Design and Analysis to Improve Buckling Strength of Light Vehicle Connecting Rod

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Abstract -
Depending on the number of cylinders in the engine, any vehicle that use an internal combustion engine requires at least one connecting rod. It is subjected to intense cyclic stresses. These loads might range from high compressive loads caused by combustion to high tensile loads caused by inertia. As a result, the component's long-term durability is crucial. As a result of these considerations, the connecting rod has been the subject of research in a variety of areas, including production, materials, performance simulation, and so on.
In this study, several materials such as aluminium, titanium, and C70 steel, as well as high strength carbon fibre, are compared to existing materials. The primary goal of this project is to find new materials that can be used to replace existing materials while also increasing buckling strength with reducing weight.

***Key Words*: Buckling strength, Connecting rod, Four wheeler (light vehicle).**

1. INTRODUCTION

Due to the demand for downsized engines, greater specific power and increased mechanical efficiency, reciprocating power cylinder components are expected to exert less force on the cylinder walls to more efficiently transfer the combustion force in the cylinder to a reciprocating motion by the crankshaft, mainly by means of lighter weight. At the same time, these lighter cylinder components are expected to maintain sufficient strength and safety even as internal combustion engines have significantly increased both specific power and maximum speed during the last decade. One critical cylinder component is the connecting rod, which transfers the oscillating movement of the piston into the rotating movement of the crankshaft. The connecting rod must not only provide the stiffness and the strength to withstand the cylinder pressure and inertia forces of the engine, but must also be of minimal mass. Additionally, the hydrodynamic performance of the small end and big end must be considered and optimized in order to improve wear and friction properties and to meet tougher NVH requirements.

This included Visual observation, metallurgical testing, magnetic particle testing, fractography analysis by stereo and scanning electron microscopy, residual stress analysis, dimensional inspection, chemical analysis, Brinell hardness testing, tensile testing, inclusion analysis, microstructure analysis and grain flow analysis. Connecting Rod is one of the most important components of reciprocating internal combustion engine. It acts as a link between piston and crankshaft to convert the traverse motion of the piston to rotational motion of the crankshaft. It consists of small end (piston side), big end (Crank side) and I-section. Small end and big end are machined to ensure proper fitting of bush (at small end) and Bearings (at Big end). The small end is connected to piston through piston pin. The small end exhibits reciprocating motion while the Big end which is split in two parts for clamping it on the crankshaft exhibits rotational motion. Due to its operational nature, complex state of stresses which includes compression stresses associated to the pressure exerted by the combustion gases, and tensile stresses related to the inertia of the components in motion, either alternative or rotational. Increasing trend of higher power density engine and harsh emission regulation tends to increase the mean effective pressure and the peak firing pressure. There are all four critical areas of the connecting rod the small end or pin end, the shank or I-beam, the crankshaft or big end and the bolted joint. A solution for an optimized component layout will be provided that combines excellent strength and improved durability with reduced mass. This optimized solution will enable automakers to design engines with higher fuel efficiency and greater reliability in order to meet the challenges of the future.

2. LITERATURE REVIEWS

[1] “Connecting Rod Buckling Analysis Using Eigenvalue and Explicit Methods” by Arden Anderson, Mercury Marine; Masahiro Yukioka, Mercury Racin.

In this research it presents the designing a connecting rod. The buckling strength is heavily affected by the beam section, and Johnson's buckling equation is used to estimate the buckling strength of a given beam section. This approach is acceptable if the beam section geometry is constant from the small end to the big end. But, recent expectations for light weight, low NVH, and low fuel consumption engines require optimizing the connecting rod section geometries to be progressively changing from the small end to the big end. Finite Element Analysis (FEA) is often used to evaluate the buckling strength of a rod that has complex changes in beam section.

[2] "Optimization Methods Applied to Automotive Connecting Rod Mechanical Design" by Rafael Augusto De Lima E Silva, Marco LúcioBittencourt

In this journal it concludes that the mechanical design of automotive connecting rods is essentially guided by analytic calculations followed by numeric methods to assess the stresses, displacements, contact pressures, fatigue and buckling. In this work it applies an alternative methodology based on the method of topology optimization to design the connecting rod aiming mass reduction. Two connecting rods designs were developed using two different methodologies, which the methodology considering the topology optimization generated a 3% lighter connecting rod and with improved lubrication performance when compared with the conventional design obtained from the current design methodology.

