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Structural Analysis of Small Aircraft Connecting Rod Made of Hybrid Composite Material

Hybride composite: Al-2024, Al_2O_3 and Graphite

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Abstract— **In IC engine, reciprocating motion of the piston is converted into rotary motion by using connecting rod (CR).It acts as the intermediate link between the piston and crank. Most of automobile connecting rods are made of steel, now a day's connecting rod are made of aluminum composite materials are used in race cars. The gas pressure inside the combustion chamber creates axial stress and inertial force due to reciprocation creates tensile and compressive stress on the connecting rod. In the present work, an investigation on structural behavior of connecting which is made of aluminum hybrid composite at different loading conditions. The Analysis done by using ANSYS WORKBENCH 15.0 and model is created in Pro/E WF4.0.Finallys comparison of analytical and FEA results are done.**

Keywords—Connecitng Rod; Piston force, Alumimum Hybride composites, Structural Analysis,FEA; ANSYS WORKBENCH 15.0, Pro/E

I. INTRODUCTION

Main function of connecting rod is to transmit the thrust of the piston to the crankshaft, and which results in conversion of reciprocating motion of piston into rotational motion of crank i.e linear motion into rotary motion. Due to reciprocating action created due to gas pressure and inertia loads, rods are subjected to the alternating loads of order 108 to 109cycle. It consists of a long shank, a small end, a big end. The cross-section of the shank may be circular, rectangular, tubular, I-section or H-section.

Sonsino and Esper (1994) have discussed the fatigue design of sintered connecting rods. They did not perform optimization of the connecting rod. They performed preliminary FEA followed by production of a prototype. Fatigue tests and experimental stress analysis were performed on this prototype based on the results of which they proposed a final shape. In order to verify that design was sufficient for fatigue, they computed the allowable stress amplitude at critical locations, taking the ratio, the stress concentrations and statistical safety factors into account and ensure that maximum stress amplitudes were below the allowable stress amplitude.

Pathade et al. (2012) analyzed the two most critical areas of the connecting rod. Specified dimensioned connecting rod was modeled in PROE which was later imported to ANSYS. In their problem statement three different loads were applied at pin end whereas the crank end was fixed. When theoretical and FEA results were compared.

II. MATERIAL PROPERTIES

Mechanical properties of Aluminum hybrid composite material are evaluated by experimental methods. The composition of composite are: Al-2024, 6 wt% of Al_2O_3 and 3 wt% Graphite. Al-2024 is the matrix and Al_2O_3, Gr are reinforcements. The reinforcements are distributed in random manner throughout the matrix, hence the material is considered as the isotropic.

Material Properties of Al-2024, Al_2O_3 and graphite	
Young's modulus	83.795 Mpa
Poisson Ratio	0.319
Density	2.809 g/cc3
Ultimate strength	275.92 N/mm2
Yield Strength	250.55 N/mm2

Table 1: Properties of Composite

III. ENGINE SPECIFICATION AND DIMENSIONS OF THE CONNECTING ROD

Engine specification	
Displacement (cc)	7.49
Bore (mm)	22.25
Stroke (mm)	19.28
Output (Kw/rpm)	1.30/17000
Practical rpm	2000-17500
Weight (g)	412

Table 2: Engine specification

Dimensions in mm	
Parameter	**Value**
Length of the CR	43.5
Big end outer diameter	9.8
Small end outer diameter	8.2
Big end inner diameter	6
Small end inner diameter	5.4

Table 3: Connecting rod dimensions

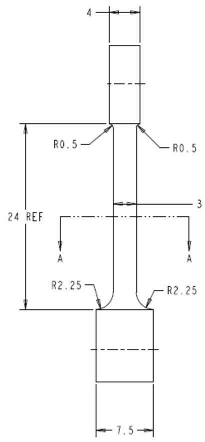

Fig 1: Side view and Dimensions of connecting rod

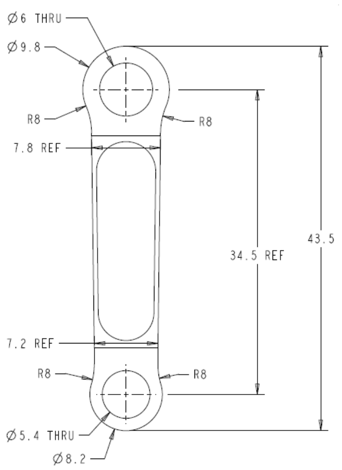

Fig 2: Top view and Dimensions of connecting rod

IV. LOAD CALCULATION

Mechanical efficiency of the engine η= 0.8
Output power BP= 1.30 kw
Indicated power IP= BP/η = (1.30/0.80) = 1.625 Kw
Indicated power IP: $\frac{(P_i\, LANnK)}{60000}$

