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Weight Optimization of Connecting Rod by Al-Si Metal Matrix Reinforced With Alumina and Flyash

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Abstract: ***The present work deals with the fabrication of Al-Si metal matrix composite reinforced with alumina and flyash. Aluminum metal matrix composite combines the strength of the reinforcements with the toughness of the matrix to achieve a combination of desirable properties which is not available in any single conventional material. The Al metal matrix has high strength to weight ratio and also have good corrosion resistance. In this work Al+12.5%Si matrix is reinforced with 9% of flyash and varying weight percentage of alumina MMC is fabricated by using stir casting. It has been found that tensile strength, compression strength and hardness properties improved considerably. The present material used for connecting rod is steel alloy which have high weight compare to Al-MMC. Static analysis is carried out on the connecting rod and it is found that current steel alloy can be replaced by Al MMC, hence material for connecting rod is optimized.***

Keywords: Pure Aluminium, Silicon, Alumina, Flyash , Stir casting technique, Mechanical properties,Abaqus,Analysis

1. Introduction

Metallic matrices are essential constituents for fabrication of Metal Matrix Composites (MMC), which have potential for structural materials at high temperatures. Metal matrix has the advantage over polymeric matrix in applications requiring a long-term resistance to severe environments, such as high temperature. The yield strength and modulus of elasticity of most metals are higher than those for polymers, which is an important consideration for applications requiring high transverse strength and elastic modulus as well as compressive strength for the composite.

Another advantage of using metals is that they can be plastically deformed and strengthened by a variety of thermal and mechanical treatments. While a variety of matrix materials has been used for making MMCs, the major emphasis has been on the development of lighter MMCs using aluminum and titanium alloys, due to the significant potential of improving the thrust to-weight ratio for the aerospace, space and automotive engines.

The connecting rod is the intermediate member between the piston and the Crank. Its primary function is to transmit the push and pull from the piston pin to the crank pin and thus converts the reciprocating motion of the piston into rotary motion of the crank shaft. Parts of the automotives should be as light as possible. they should consume lesser fuel, but it should not compromise with passengers comfort and safety.

2. Theoretical Calculation of Connecting Rod

1. Pressure calculation: Consider a 150cc engine

Engine type air cooled 4-stroke
Bore × Stroke (mm) = 57×58.6
Displacement = 149.5CC
Maximum Power = 13.8bhp at 8500rpm
Maximum Torque = 13.4Nm at 6000rpm
Compression Ratio = 9.35/1
Density of petrol at 288.855 K - 737.22*10-9 kg/mm3
Molecular weight M - 114.228 g/mole
Ideal gas constant R – 8.3143 J/mol.k

From gas equation, PV=m.Rspecific.T
Where, P = Pressure
V = Volume
m = Mass
Rspecific = Specific gas constant
T = Temperature
But, mass = density * volume
m =737.22E-9*150E3
m = 0.11 kg
Rspecific = R/M
Rspecific = 8.3143/0.114228
Rspecific = 72.76
P = m.Rspecific.T/V
P = 0.11*72.786*288.85/150E3
P = 15.4177 MPa P ~ 16 MPA.

2. Design calculation of connecting rod:

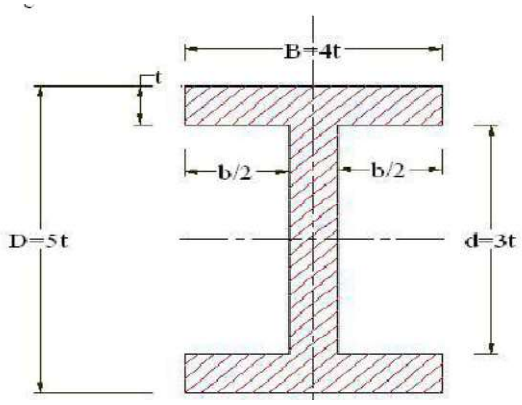

Figure 1: Standard Dimension's of I Section

From standards,

- Thickness of flange and web of the section = t
- Width of the section B = 4t
- Height of the section H = 5t
- Area of the section A = 11t2
- Moment of inertia about x axis Ixx= 34.91t4
- Moment of inertia about y axis Iyy= 10.91t4
- Therefore Ixx/Iyy = 3.2

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So, in the case of this section (assumed section) proportions shown above will be satisfactory
Length of the connecting rod (L) = 2 times the stroke
L = 117.2 mm