[3]"Fatigue Failure Analysis of Diesel Engine Connecting Rod" by Md Tauseef Alam, Anil Thakur, Venkatesh Kumar PS, and SatayaGhadei

In these article it suggests that the connecting rod of a high-performance reciprocating internal combustion engine is one of the critical components exhibiting complex motion. This is subjected to both compressive load due to combustion force as well as tensile load due to inertia of the moving components. These loadings are cyclic in nature and the component is highly prone to fatigue failure if not deigned or manufactured carefully. Therefore, connecting rods are designed and manufactured with high degree of precision for infinite loading cycle. But failures in connecting rod is often reported which is associated to either fatigue, bending, bearing failure or assembly faults.

[4] "Advanced Connecting Rod Design for Mass Optimization" by Michael T. Lapp, Roger A. Krause, Christopher C. Hall, Dan H. Dinu and Alex Antoc

In this paper it is discussed that an effort to optimize the connecting rod of an internal combustion engine for both mass and reliability, an all-new forged steel design has been developed that is 37% lighter than the lightweight production design. The connecting rod has been optimized using 3D Modeling, FEA, advanced numerical simulation such as PIMO3D, and a variety of mechanical testing and lessons learned. The four critical areas of the connecting rod are defined and discussed in detail, and an optimization solution for each area is presented. Finally, the optimized connecting rod incorporating all of the knowledge and information from the previous sections is presented.

[5] "Optimized Power Cell Unit in IC Engine – Design for Light Weight and High Strength Piston and Connecting Rod" by Dan Dinu and Michael T. Lapp MAHLE

In this article it concluded that the optimization of the connecting rod covers material and design features in order to reduce weight and improve function. Material selection for connecting rods has to consider functional and manufacturing aspects. Function The basic criterion for optimum function of the component is the fatigue strength of the material. High fatigue strength allows a reduction in the cross section and this contributes to overall weight reduction of the component.

[6] "Connecting Rod Optimization for Weight and Cost Reduction" by Pravardhan S. Shenoy and Ali Fatemi the University of Toledo

In this journal it presents an optimization study on a steel forged connecting rod with a consideration for improvement in weight and production cost. Since the weight of the connecting rod has little influence on its total production cost, the cost and the weight were dealt with separately. Reduction in machining operations, achieved by change in material, was a significant factor in manufacturing cost reduction. Literature survey suggests cyclic loads comprised of static tensile and compressive loads are often used for design and optimization of connecting rods.

[7] "Development and Application of Buckling Estimation Method in Engine Connecting Rod" byHeewook Moon, Sungwon Shin, Kyungwoo Lee, Hoon Chang and DaejoonYeom

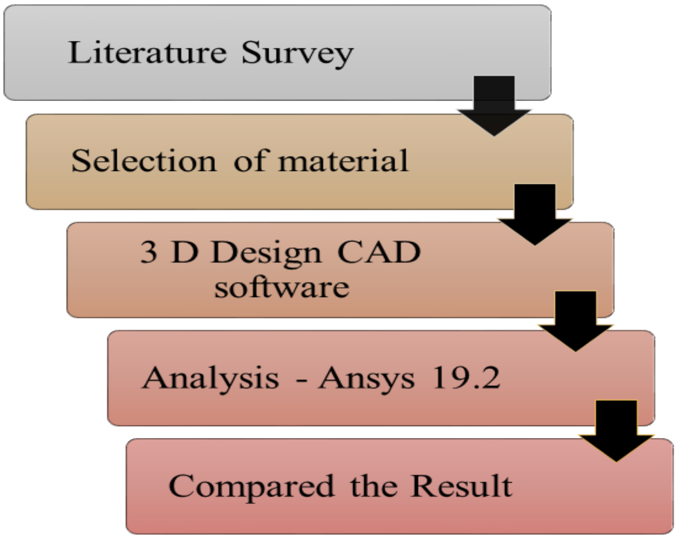
In these research it presents the studies of automobile engineering on developing the high performance and high fuel efficiency engine. Particularly most engineers have tried to reduce the weights of moving components of the engine for achieving high fuel efficiency. However, the connecting road (hereafter referred as connecting rod) tends to be overdesigned for the reliability since it is one of the main moving parts transferring the huge ignition pressure to the crankshaft. The connecting rod consists of a small-end transferring the ignition pressure through the piston, a big-end gripping the crankshaft, and finally a shank linking small-end and big-end. The reduction of cross section of shank brings a light connecting rod but increases the possibility of buckling failure as well therefore the buckling analysis in the early design phase has to be carried out.

