5 mm
Marginal thickness (tm) = 5 to 10 mm
Marginal thickness for bolt (dp) = 3 to 6 mm
=51.88+(2*2)+(2*5)+(2*3)
=71.88 mm 72 mm outside (Diameter)
Width of small end and big end = 0.45*D = 0.45*63.5= 28.60 mm

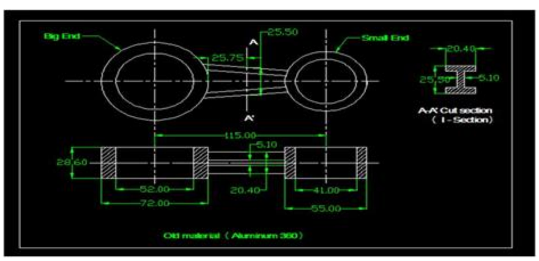
Bolt design bearing pressure for big end:

pb2 = 10.8 to 12.6 N/mm2 and length of the crank pin lC = (1.0 to 1.25) d2 Root diameter of the bolt
(2 Fi) ^0.5
x stroke
(2 x 3604.0/ x 56:4)^0.5
=6.37 mm
(db)= 1.2 root diameter of the bolt
=1.2 x 6.37
=7.65 mm

3. Analysis of connecting rod by using ansys software

A. Finite Element Method: The Finite Element Method (FEA) is a numerical technique for solving problems to find out approximate solution of a problem which are described by the partial differential equations or can also be formulated as functional minimization. A principle of interest is to represent as an assembly of finite elements. Approximating function in the finite elements are determined in the terms of the nodal values of a physical field which is sought FEM sub divides a whole problem or entity into number of smaller simpler parts called finite elements & solve these parts for the problems. The main advantage of FEM is that it can handle complicated boundary and geometries with very ease. Steps for Finite Element Method are:

- Modeling the model and Import the model.
- Defining element type
- Defining material properties and Meshing or later.



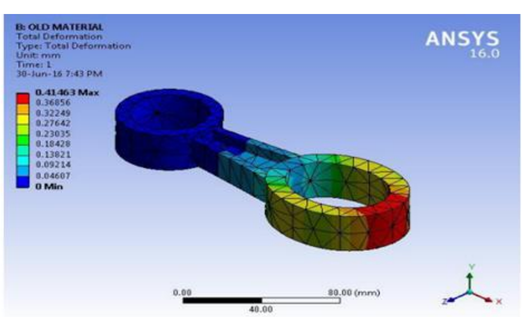
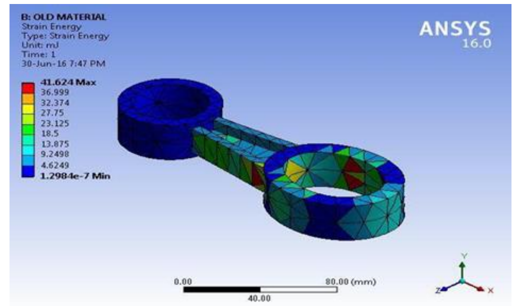
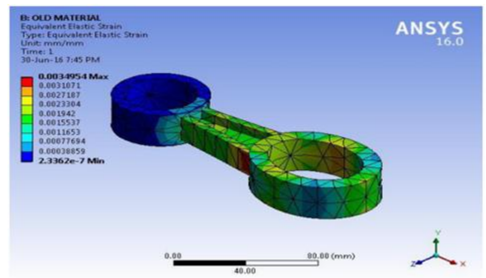
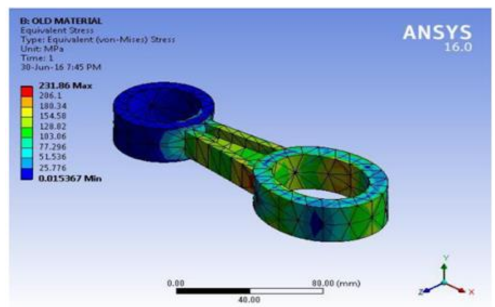