Total Force acting F = Fp-Fi
Where Fp = force acting on piston
Fi = force by inertia
Fp = (πd2/4) * gas pressure
Fp = 39473.1543 N Fi = 1000wrv2$gr*cos\theta$±cos2θnl
Wr = weight of reciprocating parts
Wr = 1.6 * 9.81 = 15.696 N
r = crank radius
r = stroke of piston / 2
r = 58.6/2 = 29.3
θ = Crank angle from the dead center
θ = 0 considering that connecting rod is at the TDC position
n1 = length of connecting rod / crank radius
n1 = 117.2/29.3 = 4
g = acceleration due to gravity, 9.81
v = crank velocity m/s
w = 2πn/60
w = 2π8500/60 = 890.1179
v = rw = 29.3e-3*890.1179 = 26.08
on substituting
Fi = 9285.5481
Therefore F = 39473.1543 – 9285.5481
F = 30187.6062 N
According to Rankine's – Gordon formula,
$F= fcA$1+($lkxx$)
Let, A = C/s area of connecting rod,
L = Length of connecting rod
fc = Compressive yield stress,
F = Buckling load
Ixx and Iyy = Radius of gyration of the section about x – x and y – y axis respectively and
Kxx and Kyy = Radius of gyration of the section about x – x and y – y axis respectively.

1. For Steel
On substituting to rankine's formula
30187.6 = 170∗11t21+0.002(117.21.78t)2 t = 4.7321
There fore
Width B = 4t = 18.9284 mm
Height H = 5t = 23.6605 mm
Area A = 11t = 246.32 mm2
Height at the piston end H1 = 0.75H – 0.9 H
H1 = 0.75*23.66 = 17.745
Height at the crank end H2 = 1.1H – 1.25H
H2 = 1.1*23.66 = 26.026

2. For al-9%Alumina -9%fly ash

On substituting to rankine's formula
30187.6 = 363∗11t21+0.002(117.21.78t)2
t = 3.5658
There fore
Width B = 4t = 14.2632 mm
Height H = 5t = 17.829 mm
Area A = 11t = 246.32 mm2
Height at the piston end H1 = 0.75H – 0.9 H
H1 = 0.75*23.66 = 13.37
Height at the crank end
H2 = 1.1H – 1.25H
H2 = 1.1*23.66 = 19.6119

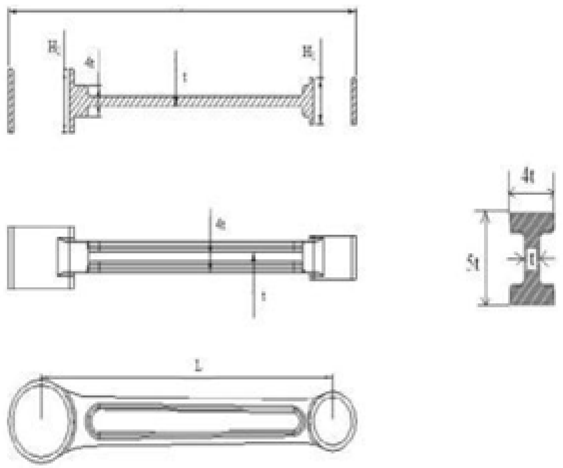

Figure 2: General dimensions of connecting rod

Table 1: Materials Used For Analysis

S. No	Parameters	Old material (steel)	New Material (Al-12.5%Si-9%F.A-9% Alumina)
1	Ultimate tensile strength (MPa)	440	402
2	Yield strength (MPa)	370	312
3	Youngs modulus (GPa)	207.0	85
4	Poisson's ratio	0.3	0.34
5	Density (g/cm3)	7.6	2.631