2.1. OBJECTIVES

- Modelling four-wheeler connecting rod in 3D Design software.
- Find out the new material which can replace the existing material

- To perform static analysis for existing 4-wheeler connecting rod with composite reinforcement to determine the enhancement in mechanical properties under buckling analysis in ANSYS 19 software.
- Reduce the weight of the connecting rod and Improve the Buckling Property.

2.3. RESEARCH METHODOLOGY:



Flow chart .01
Organization of the Project (Methodology Detail)

[1]. I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers, we learnt about buckling strength of 4 wheeler connecting rod.

[2]. After that the components which are required for our project are decided. after finalizing the component, we can also find out the different material which we are use in this Project like aluminum, High strength carbon fiber, titanium, C 70 steel etc.

[3]. After deciding the components, the 3D Model will be done with the help of Solid works software.

[4]. The Analysis of the components will be done with the help of ANSYS using FEA.

[5]. In the analysis we are performing Static structure analysis for connecting rod in buckling with different material.

[6]. Comparative analysis between the Existing material & analysis result of other material which we are consider.

3. DESIGN AND ANALYSIS:

In the project we are creating 3D CAD Model Drawn in the SOLID WORKS software show in the figure 1.

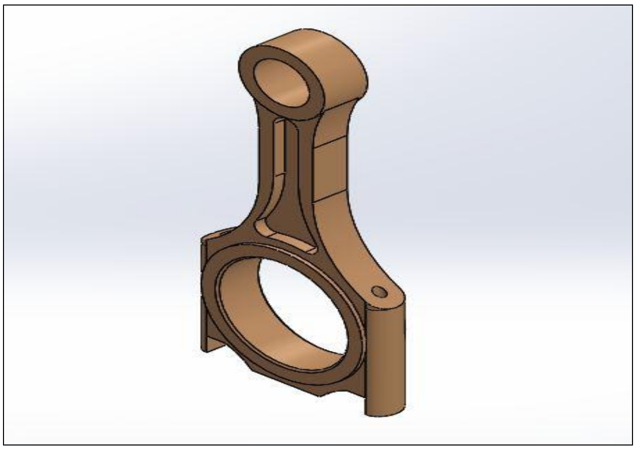


Fig. 1: Connecting Rod Model in Solid works

The figure 1. show that 3D CAD model of Connecting rod after completing the 3D model we moved for the drafting of the component.

The drafting of the component is show in the figure 2 and providing the dimension of the component.

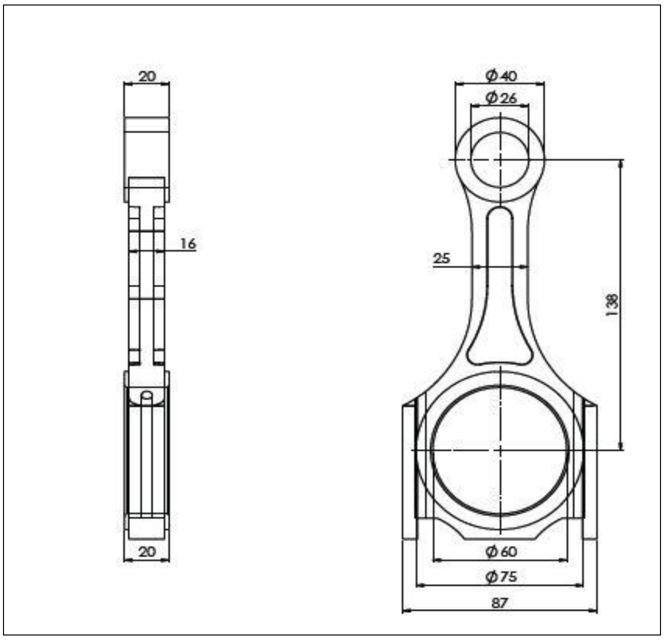


Fig. 2: Connecting Rod Draft in Solid works

3.1. Calculations

Bore diameter – 75 mm

Stroke length – 95 mm

Bore x Stroke (mm) = 75 × 95

Displacement – 3.14/2 x (Bore diameter)2 x Stroke length

Displacement = 419.4 CC

Maximum Power = 60 PS @ 4500 rpm

Maximum Torque = 105 Nm @ 2500 rpm

Compression Ratio = 9/1

Density of Petrol C8H18 = 737.22 kg/m3

= 737.22E-9 kg/mm3

Temperature = 600 F= 288.8550 K

Molecular Weight of Petrol - 114.228 g/mole

From Gas Equation,

PV = mR specific T

P = Pressure, V= Volume, m = Mass, T = Ideal room temperature and R specific = Specific gas constant

