



Structural Analysis of Connecting Rod Made by Heat Treated Al7075 Alloy Reinforced Aluminium Nitride Composites

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Abstract: Automotive sectors are concentrating more on weight reduction process, which can be achieved by incorporating new designs, cost-effective production processes, or employing alternative materials. Researchers have been attempting to optimize engine parts including the piston, connecting rod and crankshaft. The connecting rod, one of the most important components of an external combustion engine, is subjected to extremely high pressures from forces generated by the piston. It has been noted that the engine's efficiency is significantly increased by its reduced weight. Here, two alternate materials other than the connecting rods of existing material are introduced in an effort to reduce the connecting rod's weight. In this paper Al7075 and aluminum nitride (AlN) the new material for connecting rod is used. The ANSYS 21 R2 software performs the finite element analysis in accordance with the estimated loading conditions to analyze maximum shear stress, total deformation etc. The optimized results were then contrasted.

Keywords - Connecting Rod, FEA using ANSYS, Al7075, Aluminum Nitride.

I. INTRODUCTION

The engine's connecting rod, which is a moving part, transmits the pressure of the gas from the burned gases to the shaft. One of the three processes—casting, powder metallurgy, or forging—is used to make them. The most recommended procedure among them is forging since it yields incredibly robust components. The maximum gas pressure for Tata LPT diesel engine was computed by Biradar Akshaydatta Vinayakrol [1]. As he had selected the I-section for the connecting rod modelling, he determined the moment of inertia of either axis using the standard formulas. The thickness of the load on the I-buckling section is then determined. The connecting rod's dimensions, which are necessary for connecting rod modelling, were computed using thickness and other secondary formulas. The design tool Catia V5 is used to create the CAD model. The asymmetric component is employed in modelling. 0.25 cm mesh size was used to create the mesh. For high levels of accuracy, the parabolic tetrahedral element was selected. Steel 4340 and Al 7075-T651 were the materials selected for the study and the dynamic analysis was also performed. Using SOLID WORKS, Mohamed Abdusalam Hussin [2] developed a parametric model with many aluminium alloy grades. Suzuki 150 cc motorcycle engines was picked as the preferred type. By locating the sections of the connecting rod with low stress, he was able to lower the material cost. The mode form, frequency, and dynamic behavior of connecting rod made of various materials were determined by Gangadhar R. Patil [3]. He chose the Grey cast iron connecting rod in the end because of its suitably dynamic response. Abhishek Kumar [4] selected four different materials, however this time UNIGRAPHICS NX 11 modelling software was chosen. The best of these materials, aluminium alloy, was considered to be the most effective.

II. EXPERIMENTAL PROCEDURE

Preparation of composite

Al7075 matrix material's chemical composition is indicated in Table.1.

Table-1 chemical composition of Al7075 matrix material

Elements	Cu	Mg	Si	Fe	Mn	Cr	Zn	Ti	Al
chemical composition	1.539	2.191	1.783	0.290	0.275	0.117	4.416	0.047	89.3

Aluminum nitride has excellent thermophysical qualities, proper interfacial adhesion without interfacial reactivity, and high compatibility with aluminium alloy. As reinforcement, aluminium nitride with an average particle size of 75 to 150 m and a density of 3.26 g/cm³ is utilized. In the graphite crucible, the clean extruded Al7075 alloy is placed with 0.5% magnesium added to the alloy's total weight because magnesium functions as wetting agent to bind the reinforcement and matrix. It takes 30 minutes for the aluminium alloy to completely melt after the furnace's heating temperature is raised to 750° C. The surface of the molten metal is cleaned of

aluminium draught. Through the vertex side that was formed by the stir impeller's mechanical stirring, warmed aluminium nitride reinforcement was continually fed to the molten metal. Prior to doing this experiment, 450 rpm was the optimal speed discovered and chosen. This is done to prevent the casting from having an undesirable amount of porosity due to excessive gas content brought on by excessive metal agitation [5]. The stirring technique is used to help incorporate and evenly distribute particle aluminium nitride into the molten metal. The cast is immediately placed into a permanent mould after the mixture melts and is churned for five minutes. This prevents metals from contaminating the molten metal. The Al7075/AIN composite metal matrix that is solidified is taken out of the mould, and samples are made in accordance with ASTM standards for microstructural examination and mechanical property testing.,etc.

