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# Analysis of Connecting rod of Al2024 Alloy Composite using FEA Technique

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## ABSTRACT

Connecting rods which are commonly called as Conrods are applied in numerous situations. Connecting rod which forms the intermediate link between the piston and the crank to transmit the reciprocating motion of the piston to the rotary motion of the crank shaft. Usually Steel alloy, Aluminium alloy are commonly used materials in the manufacture of connecting rods. In this present Investigation an effort has been made to evaluate Buckling analysis utilizing Rankine's formula and also various parameters like Displacement and Von Mises stress were evaluated using ANSYS as tool utilizing Implicit Finite Element Technique for the base alloy and metal matrix composites which were produced through squeeze cast technique. The present Investigation revealed that the Metal matrix Composite showed better results when compared with the base alloy composite which is suitable for low speed engines. The analysis resulted in 50% saving of material when compared with the existing material.

**KEYWORDS:**Metal matrix Composite; ANSYS; Buckling; Von Mises stress.

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## 1. INTRODUCTION

Connecting rods are mechanical components that convert the piston to and fro motion to rotational motion of the crankshaft. The connecting rod is subjected to a complex stresses which includes compression stresses arising from the pressure exerted by the combustion gases, and tensile stresses related to the inertia of the components in motion, either alternative or rotational [1,2].Webster et al. [3] performed three dimensional finite element analysis of a high-speed diesel engine connecting rod. s In their analysis, they used the maximum compressive load obtained from the experimental analysis, and the maximum tensile load was taken from the inertia load of the piston assembly mass. The load distributions on the piston pin end and crank end were determined experimentally. They modeled the connecting rod cap separately, and also modeled the bolt pretension by using beam elements and multi point constraint equations.Yoo et al.[4] used variation equations of elasticity, material derivative idea of continuum mechanics and adopted an adjoint variable technique to calculate shape and design sensitivities of stress. The results were used in an iterative optimization algorithm of steepest descent algorithm, to numerically solve an optimal design problem. The focus was on shape design sensitivity analysis with application to the example of a connecting rod. The stress constraints were imposed on principal stresses of inertia and firing loads. But fatigue strength was not addressed. The other constraint was the one on thickness to bind it away from zero. They could obtain 20% weight reduction in the neck region of the connecting rod. Seraget al.[5]developed approximate mathematical formulae to define connecting rod weight and cost as objective functions and also the constraints. The optimization was achieved using a Geometric Programming technique. Constraints were imposed on the compression stress, the bearing pressure at the crank and the piston pin ends. Fatigue was not addressed. The cost function was expressed in some exponential form with the geometric parameters. El-Sayed and Lund [6] presented a method to consider fatigue life as a constraint in optimal design of structures. They also demonstrated the concept on a SAE key whole specimen. In this approach a routine calculates the life and in addition to the stress limit, limits are imposed on the life of the component as calculated using FEA results. Sudershankumar[7]et al described modelling and analysis of Connecting rod. In his project carbon steel connecting rod is replaced by aluminium boron carbide connecting rod. Aluminium boron carbide is found to have working factory of safety is nearer to theoretical factory of safety, to increase the stiffness by 48.55% and to reduce stress by 10.35%. Leela Krishna Vegietal[8]demonstrated that the factor of safety (from Soderberg's), stiffness of forged steel is more than the existing carbon steel found and the weight of the forged steel material is less than the existing carbon steel and reported that by using fatigue analysis life time of the connecting rod can be determined.

It is estimated that mechanical friction loss accounts for around 10% of the total energy in the fuel for a diesel engine, and about 40–55% of the friction losses are due to the power cylinder system, made up of the piston (25–47%), ring-pack (28–45%) and connecting-rod bearings (18–33%) [9]

Fantino and Frêne[10]studied the influence of the engine type petrol and diesel on the same result, but no conclusion could be made about the impact of other parameters load and speed, he also focused on the effect of the viscosity on the minimum film thickness for a connecting rod big-end bearing.

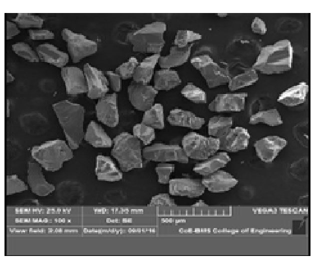
Francisco [11]used design of experiments to analyze the connecting rod big-end bearing behavior, and the main objective of the present work is to identify the factors dominating the bearing behavior.