Mass = Density × Volume

= 737.22E-9 x 419.4 X E3

= 0.309 kg

R specific = R / M

= 8.314 / 0.309 = 26.88 J / kgK

Maximum pressure exerted on the surface of small piston end

P = (0.30 × 26.88 ×288.85) /4.19 X E-4

P = 5.5 MPa.

4. MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multi physics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation. Creating the most appropriate mesh is the foundation of engineering simulations. ANSYS Meshing is aware of the type of solutions that will be used in the project and has the appropriate criteria to create the best suited mesh. ANSYS Meshing is automatically integrated with each solver within the ANSYS Workbench environment. For a quick analysis or for the new and infrequent user, a usable mesh can be created with one click of the mouse. ANSYS Meshing chooses the most appropriate options based on the analysis type and the geometry of the model. Especially convenient is the ability of ANSYS Meshing to automatically take advantage of the available cores in the computer to use parallel processing and thus significantly reduce the time to create a mesh. Parallel meshing is available without any additional cost or license requirements.

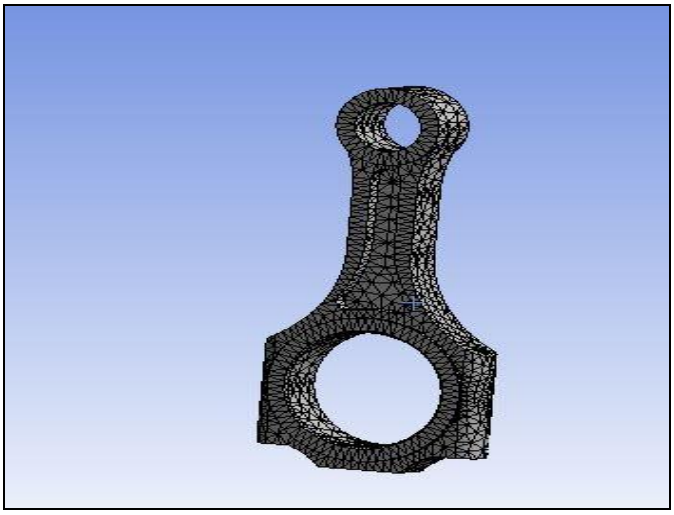


Fig. 3: Meshing of steel material

Statistics	
Nodes	17031
Elements	9529

Fig. 4: Meshing Details of stainless-steel material

4.1. Boundary Condition

A boundary condition for the model is that the setting of a well-known value for a displacement or an associated load. For a specific node you'll be able to set either the load or the displacement but not each. The main kinds of loading obtainable in FEA include force, pressure and temperature. These may be applied to points, surfaces, edges, nodes and components or remotely offset from a feature.