III. METHODOLOGY

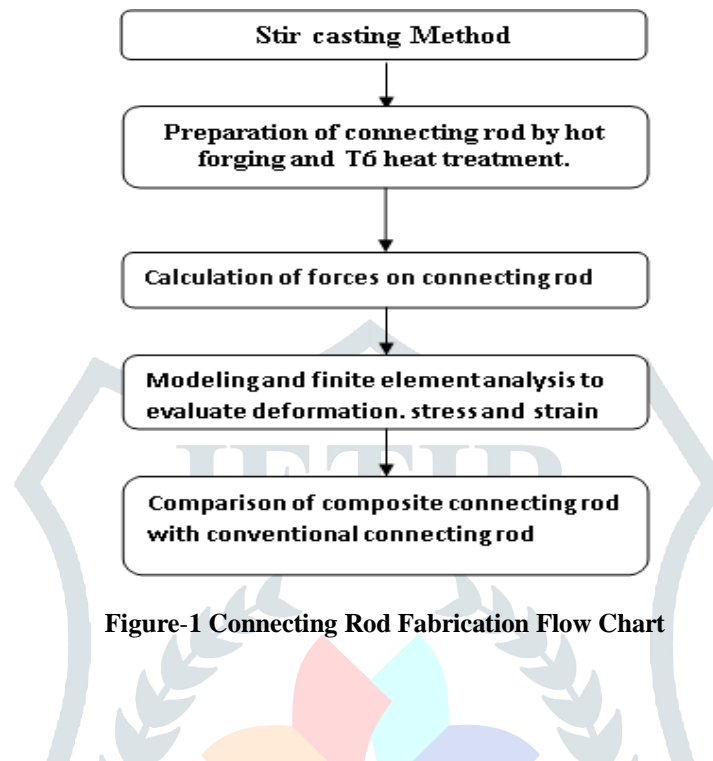


Figure-1 Connecting Rod Fabrication Flow Chart

IV. CONNECTING ROD



Figure-2 Connecting Rod-As forged

A connecting rod for an automotive application was developed by hot forging of the developed composites. The procedure [6] used for industrial forging of aluminum alloys was adapted for developing the connecting rod. A closed die with two cavities was used for forging trial. The composite bars were heated at $500 \pm 20^\circ\text{C}$ for 2h prior to forging. The process of forging was performed in six steps by closed-die forging. The forgings were obtained on a press with a capacity of 300 tonne with a deformation rate of 0.0107mm s^{-1} . Hot forging was followed by hot trimming.

V. DENSITY AND POISSON'S RATIO DETERMINATION BY THE RULE OF MIXTURES

Table 2: Determination of Density of the Composites Using Rule of Mixtures

Heat Treated Al7075 Composites	Volume Fraction (V_f)	Density of the Composite (ρ) (kg/m^3)
	$V_f = \left\{ \frac{\frac{M_f}{\rho_f}}{\frac{M_f}{\rho_f} + \frac{M_m - M_f}{\rho_m}} \right\}$	$\rho = \rho_f V_f + (1 - V_f) \rho_m$ (kg/m^3)
1kg - Al7075	0	2760
2% (20g AlN) (1kg - Al7075)	0.0374	2700
4% (40g AlN) (1kg - Al7075)	0.0721	2660
6% (60g AlN) (1kg - Al7075)	0.104	2620
8% ((80g AlN) 1kg - Al7075)	0.134	2580
10% (100g AlN) (1kg - Al7075)	0.162	2540

Poisson's Ratio of Composites Calculation Using the Rule of Mixtures

$$\nu = \nu_f V_f + (1 - V_f) \nu_m = 0.316$$

The Rule of Mixtures is used to evaluate the Poisson's ratio and density of Al7075 composite. Al7075 composites with 8% AlN reinforcement have a 2580 kg/m³ density, which is substantially less than forged steel's density, which is 7800 kg/m³. The cast Al7075 composite connecting rod has a lower mass due to its decreased density, facilitating engine acceleration and deceleration, which is very important in racing engines with high speeds.