3. FEA Connecting Rod

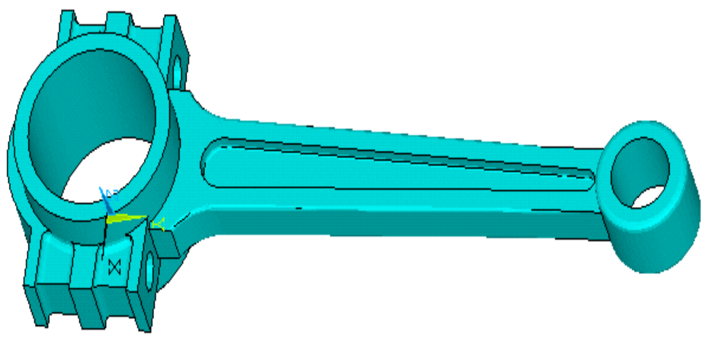

Figure 3: model of connecting rod

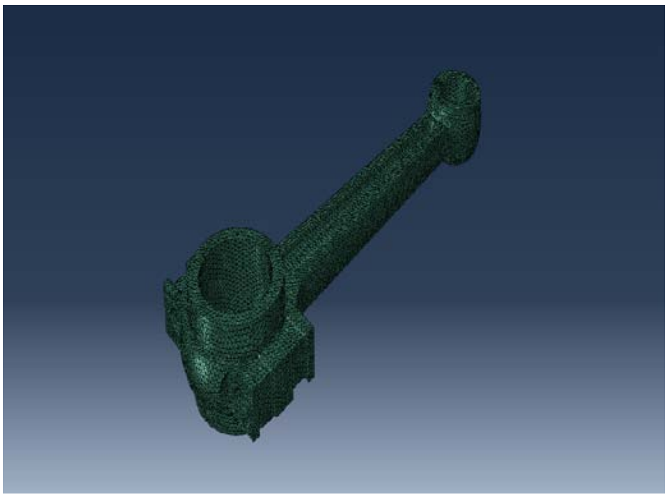

Figure 4: meshed model of connecting rod

- **Loads and constraints:**

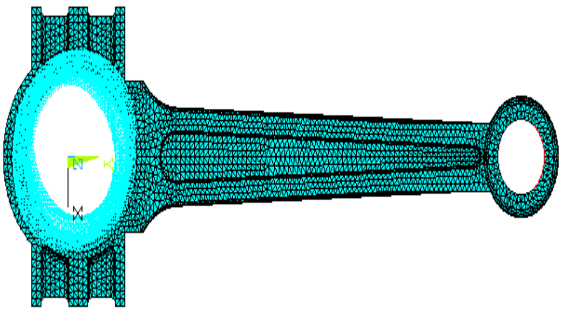

Figure 5: all DOF constrained at crank end

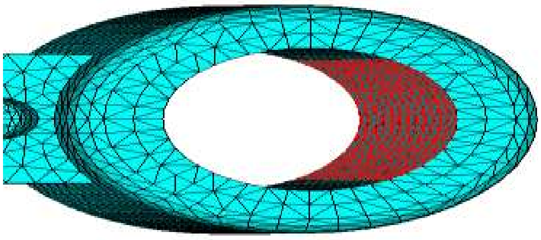

Figure 6: tensile load applied at the piston end

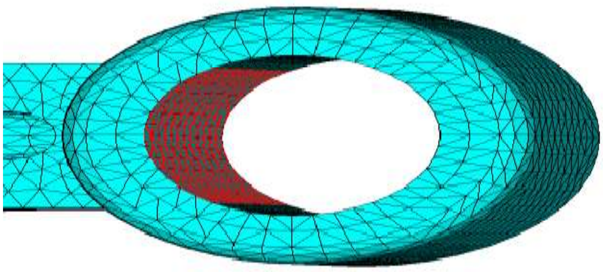

Figure 7: compressive load applied at the piston end

4. Results and Discussion

- **Analysis**

For the finite element analysis 16 Mpa of pressure is used. The analysis is carried out using ANSYS software. The pressure is applied at the small end of connecting rod keeping big end fixed. The maximum and minimum von-misses stress, strain and displacement are noted from the ANSYS.