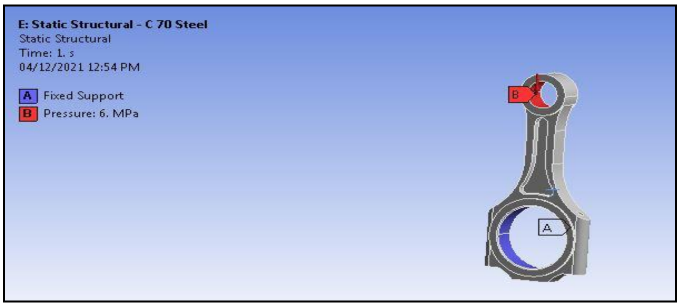


Fig.5: Boundary condition

FEA Result of Steel

- **Equivalent stress**

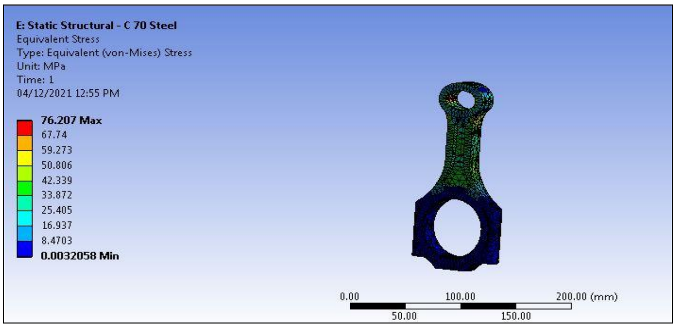


Fig. 6: Details of Equivalent Stress of stainless-steel material

In the boundary condition of the steel we give the Pressure to the component of 6 Bar. So that the Equivalent stress in connecting rod are 76.20 MPA.

- **Deformation**

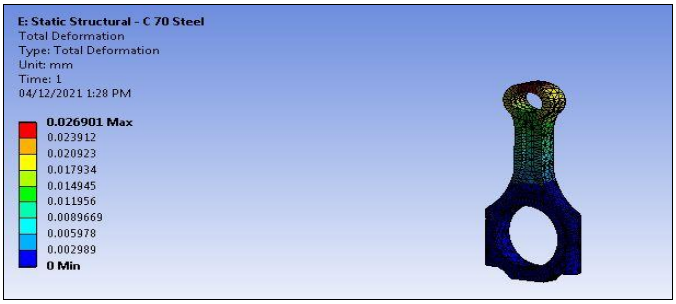


Fig. 7: Details of Deformation in Steel material

In the boundary condition of the steel we give the Pressure to the component of 6 Bar, so that deformation in connecting rod are 0.026 mm.

- **Strain energy**

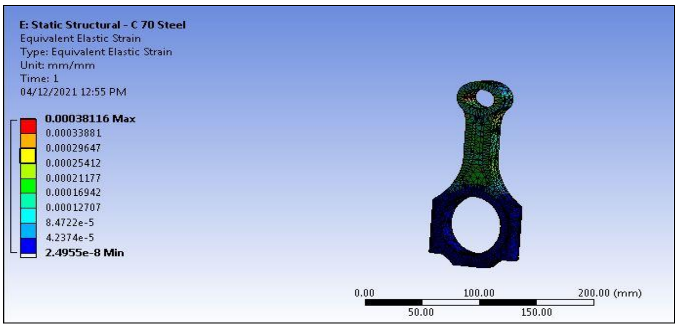


Fig. 8: Strain energy results of stainless-steel material

In the boundary condition of the steel we give the Pressure to the component of 6 Bar, so that strain in connecting rod are 0.0003 Mpa.

FEA Result of Al7075

- **Equivalent stress**

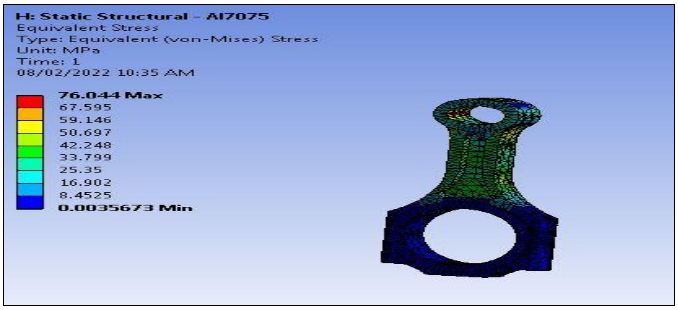


Fig. 9: Details of Equivalent Stress of AL7075

Material

In the boundary condition of the Al7075 we give the Pressure to the component of 6 Bar. So that the Equivalent stress in connecting rod are 76.04 MPA.

- **Deformation**

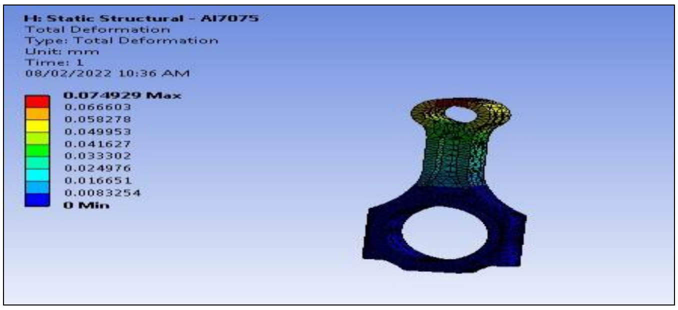


Fig. 10: Details of Deformation in Al7075 material

In the boundary condition of the Al7075 we give the Pressure to the component of 6 Bar, so that deformation in connecting rod are 0.074 mm.