VI. CALCULATION

A. Pressure calculation for connecting rod

Calculations 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

$$= 737.22 \times 10^{-9} \text{ kg/mm}^3$$

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

Mass = Density x volume

$$= 737.22 \times 10^{-9} \times 149.01 \times 10^3$$

$$= 0.1098531522 \text{ kg}$$

= 0.11423 kg/mole

From gas equation,

$$PV = m \times R_{\text{specific}} \times T$$

Where, P = Gas Pressure, MPa

V = Volume

m = Mass, kg

T = Temperature, °K

R_{specific} = Specific gas constant

$$R_{\text{specific}} = R/M = 8.3144/0.114228$$

$$R_{\text{specific}} = 72.788 \text{ Nm/kg K}$$

$$P = (m \times R_{\text{specific}} \times T)/V$$

$$P = (0.18356 \times 72.788 \times 10^3 \times 553.15)/(149.01 \times 10^3)$$

$$= 29.67 \sim 30 \text{ MPa}$$

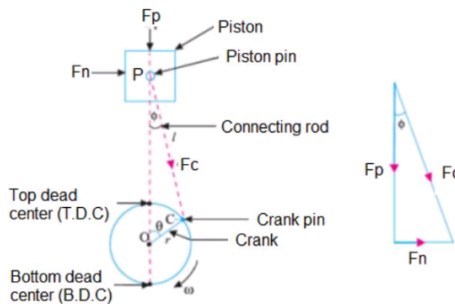


Figure 3: Forces on Connecting Rod

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

B. Calculation for total force

Total Force acting $F = F_p - F_I$

Where,

F_p = force acting on the piston

F_I = force of inertia

$$F_p = (\pi/4) \times D^2 \times \text{Gas pressure}$$

where, D = Bore

Diameter

$$F_p = (\pi/4) \times (58)^2 \times 15$$

$$= 39631.19133 \text{ N}$$

$$F_I = m \times \omega^2 \times r (\cos\phi + (\cos 2\phi)/n)$$

Where, M = Mass of the reciprocating part

ω = Angular speed of crank

$$= (2\pi N)/60$$

$$= (2\pi 9000)/60$$

$$= 942.47 \text{ rad/sec}$$

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

$$= (2 \times \text{stroke})/(\text{stroke}/2)$$

$$= 112.8/28.2$$

$$\therefore n = 4$$

Refer fig for ϕ , the maximum gas load occurs shortly after the dead centre position at $\phi = 3.3^\circ \cos(3.3) =$

$$0.9983 \cong 1$$

On substituting these

$$F_I = m \times \omega^2 \times r (\cos\phi + (\cos 2\phi)/n)$$

$$\therefore F_I = 0.10985 \times (942.47)^2 \times 0.0282 \times (1 + 1/4)$$

$$= 0.10985 \times 888249.70 \times 0.0282 \times 1.25$$

$$= 3439.49 \text{ N}$$

$$F = F_p - F_I$$

$$= 39631.19133 - 3439.49$$

$$= 36191.70133 \text{ N}$$

VI. ANALYSIS USING ANSYS

Connecting rod Modelling

For the present study, a connecting rod from a 150cc four-stroke single-cylinder Bajaj pulsar engine has been chosen. The connecting rod model is made using Catia V5 according to the dimensions. Figure 4 displays a model of a connecting rod.