Ramanpreet Singh[12]in his study used isotropic and orthotropic composite materials. The modeling of connectingrod was done using CATIA v5 and stress analyzed in MSC. PATRAN. Linear static analysis was carried out for both materials with tetrahedron with element size of 4mm to obtain stress results. Comparison of both materials was done keeping the boundary conditions same. Author concluded that there was a reduction of 33.99% of stresses when isotropic material (i.e. steel) is replaced with orthotropic material (i.e. E-glass/Epoxy). also there was reduction in displacement of about 0.026% .

## 2. MATERIAL AND METHODS

### *2.1 Experimentation:*

In the present work Al - 4.5 wt. % Cu alloy having theoretical density 2800 $kg/m^3$ is used as the base matrix. Fly Ash particulates with theoretical density of 2300 $kg/m^3$ and SiC particulates with theoretical density of 3200 $kg/m^3$were used as reinforcements. The size of the particulates is evaluated by Scanning Electron Microscope Analysis and it is clearly indicated inFigure.1 and 2.



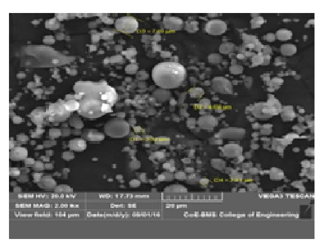


**Fig.1** **Fig.2**

**Fig. 1,2Scanning electron microphotographs of SiC&Fly Ash particulates.**

### *2.2 Fabrication of composites*

Al–4.5% Cu alloy which forms the base matrix which is in the billet shape is placed in the graphite crucible and heated to 780 ºC. The reinforcement of SiC particulates is weighed in the ratios of 5% &7% by keeping the constant weight percentage of Fly Ash which was preheated to 400 ºC to remove the moisture contents in the reinforcement. The reinforcements were preheated prior to their addition in the aluminium alloy melt. The preheating of the reinforcement is necessary in order to reduce the temperature gradient and to improve wetting between the molten metal and the reinforcements. The molten metal mixture was degassed at a temperature of 780 ºC. Usinghexa-chloroethane degassing tablet. The tablet helps inthe removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. The molten metal matrix Al–4.5% Cu alloy was stirred using a Stirrer to create a vortex and 0.4% wt. of mg was added to ensure good wettability and the preheated reinforcements were added to the molten metal mixture with a continuous stirring speed of 300 rpm to a time span of 3 minutes. The stirred molten metal mixture with the reinforcements is poured into the preheated cast iron die and the die was placed in a compression testing machine. The plunger is placed into the die and a load of 120 MPa was applied for 4 minutes. The melt was then allowed to solidify in the molds

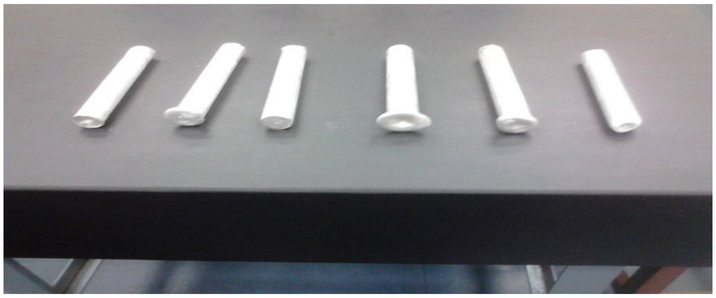


**Fig3. Squeeze casted composites**

The squeeze casted composites are further subjected to the secondary operations like forging in transforming the squeeze casted composite which is plastically deformed in the hydraulic press creating impressions in the upper and lower half of the die to get semi-finished connecting rod.

**Fig 4. Semi-finished connecting rod squeeze casted composites**

The semi-finished connecting rods are subjected to finishing process by removing the flash as shown in the Figure.5.

**Fig 5. Finished connecting rod squeeze casted composite**

# 3. RESULTS ANDDISCUSSION

## *3.1 FEM analysis of Connecting Rod*

FEM analysis of Connecting rod was carried out using Solid 45 element type and the material properties is listed as below.

1. Material Properties (From Tensile Test):

For Base alloy (Al- 4.5% Cu alloy) E = 70 GPa

For MMC1 (3% Fly ash and 3% SiC) E = 80.44 GPa

For MMC2 (3% Fly ash and 7% SiC) E = 82 GPa

The material properties are imported to Ansys for both base alloy and Metal matrix composites.

The modeling of the connecting rod as per the dimensions was modeled utilizing ANSYS as a tool asdepicted inFigure 6.

