International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

Linear Buckling Analysis of Connecting Rod using Composite Materials through FEM approach

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Abstract - *Composite materials are now widely used in the engineering field. The general characteristics possessed by the composite materials are found to be the reason for using it in the automotive applications. The objective of the project is to Evaluation of composite material connecting rod by using Aluminium 2024-T6, Aluminium 7075-T6, Carbon steel 43CrMo4, Ti-6Al-7v. The connecting rod primarily undergoes tensile and compressive loading under engine cyclic process. The forces acting on connecting rod are: - forces due to maximum combustion pressure, force due to inertia of connecting rod and reciprocating mass. Finite element method is used to analyse the connecting rod's stress, deformation and buckling load factor using ANSYS Software. For this case, a Static Structural and Eigenvalue Buckling Analysis will be performed. This analysis shows the importance of the solution of the connecting rod deformation in view of the changes in materials at the most important variants of the stress. This variant is frequently overlooked and primary importance is analysed with the strength. Factor of Safety and the Buckling load factor of connecting rod is checked and analysed*

Key Words: Connecting rod, Aluminium 2024-T6, Aluminium 7075-T6, Carbon steel 43CrMo4, Ti-6Al-7v, ANSYS, Eigenvalue Buckling, deformation, Maximum Von Mises Stress, Maximum Equivalent Elastic Strain, Factor of safety.

1.INTRODUCTION

The connecting rod or the con rod acts as a linkage mechanism between the piston and the crankshaft and it must have properties such as high strength, uniformity of mass and inertial mass. There is enormous amount of stress acting on the connecting rod due to the reciprocating motion of the piston and cylinder arrangement. There is continuous or repeated fluctuation in stress intensities, strain in a particular location in the connecting rod. This degradation at a particular location can be called as fatigue degradation. The con rod undergoes high cyclic loads of the order of 10^8 to 10^9 cycles, which ranges from high compressive loads due to combustion, to high tensile loads due to inertia. Therefore, durability of this component is critical importance. Lot of research has been carried out with different materials which can be used as substitute materials. This paper discusses the various composite materials which can be used as an effective replacement from the conventional steel. The materials have been chosen upon careful evaluation and according to the previous research works..

Webster et al. (1983) performed 3 dimensional finite component analysis of a high-speed ICE rod. For this analysis they used the utmost compressive load that was measured through an experiment, and also the most tensile load that is basically the inertia load of the piston assembly mass. The load distributions on the piston pin finish and crank finish were determined through an experiment. They sculptured the rod cap singly, and conjointly sculptured the bolt pretension victimisation beam components and multi purpose constraint equations.

In a study reported by Repgen (1998), supported fatigue tests distributed on identical parts fabricated from powder metal and C-70 steel (fracture rending steel), he notes that the fatigue strength of the cast steel half is twenty first more than that of the powder metal element. He additionally notes that victimization the fracture rending technology ends up in a twenty fifth price reduction over the standard steel shaping method. These factors counsel that a fracture rending material would be the fabric of alternative for steel solid connecting rods. He additionally mentions 2 alternative steels that square measure being tested, a changed micro-alloyed steel and a changed steel. alternative problems mentioned by Repgen square measure the requirement to avoid jig spots on the parting line of the rod and therefore the cap, want of consistency within the chemical composition and producing method to cut back variance in microstructure and production of close to internet form rough half.

Sarihan and Song (1990), for the improvement of the pin finish, used a fatigue load cycle consisting of compressive gas load correspond ing to most torsion and tensile load such as most inertia load. Evidently, they used the most hundreds within the whole operative vary of the engine. to style for fatigue, changed Benny Goodman equation with alternating octahedral shear stress and mean octahedral shear stress was used. For improvement, they generated associate approximate style surface, and performed improvement of this style surface. the target and constraint functions were updated to get precise values. This method was perennial until convergence was achieved. They additionally enclosed constraints to avoid fretting fatigue. The mean and therefore the alternating parts of the strain were calculated exploitation most and minimum values of octahedral shear stress. Their exercise reduced the rod weight by nearly twenty seventh.