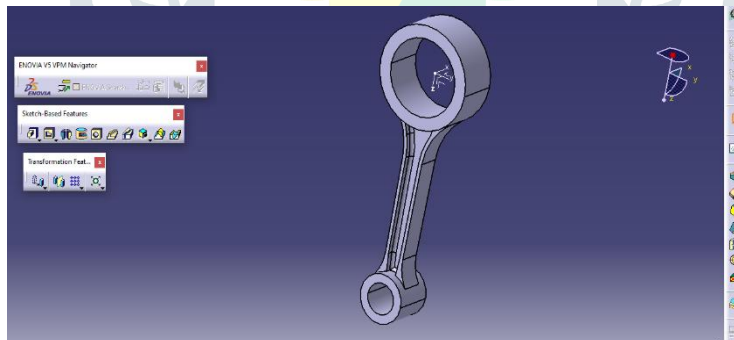


Figure-4 Connecting Rod 3D Model

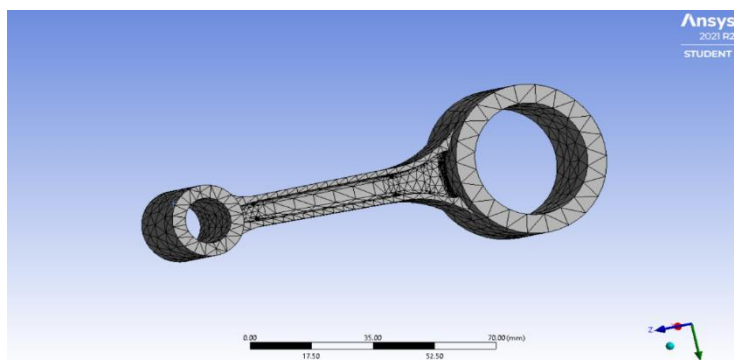


Figure-5 Connecting Rod is meshed

FEA OF FORGED STEEL CONNECTING ROD

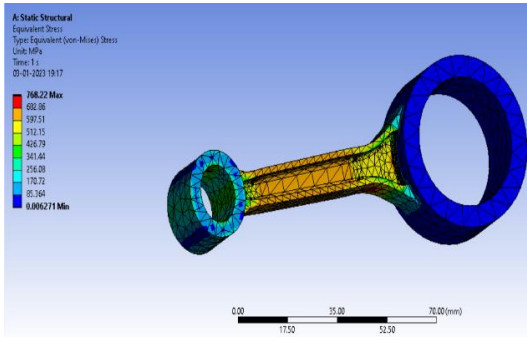


Figure-6 Forged steel Equivalent (von-Mises) Stress

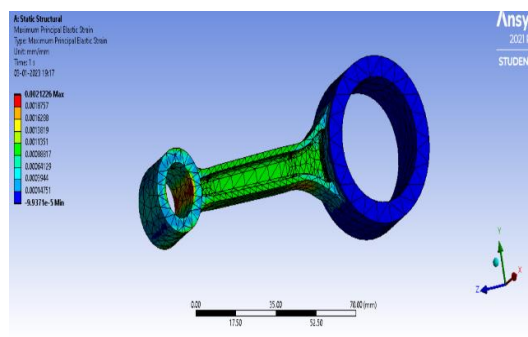


Figure-7 Forged steel Maximum Principal Elastic Strain

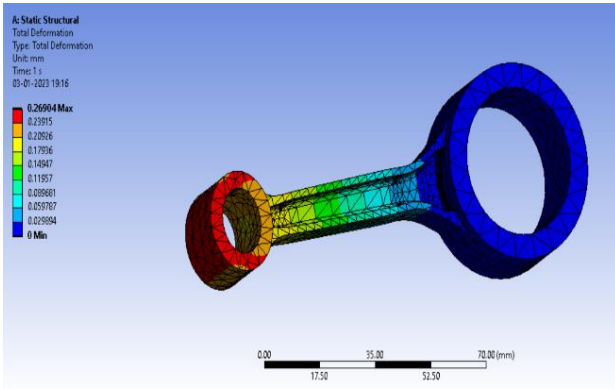


Figure-8 Forged steel Total deformation

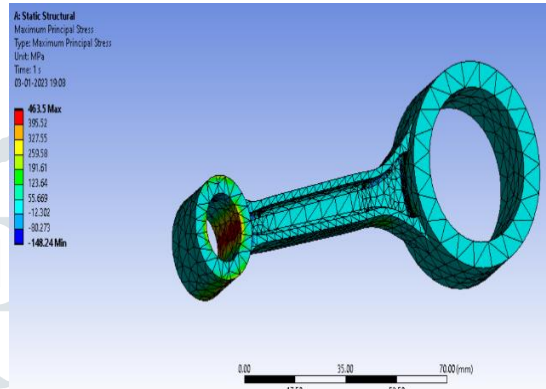


Figure-9 Forged steel Maximum Principal Stress

FEA OF Al7075 ALLOY CONNECTING ROD

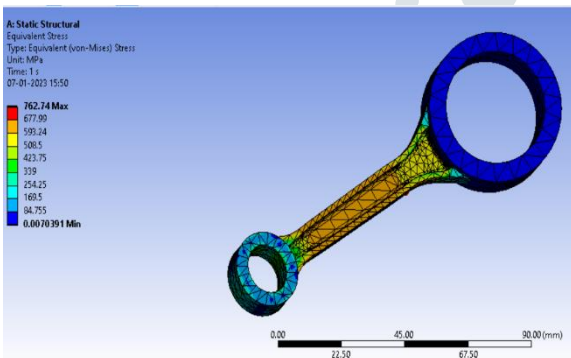


Figure-10 Al7075 alloy Equivalent (von-Mises) Stress

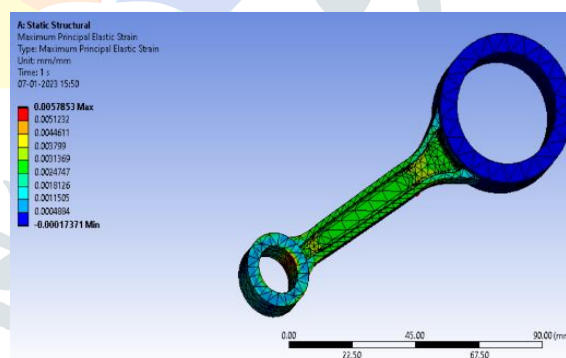


Figure-11 Al7075 alloy Maximum Principal Elastic Strain

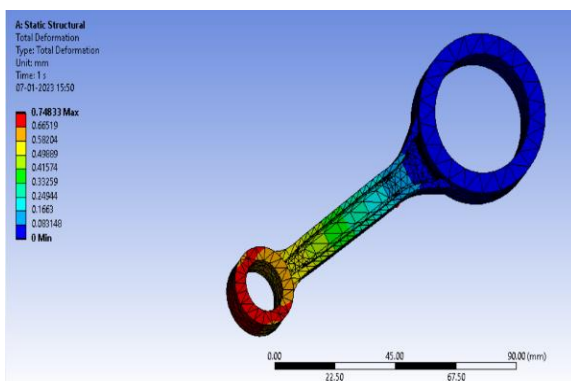