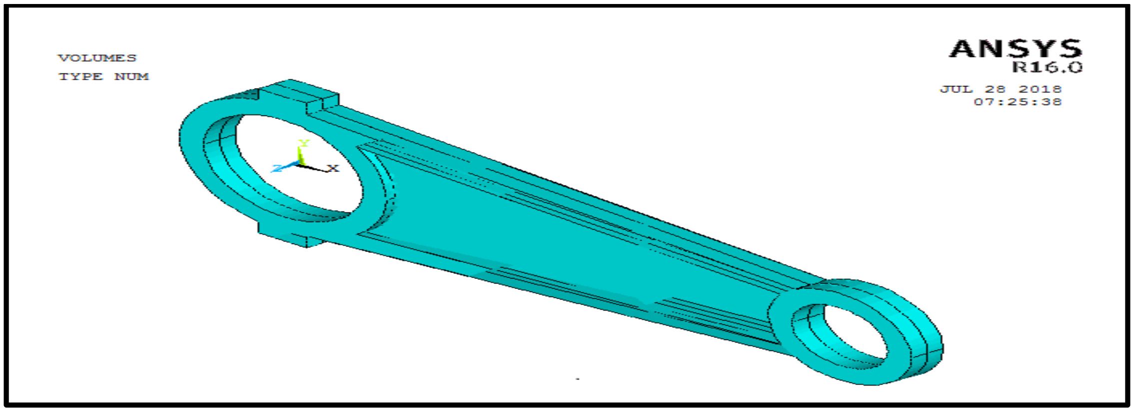



**Fig6.Modelling of Connecting Rod**

## *3.2 Loading and Boundary Conditions:*

In the pre-processing stage, the big end of the connecting rod is constrained ( Crank Shaft end) in all degrees of freedom and the Maximum load is applied at the small end of the Connecting rod (Piston end) is clearly highlighted as shown in Figure7..

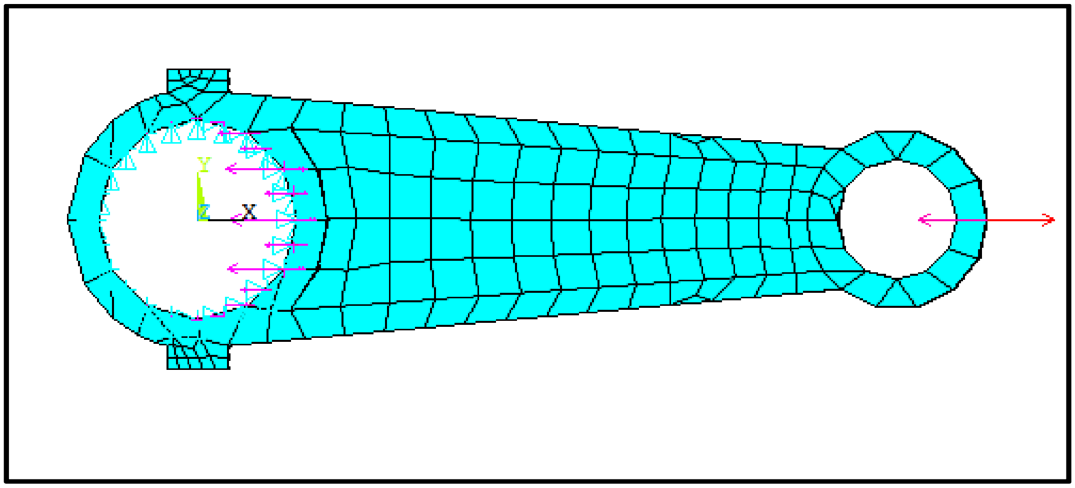


**Fig7.. Loading and Boundary conditions**

The meshing details of connecting rod utilizing the solid element and also I section is depicted in

Figure 8.