- **Strain energy**

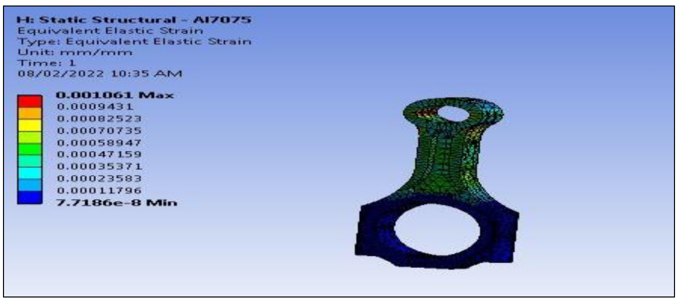


Fig. 11: Strain energy results of Al7075 material

In the boundary condition of the Al7075we give the Pressure to the component of 6 Bar, so that strain in connecting rod are 0.00010 mm.

FEA Result of Titanium Alloy

- **Equivalent stress**

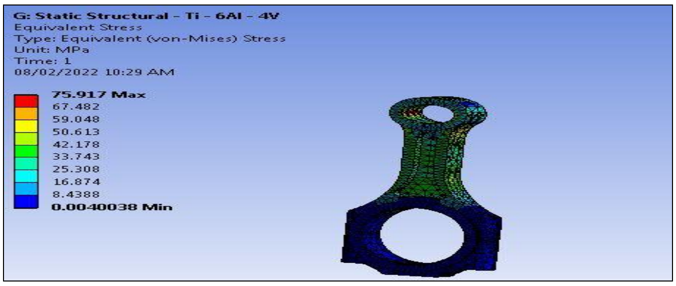


Fig. 12: Details of Equivalent Stress of Titanium Alloy material

In the boundary condition of the Titanium Alloy we give the Pressure to the component of 6 Bar. So that the Equivalent stress in connecting rod are 75.91 MPA.

- **Deformation**

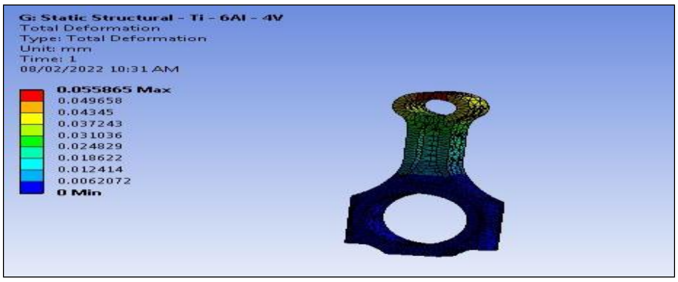


Fig. 13: Details of Deformation in Titanium Alloy material

In the boundary condition of the Titanium Alloy we give the Pressure to the component of 6 Bar, so that deformation in connecting rod are 0.055 mm.

FEA Result of Carbon Fiber

- **Equivalent stress**

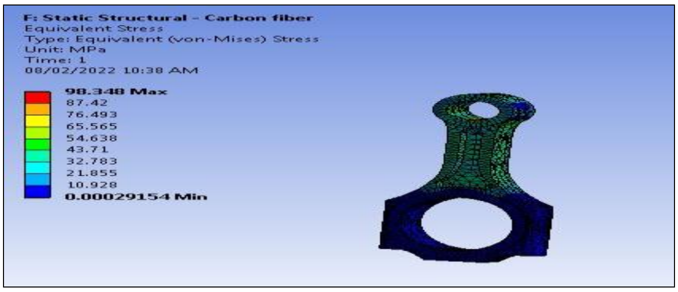


Fig. 14: Details of Equivalent Stress of Carbon Fiber material

In the boundary condition of the Carbon Fiber we give the Pressure to the component of 6 Bar. So that the Equivalent stress in connecting rod are 98.34 MPA.