Figure-12 Al7075 alloy Total deformation

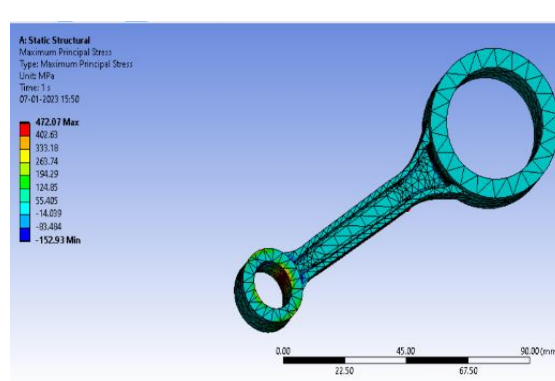


Figure-13 Al7075 alloy Maximum Principal Elastic Stress

FEA OF Al7075-AIN COMPOSITE CONNECTING ROD

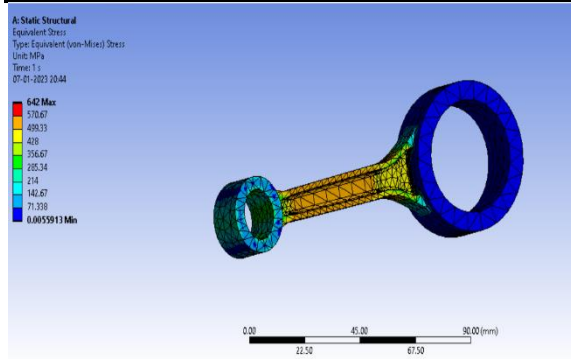


Figure-14 A17075-AIN Equivalent (von-Mises) Stress

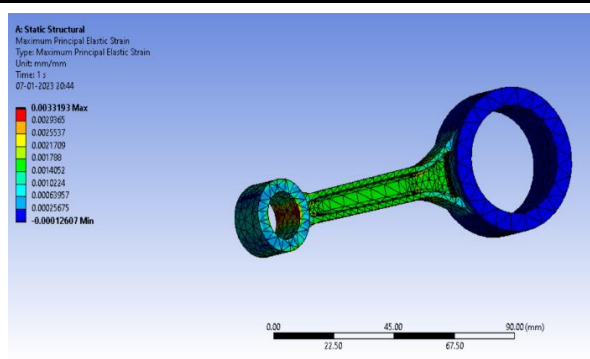


Figure-15 A17075-AIN Maximum Principal Elastic Strain

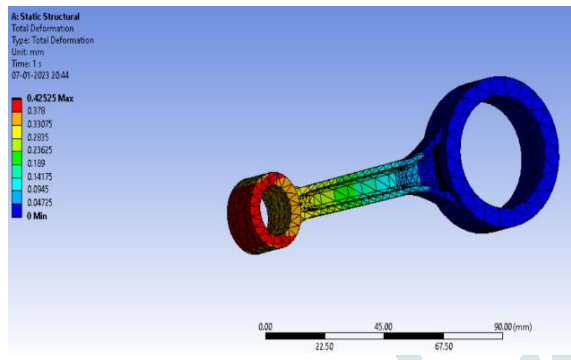


Figure-16 A17075-AIN Total deformation

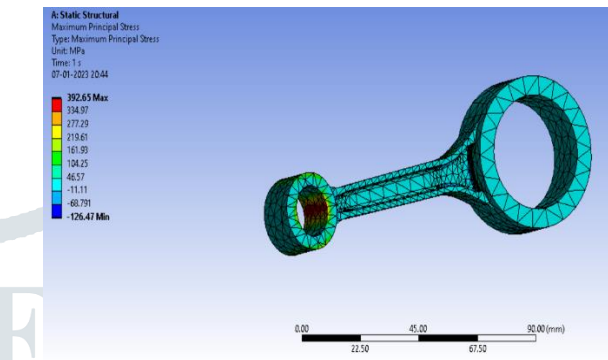


Figure-17 A17075-AIN Maximum Principal Elastic Stress

TABLE-3 Structural analysis Values of Connecting Rod

Parameters	Forged steel	Aluminium 7075 Alloy	AL7075-8%AIN composite
Equivalent (Von-Mises) Stress (MPa)	768.22	762.74	642
Total Deformation (mm)	0.26904	0.74833	0.42525
Maximum principal stress (mm/mm)	463.5	472.07	392.65
Maximum principal Elastic Strain (mm/mm)	0.002122	0.0057	0.003319
Mass(kg)	0.6942	0.2441	0.2281

CONCLUSIONS

Forged steel, aluminium alloy, and AL7075-AIN composite were used to model and analyse the connecting rod for a Bajaj motorbike. The connecting rods were all subjected to the same load, and it was discovered that the forged steel connecting rod had the highest von-mises stress while the aluminium alloy connecting rod had the highest degree of deformation. A17075-AIN composite connecting rod had the lowest stress of the three materials. With connecting rods made of aluminium alloy, the elastic strain was highest, while it was least in forged steel. A17075-8%AIN composite, which has the lowest mass and the highest strength to weight ratio among the three, was discovered to be the best material in the study.

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