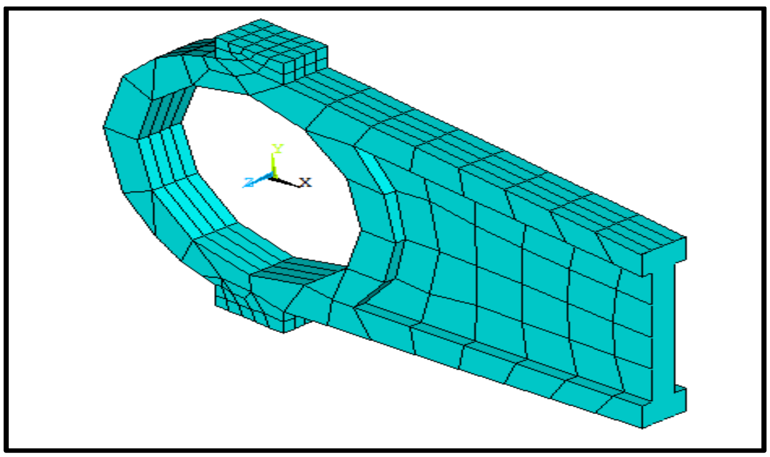


**Fig8. Meshing Details and I Section of the Connecting rod**

In I section, flanges are far away from the Centre of Gravity and therefore the I section is the must preferred section to withstand various types of load.

### *3.3 Post Processing Stage:*

The post processing plots like displacement, von-mises stress of connecting rod were analyzed for the base alloy, MMC1 (3% Fly ash and 3% SiC) and MMC2 (3% Fly ash and 7% SiC) and were tabulated as

in Table 1.