Yoo et al. (1984) used variational equations of physical property, material by-product plan of time mechanics ANd an adjoint variable technique to calculate form style sensitivities of stress. The results were utilized in AN unvarying improvement algorithmic rule, steepest descent algorithmic rule, to numerically solve AN optimum style downside. the main focus was on form style sensitivity analysis with application to the instance of a rod. the strain constraints were obligatory on principal stresses of inertia and firing masses. however fatigue strength wasn't self-addressed. the opposite constraint was the one on thickness to sure it aloof from zero. they may acquire 2 hundredth weight reduction within the neck region of the rod. The optimum style

Hippoliti (1993) according to the methodology in use at Piaggio for rod style, which contains AN improvement session. However, neither the main points of improvement nor the load below that improvement was performed were mentioned. 2 constant quantity iron procedures exploitation 2nd plane stress and 3D approach developed by the author were compared with experimental results and shown to possess sensible agreements. The improvement procedure they developed was supported the 2nd approach.

For their optimization study, Serag et al. (1989) 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

Folgar et al. (1987) developed a fiber FP/Metal matrix composite connecting rod with the aid of FEA, and loads obtained from kinematic analysis. Fatigue was not addressed at the design stage. However, prototypes were fatigue tested. The investigators identified design loads in terms of maximum engine speed, and loads at the crank and piston pin ends. They performed static tests in which the crank end and the piston pin end failed at different loads. Clearly, the two ends were designed to withstand different loads.

Balasubramaniam et al. (1991) according procedure strategy utilized in Mercedes- Benz victimisation samples of engine parts. In their opinion, 2nd iron models will be accustomed acquire fast trend statements, and 3D iron models for a lot of correct investigation. the varied individual hundreds working on the rod were used for playing simulation and actual stress distribution was obtained by superposition. the masses enclosed inertia load, firing load, the press work of the bearing shell, and also the bolt forces. No discussions on the optimisation or fatigue, particularly, were bestowed.

2. MATERIAL PROPERTIES

The various materials were chosen based on[1] and the properties have been mentioned in this section.

2.1 ALUMINIUM 2024-T6

Brinell Hardness = 120, Elastic (Young's, Tensile) Modulus = 73.1 GPa, Tensile Strength: Ultimate (UTS) = 469 MPa, Tensile Strength: Yield (Proof) = 324 MPa, Elongation at break = 19%,Fatigue Strength = 138 MPa,Poisson's Ratio = 0.33, Shear Modulus = 28 GPa, Shear Strength = 283 Mpa, Aluminium alloy 2024 has a density of 2.78 g/cm^3 (0.1 lb/in^3), electrical conductivity of 30% IACS, Young's Modulus of 73 GPa (10.6 Msi) across all tempers, and begins to melt at 500 °C (932 °F). 2024 aluminium alloy's composition roughly includes 4.3-4.5% copper, 0.5-0.6% manganese, 1.3-1.5% magnesium and less than a half a percent of silicon, zinc, nickel, chromium, lead and bismuth.

2.2 ALUMINIUM 7075-T6

Brinell Hardness = 150,Elastic (Young's, Tensile) Modulus = 70 GPa,Tensile Strength: Ultimate (UTS) = 560 MPa,Tensile Strength: Yield (Proof) = 480 MPa, Elongation at break = 7.9%,Fatigue Strength = 160 MPa, Poisson's Ratio = 0.32, Shear Modulus = 26 GPa, Shear Strength = 330 MPa

2.3 CARBON STEEL 43CrMo4

Young's modulus = 200000MPa, Tensile strength = 650-880MPa, Elongation = 8- 25 %, Fatigue = 275 Mpa, Yeild strength =350 – 550 MPa

2.4 TITANIUM ALLOY Ti-6Al-7V

Brinell Hardness = 334, Elastic (Young's, Tensile) Modulus = 113.8 GPa,Tensile Strength: Ultimate (UTS) = 950 MPa,Tensile Strength: Yield (Proof) = 880 MPa,Elongation at break = 14%,Fatigue Strength = 240 MPa,Poisson's Ratio = 0.342,Shear Modulus = 44 GPa.,Shear Strength = 550

3. FEM ANALYSIS

The following Analysis was done using Ansys WorkBench v16.0. A typical simulation consists of setting up the model and the loads applied to it, solving for the model's response to the loads, the design has 77544 nodes and 46511 elements as shown in Fig 1.

Fig 1: Meshed connecting rod showing the various elements and nodes of the mesh

The boundary conditions that has been applied on the connecting has been shown in Fig 2. The bearing load of 22397N as calculated [1] was applied by selecting the inner surface of the small end. The big end was fixed by arresting all the Degrees of freedom. Hence the load will be acting only on the small end.