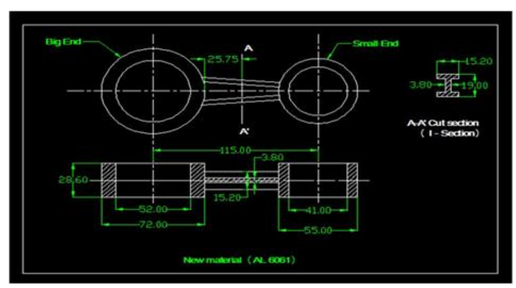
Fig. 2. 3D Drawing on Solid workbench 16.0 for Old material and new material

A. Analysis for old material

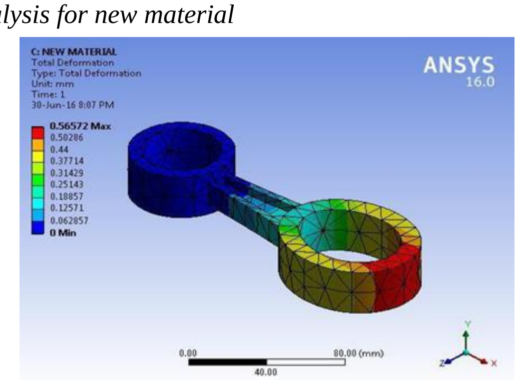


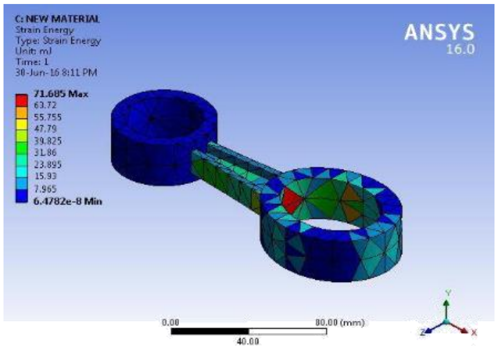






B. Analysis for new material





C. Comparison Between aluminum cast alloy and ALFASIC Composite connecting Rod: Comparison Between aluminum cast alloy and ALFASIC Composite connecting Rod

Table 1
Comparison Between aluminum cast alloy and ALFASIC Composite connecting Rod

Parameters	Old material (A360)	New material (AL 6061)
Total Deformation (mm) Minimum Maximum	0 0.41463	0 0.56572
Equivalent Elastic Strain Minimum Maximum	2.3362 e -007 3.4954 e -003	1.6456 e -007 5.0297 e -003
Equivalent stress (MPA) Minimum Maximum	1.5367 e -002 231.86	1.083 e -002 330.87
Strain Energy (MJ) Minimum Maximum	1.2984 e -007 41.624	6.4782 e -008 71.685

4. Conclusion

- New ALFASIC composite Connecting rod the total area of I section is less than the Old material. It's around 44.41 % reduction of area Found. Because of A 360 material have low compressive Yield strength as compare to new material ALFASIC.
- Weight can be reduced by changing the material of the current material connecting rod to new material. The optimized connecting rod is 11.66% lighter than the current connecting rod. Because of A 360 material have High Density as compare to new material ALFASIC.
- The optimized ALFASIC Composite Connecting rods have low stiffness as compare to Aluminum cast alloy A 360. Because of New material have less weight as compare to Old material.
- I got more value of deflection in ANSYS software as compare to theoretical value because of in theoretical calculation it's not including all mechanical properties. Hence I preferred software values for deflection

Weight can be reduced by changing the material of the current Aluminum cast alloy (A360) connecting rod to ALFASIC composites (AL 6061). Due to weight reduction in ALFASIC Connecting Rod, Engine Performance will be better.? ANSYS Equivalent Stresses Induced on both the connecting rod (Aluminum cast alloy and ALFASIC) are nearly same. And the ratio of Ultimate stress to working stress (F.O.S) it's near about 1.3 its means ALFASIC is better option to replace existing material. But the Deformation and Stiffness of the Connecting Rod (A 360) is better than the ALFASIC Composite Connecting Rod. If connecting rod having more weight, it's consume more fuel they lead to increase in weight of engine as well as vehicle. According to above problem we need to find out the new material which having similar mechanical properties but having less weigh and less Area for better performance. And ALFASIC Composite connecting rod is better option by replacing existing material which can use for High-Speed Application in IC Engine.

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