Where
Pi = Mean effective pressure
L= Stroke length
D= Bore diameter
K=no. Of cylinder
N= N/2 For 4 stroke engine
N= Speed in RPM

N= N/2 = (17000/2) = 8500 rpm
A= (πd^2)/4 = (π(22.25)^2)/4 = 388.82 mm^2
Pi= (IP X 60000)/LAnK
Pi = (1.625 X 60000)/(19.28 X 388.82 X 8500 X 1)
= 0.001530 N/mm^2

At the TDC of piston,
Force transmitted through connecting rod
Piston force = Cylinder bore are X Mean affective pressure

= 0.001530 X 388.82

F_p = 0.5948 N

V. COMPONENT MODELING AND FEA OF CONNECTING ROD

Connecting rod is modeled as per the dimension shown in the fig 1 & 2, using Pro/E WF 4.0. Model is exported to desired folder in *IGES format. Model in *IGES format is imported to ANSYS WORKBENCH 15.0. Mechanical properties are specified to the model.

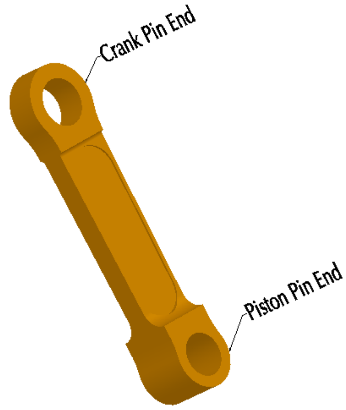

Fig 3: Pro/E model of Connecting rod

A. *Meshing*

Descritization of the domain into small sub domain is done by meshing. The elements used for meshing here is tetrahedron. Total number of element is 19196 and nodes are 37921.

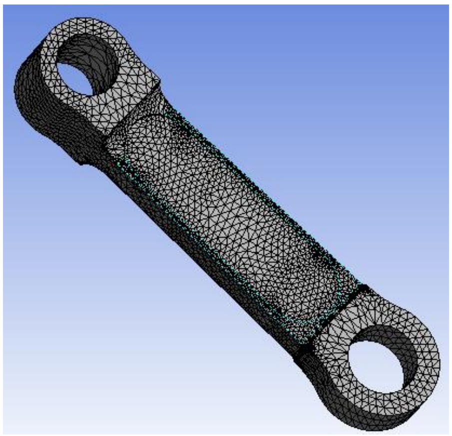

Fig 4: Mashed Connecting Rod

A. *Boundary conditions*

Loading condition	Tensile Load condition		Compressive Load condition	
Load application	Crank Pin End	Piston Pin End	Crank Pin End	Piston Pin End
Fixed constrain	Piston Pin End	Crank Pin End	Piston Pin End	Crank Pin End

Table 4: Boundary conditions applied to connecting rod

B. *Analytical Stress calculation at different cross sections*

Stress Along A-A

$$\sigma = \frac{P}{(b-d)t} = \frac{0.5948}{(9.8-6)4} = \mathbf{0.03913}\ N/mm^2$$

Stress along B-B

$$\sigma = \frac{P}{(b-d)t} = \frac{0.5948}{(7.8-0)4} = \mathbf{0.02542}\ N/mm^2$$

Stress along C-C

$$\sigma = \frac{P}{(b-d)t} = \frac{0.5948}{(7.2-0)4} = \mathit{0.02754}\ N/mm^2$$

Stress along D-D

$$\sigma = \frac{P}{(b-d)t} = \frac{0.5948}{(8.2-5.4)4} = \mathbf{0.02832}\ N/mm^2$$