- **Deformation**

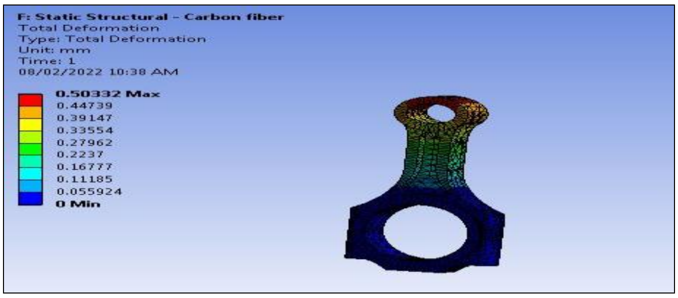


Fig. 15: Details of Deformation in Carbon Fiber material

In the boundary condition of the Carbon Fiber we give the Pressure to the component of 6 Bar, so that deformation in connecting rod are 0.5 mm.

- **Strain energy**

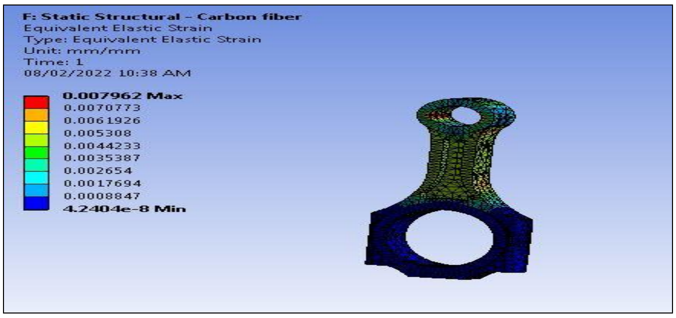
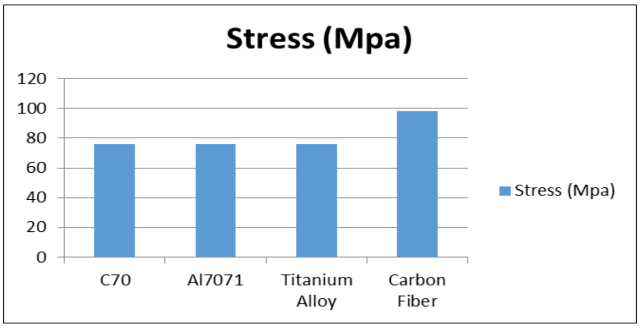


Fig. 16: Strain energy results of Carbon Fiber material

In the boundary condition of the Carbon Fiber we give the Pressure to the component of 6 Bar, so that strain in connecting rod are 0.0079 mm.

4.2. RESULT & DISCUSSION:

In this project of connecting rod we can analyzed the different material with stress, Strain and Displacement.



Graph 1: Stress in Material

In this Graph show that Titanium Alloy has the Less Stress generate compared to the Steel & Aluminum Material

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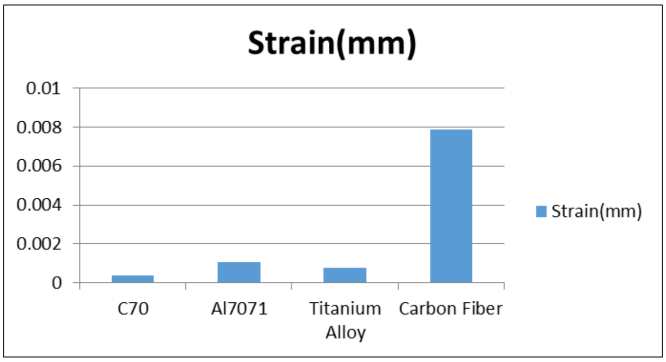
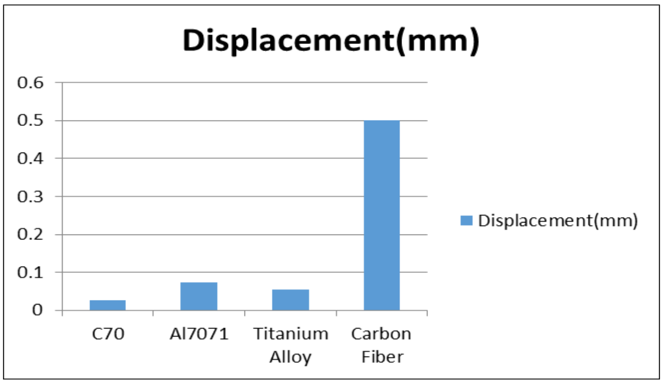