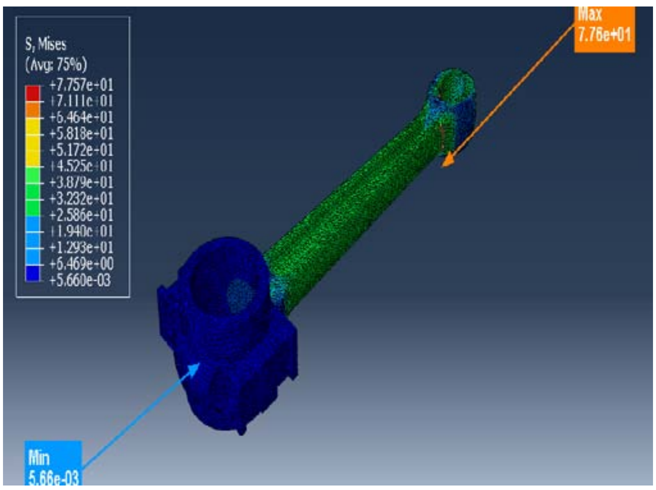

Figure 8: Von-Misses Stress for Compressive Load, steel material

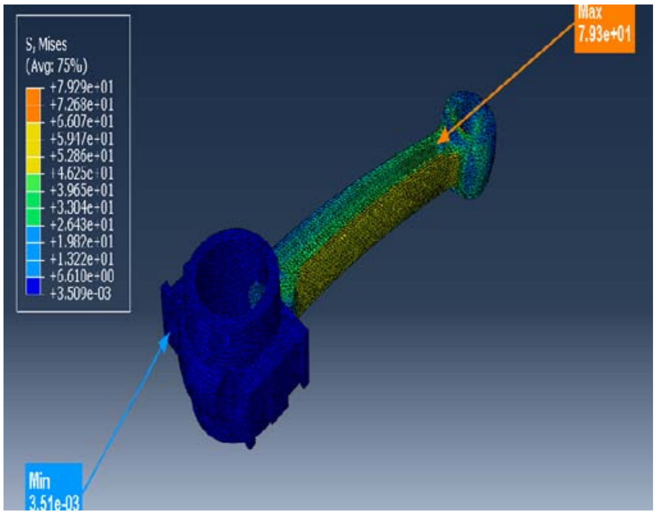

Figure 9: Von-Mises Stress for Tensile Load, steel material

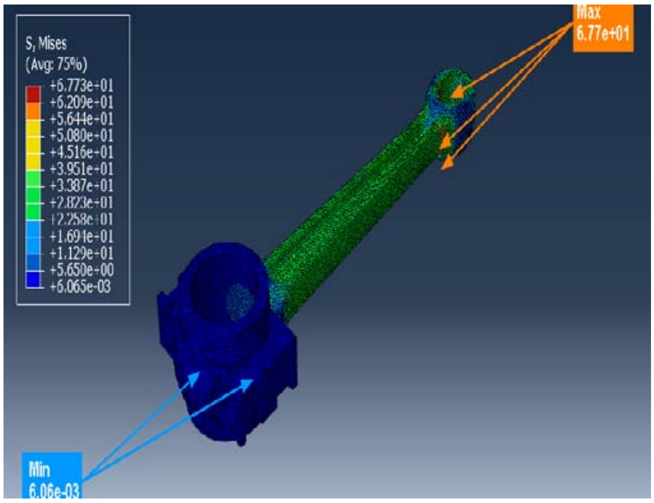

Figure 10: Von-Misses Stress for Tensile Load, Al-Si MMC material

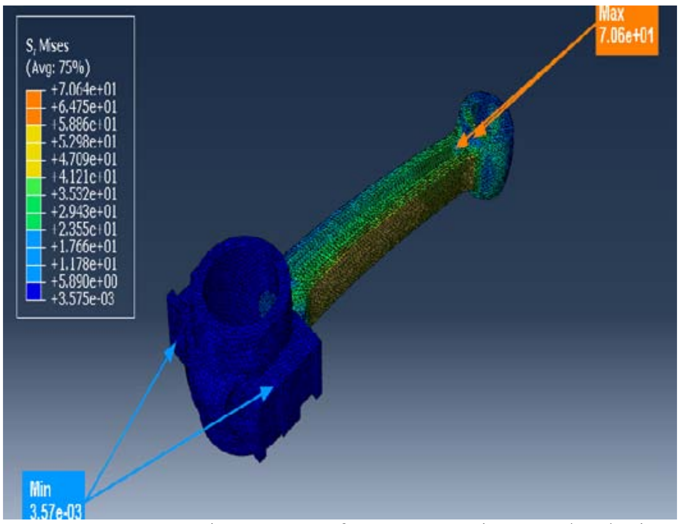

Figure 11: Von-Misses Stress for Compressive Load, Al-Si MMC material

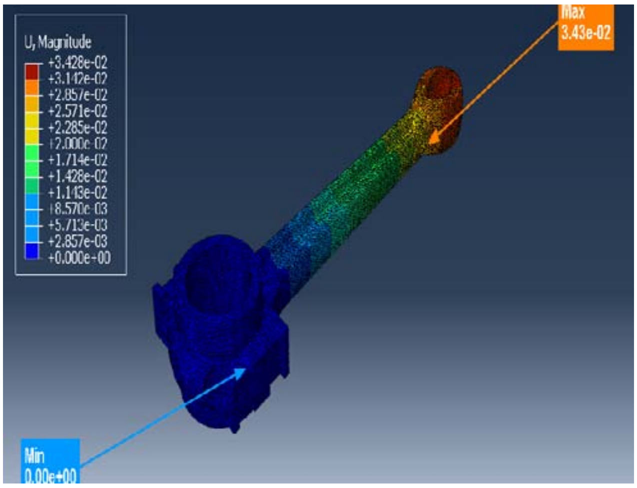

Figure 12:.Displacement of Steel For Compressive load

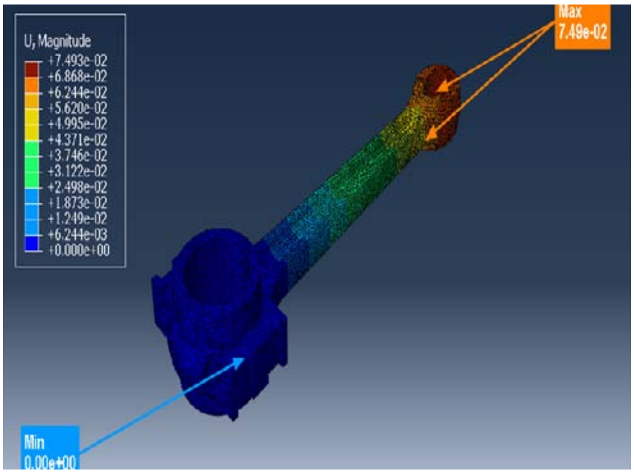

Figure 13: Displacement of Al-Si MMC For Compressive load

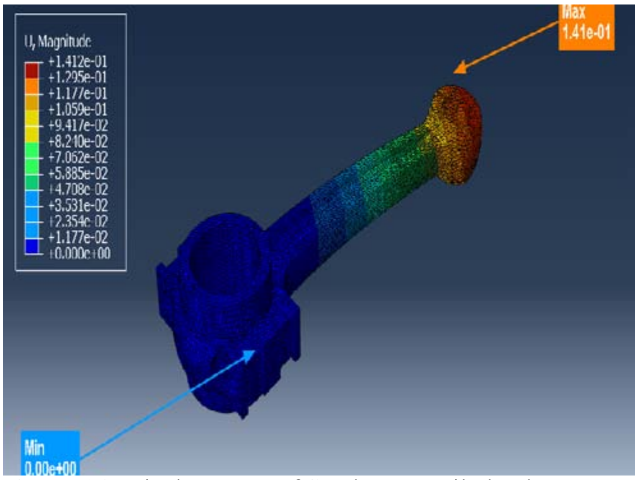

Figure 14: Displacement of Steel For tensile load

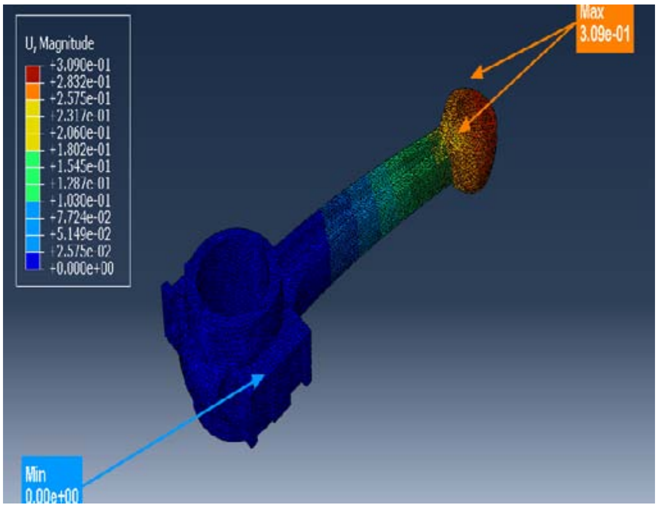

Figure 15: Displacement of Al-Si MMC for Tensile load

Table 2: Comparison Of Stress, Strain And Displacement For Different Materials.

S. No	*Material*	*Tensile load*		*Compressive load*	
		Stress (MPa)	*Displacement (mm)*	*Stress (MPa)*	*Displacement (mm)*
1	steel	79.3	0.141	77.6.	0.034
2	Al-12.5%si 9%alumina-9%fly ash	70.6	0.309	67.7	0.0749
3	% Difference	10.97	119.14	12.75	74.18

5. Volume and Weight of the Connecting Rod

a) Weight of the Connecting Rod.

- For steel:

The volume of the connecting rod used is 100829.348 mm^3. Therefore the mass of the connecting rod for respective materials are:
Weight = volume * density
Weight = 100829.348 * 7.6 e-3
Weight = 766.303 grams

- For pure aluminium-12.5%Si-9%fly ash-9%alumina

The volume of the connecting rod used is 100829.348 mm^3. Therefore the mass of the connecting rod for respective materials are:
Weight = volume * density
Weight = 57472.72836 * 2.61325e-3
Weight = 150.1906 grams
Therefore there is net difference of 616.1123 grams in the new connecting rod for the same volume, i.e., is 80.4006 % reduction in weight.

6. Conclusion

- Weight reduction of 80.40% can be achieved by using Al-Si-FA-Alumina MMC.
- Stress is reduced by 10.97 % by using Al-Si-FA-Alumina MMC over Steel.
- The new optimized connecting rod is comparatively much stiffer than the former.

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