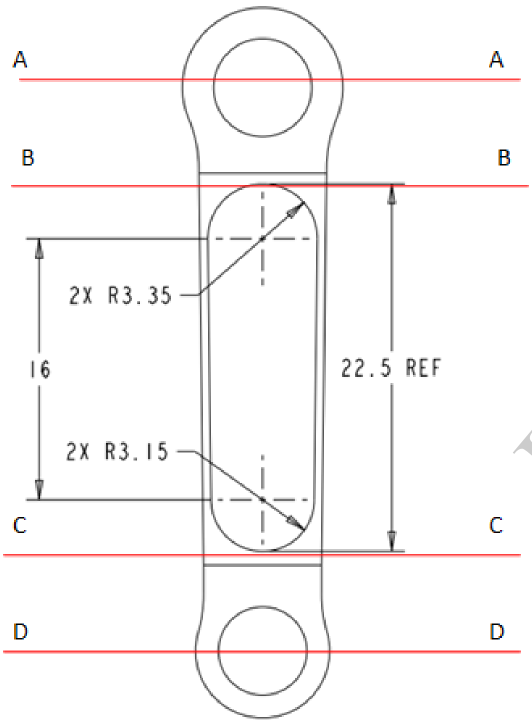

Fig 5: Sections of connecting rod

VI. RESULTS AND DISCUSSION

Results obtained in finite element analysis using ANSYS WORKBENCH are.

	Load Applied at	Load-N	Max.Von Mises Stress-N/mm2	Total deformation-m
Tensile Load condition	Crank Pin End	0.595	0.068409	1.55E-08
	Piston Pin End	0.595	0.042069	1.35E-08
Compressive Load condition	Crank Pin End	0.595	0.069547	1.53E-08
	Piston Pin End	0.595	0.046012	1.35E-08

Table 5: FEA results

a. *Tensile Load at Piston Pin End*

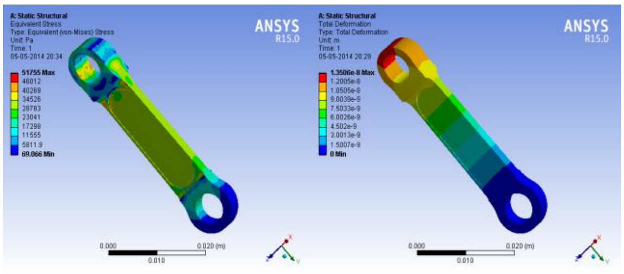

Fig 6: von mises stress and deformation for condition 'a'

b. *Tensile Load at Crank Pin End*

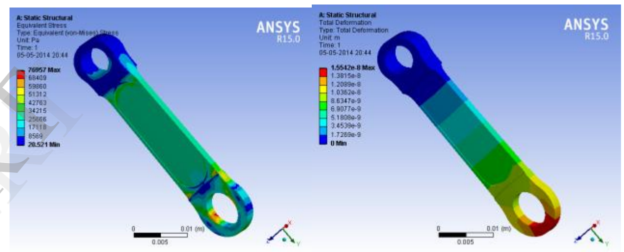

Fig 7: von mises stress and deformation for condition 'b'

c. *Compressive Load at Piston Pin End*

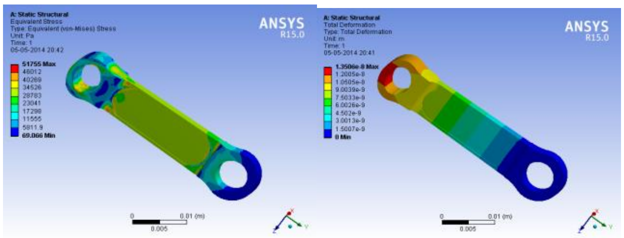

Fig 8: von mises stress and deformation for condition 'c'

d. Compressive Load at Crank Pin End

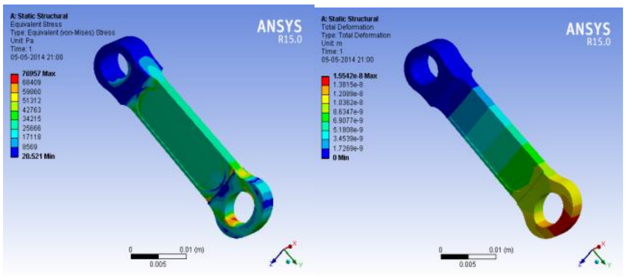

Fig 9: von mises stress and deformation for condition's'

The following factors have been found in the finite element analysis.

1. Maximum Von-mises stress occurred at the crank end and minimum at the piston end.
2. Max Deformation occurred at the side, where the application of load.
3. Stress induced is maximum at the circular ring section, so there is a chance of failure in that location.

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