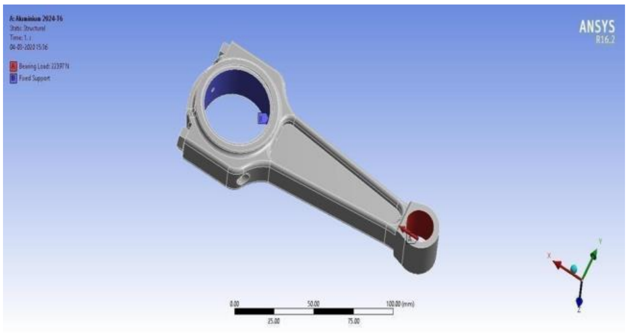

Fig 2: The boundary condition is set with the big end being fixed and the bearing load applied at small end

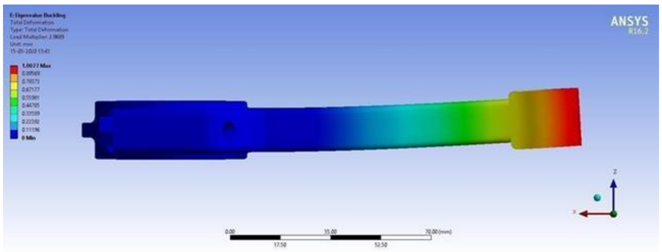

Fig 3: Buckling Analysis – Mode 1

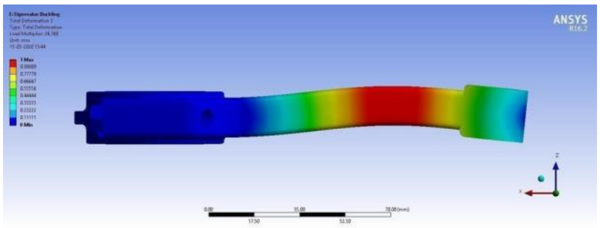

Fig 4: Buckling Analysis – Mode 2

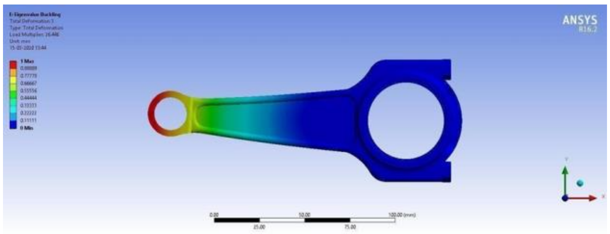

Fig 5: Buckling Analysis – Mode 3

4. RESULT AND DISCUSSION

The Results were taken for the materials and were tabulated as shown in Fig 6. The Maximum Deformation, Mazimum Von- Mises Stress, Maximum Equivalent Strain and the Factor of Safety were found out. It can be seen that the maximum deformation occurs in Aluminium 7075 – T6 whereas the Carbon Steel undergoes very minimal changes in the deformation. Maximum Von-Mises stress was observed in Titanium allow and the minimum in Aluminium 2024- T6. Maximum Equivalent Elastic Strain was observed in Aluminium 7075-T6 and minimum in the Carbon Steel. As far as Factor of Safety is concerned the permissible limit 4-6 but the aluminium doesn't stand a chance and hence carbon steel and Titanium alloy fall within the range.

It can be seen from the Graph that carbon steel seems to have the least value in all the graphs as shown in Fig 7, Fig 8 and in Fig 9 it has the highest Factor of safety as discussed earlier.

Material	*Maximum Deformation (mm)*	*Maximum Von-Mises Stress (MPa)*	*Maximum Equivalent Elastic Strain (mm/mm)*	*Factor of Safety*
Aluminium 2024-T6	0.15597	198.63	0.00302	2.36
Aluminium 7075-T6	0.16307	203.98	0.00315	2.81
Carbon Steel 43CrMo4	0.06147	208.51	0.00122	4.8
Ti-6Al-7V	0.10849	210.74	0.00212	4.52

Fig 6: Table showing the different values obtained from the FEM Analysis of the Connecting rod for the various composite materials