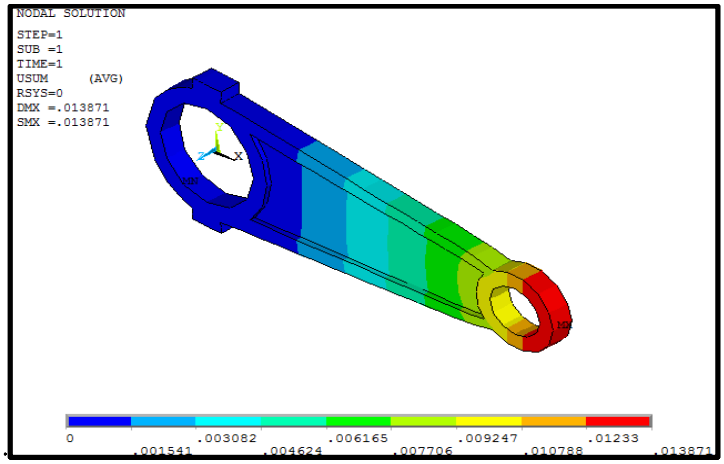



**Fig9. Displacement Plot of Base alloy (Al- 4.5% Cu alloy)**

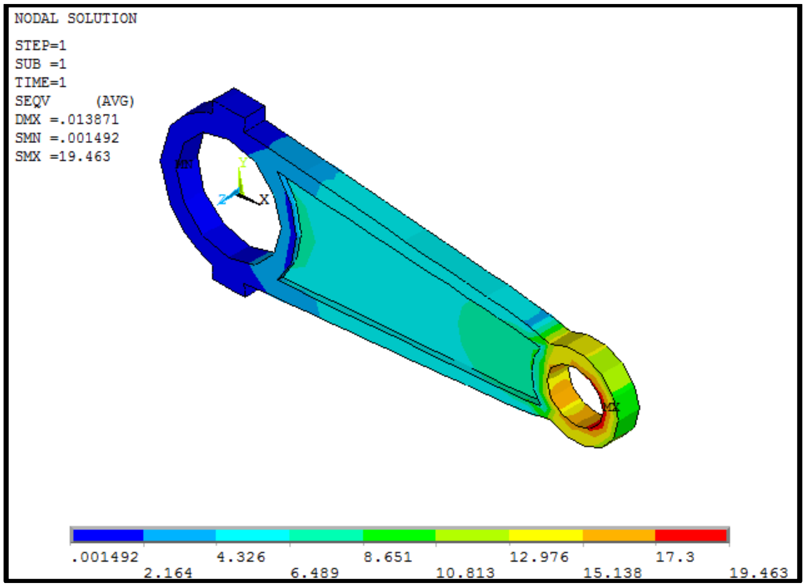



**Fig10.. Von-mises stress Plot of Base alloy (Al- 4.5% Cu alloy)**

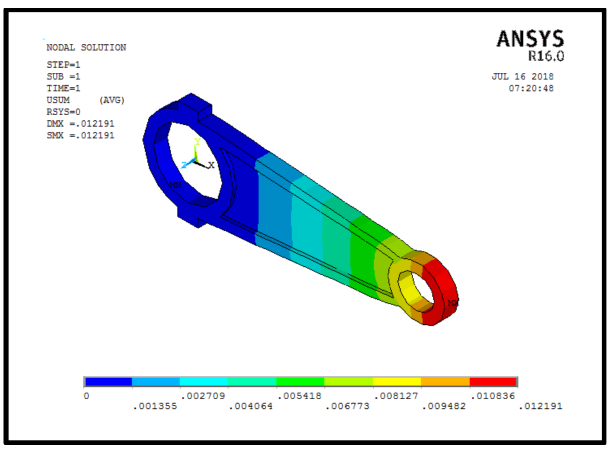



**Fig11. Displacement Plot of MMC1 (3% Fly ash and 3% SiC)**

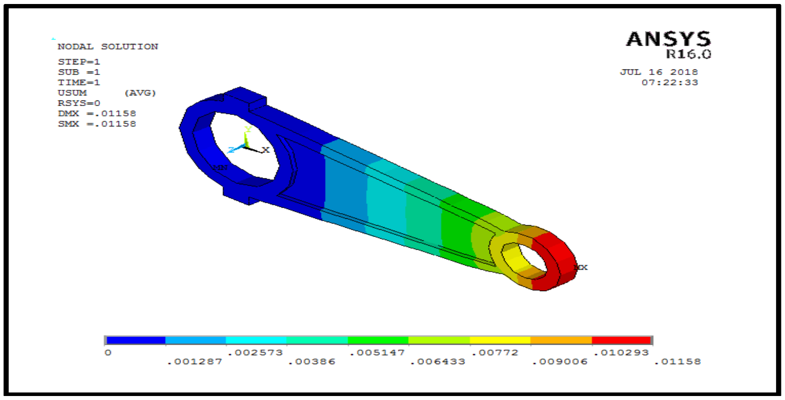



**Fig12. Displacement Plot of MMC2 (3% Fly ash and 7% SiC)**

Figure 9 - 12 represents the Displacement and Von Misses Plot of Base Alloy and Composite.

**Table.1 Analysis Results of Connecting rod**

| SL No | Material | Max Displacement (mm) | Von Mises Stress (MPa) |
|---|---|---|---|
| 1. 11 | Base alloy ( Al- 4.5% Cu alloy) | 0.0138 | 19.463 |
| 2. 222 | MMC1 ( 3% Fly ash and 3% SiC) | 0.0121 | 19.463 |
| 3. 3 | MMC2 ( 3% Fly ash and 7% SiC) | 0.0115 | 19.463 |

From the Table.1, the displacement of the developed composite is minimumin comparison with the base alloy.

## *3.4 Calculation of Allowable Stress/ Design Stress:*

The Base alloy ( Al- 4.5% Cu alloy) MMC1 and MMC 2 do not exhibit a definite yield point and therefore the calculation of Allowable stress is computed by considering the Ultimate tensile strength with a Factor of safety of 2.0.

The material properties of Base alloy, MMC1 and MMC 2 are clearly indicated in Table.2.

**Table2. Details of Mechanical Properties**

| SL No | Material | Yield stress (MPa) | Ultimate tensile Strength (MPa) |
|---|---|---|---|
| 1. | Base alloy ( Al- 4.5% Cu alloy) | 124 | 153 |
| 2. | MMC1 ( 3% Fly ash and 3% SiC) | 142 | 178 |
| 3. | MMC2 ( 3% Fly ash and 7% SiC) | 157 | 197 |

From the table2 it is understood that the Base alloy (Al- 4.5% Cu alloy) has the Maximum allowable stress of 153 MPa with the Factor of Safety of 2.0, and the Maximum allowable stress is 76.5 MPa. And for the MMC1 (3% Fly ash and 5% SiC) the Maximum allowable stress was 178 MPa and Maximum allowable stress was 89 Mpa. Also for the MMC2 (3% Fly ash and 7% SiC) the Maximum allowable stress is 197 Mpa and Maximum allowable stress obtained 98.5 Mpa.

## 4. CONCLUSIONS

The composites namely the base alloy (Al- 4.5% Cu alloy) , MMC1 (3% Fly ash and 5% SiC) and MMC2 (3% Fly ash and 7% SiC) were produced by Stir Squeeze Cast technique has led to the following conclusions.

- The young's modulus of MMC2 (3% Fly ash and 7% SiC) was found to be 15% more than the base alloy.
- The ultimate tensile strength of MMC2 (3% Fly ash and 7% SiC) was found to be 30%more than the base alloy.
- The Maximum allowable stress for MMC2 (3% Fly ash and 7% SiC) was found to be 15% more than the
- base alloy .
- ➢ From the FEM analysis of the connecting rod, It is clear that the MMC2 will withstand a maximum stress upto 98.5 MPa in comparison with Base alloy and MMC1.

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