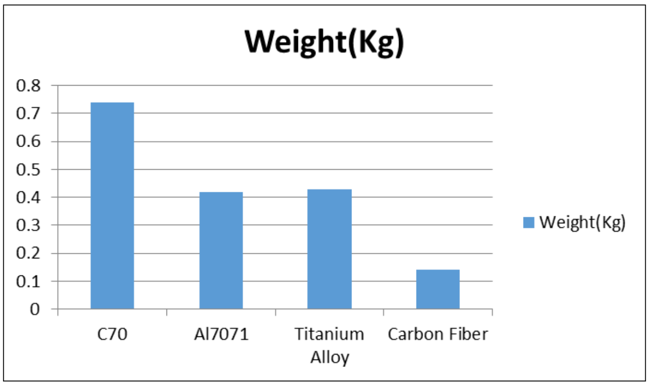
Graph 2: Strain in Material

In this Graph show that Titanium Alloy has the Less Strain generate compared to the Steel & Aluminum Material



Graph 3: Displacement in Material

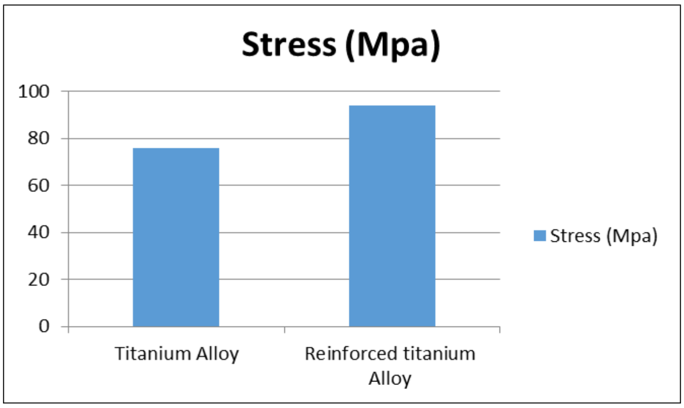
In this Graph show that Titanium Alloy has the Less Displacement compared to the Steel & Aluminum Material



Graph 4: Weight Comparison of Material

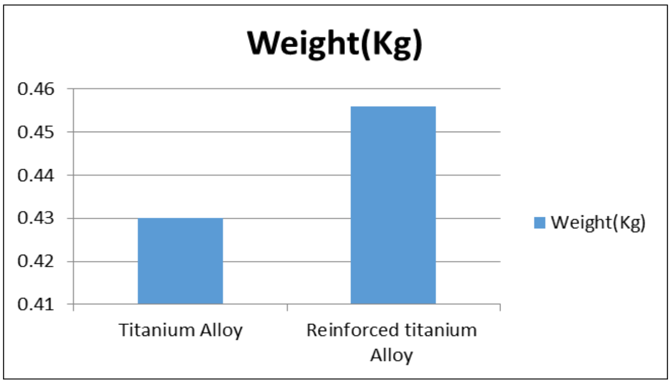
Titanium alloy and carbon fiber has the less weight compared to the other material

- In the graph result we can see that Titanium alloy has been generating less stress and displacement compared to the other material (Existing material)
- So that we can here improving the strength of our connecting rod we can reinforced the Titanium alloy with Carbon fiber.
- In the carbon fiber each layer stress caring capacity is around 6 Mpa (98Mpa/16 Width THK).
- Hence by applying the Carbon fiber layer on the titanium alloy we can increase the strength of the Connecting rod with negligible increase in weight.



Graph 5: Reinforced material Stress Comparison

Strength of titanium alloy is increase by applying the 3 layer of carbon fiber with negligible increase in weight



Graph 6: Reinforced material Weight Comparison

Hence for improving the Strength we can applying the Carbon fiber on Titanium Alloy then we got the result Improving the strength of 13% Compared to the Existing material C70 and Simultaneously reduced the weight 23%

4.3. CONCLUSIONS

- In present investigation with existing material analysis with determine stress, strain energy and displacement
- It is observed from analysis that stress produced in the connecting rod with Titanium alloy is less than Al7071 & C70 Material.

- Hence for improving the Strength we can applying the Carbon fiber on Titanium Alloy then we got the result Improving the strength of 13% Compared to the Existing material C70 and Simultaneously reduced the weight 23%.
- Hence we can Successfully complete the project by achieving the objective of our project.

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