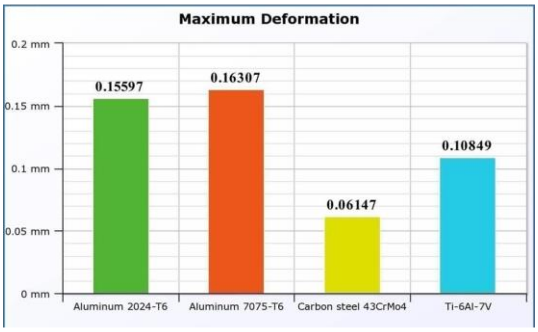

Fig 7: Graph indicating the various levels of maximum deformation

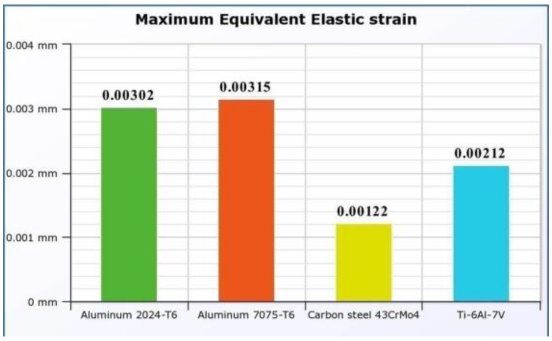

Fig 8: Graph indicating the various levels of maximum equivalent elastic strain

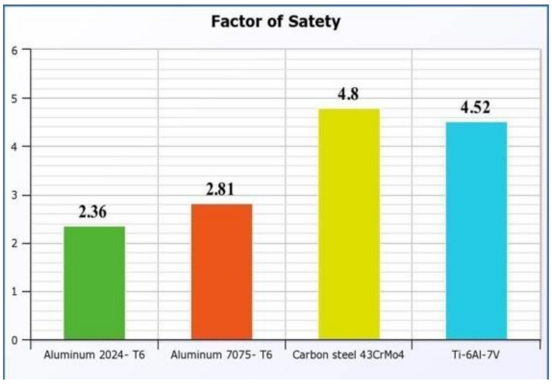

Fig 9: Graph indicating the various levels of factor of safety

Material	MODE 1	MODE 2	MODE 3
Aluminium 2024-T6	1.9723	16.446	17.543
Aluminium 7075-T6	1.9372	16.153	17.231
Carbon Steel 43CrMo4	5.1234	42.767	45.7
Ti-6Al-7V	2.9689	24.769	26.446

Fig 10: Table showing the values obtained in three different modes for the various composite materials

Eigen value Linear Buckling Analysis was done for the four composite materials at three different modes. The Mode shapes have been shown in Fig 3, Fig 4 and Fig 5. Carbon steel seem to have an upper hand over the other three composite materials and this shows that the carbon steel is an appropriate material compared to Aluminium alloys and Titanium alloy

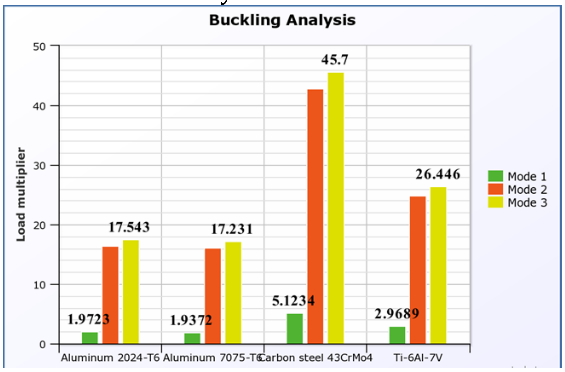

Fig 11: Graph indicating the loads at which the buckling happened three different modes

5. CONCLUSIONS

From the above work it is clear that titanium alloy is the best for manufacturing of connecting rod. As it has the best von-mises stress, but the cost of the titanium alloy is much higher than other materials . Carbon steel:43CrMo4 is second choice for production although it has a lower von-mises stress than titanium alloy but the factor of safety of carbon steel much higher than titanium alloy. It can also be observed that aluminium alloy 2024-T6 & aluminium 7075 –T6 is not effective as its factor of safety is low and product may fail. It can also be concluded that carbon steel has greater factor of safety & lower total deformation than any other materials from the above results and carbon steel is also cheapest material than aluminium 7075-T6 Where when we look into the Eigenaluve buckling analysis the Carbon steel : 43CrMo4 is considered to be having the highest Buckling load factor. So we conclude that Carbon Steel :43CrMo4 will be the suitable material for Connecting rod to increase the engine efficiency and lifetime.

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