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Material Comparison for a Two-Wheeler Connecting Rod using Finite Element Analysis(FEA)

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Abstract - *An internal combustion engine has a connecting rod as a major component. It acts as a transmission mechanism to convert the reciprocating piston motion into rotary motion by transmitting the push and pull from the piston pin to the crank pin. A 4-stroke petrol engine of a specified model, with a market-available connecting rod, is the object of the current study. This investigation uses solid modeling software called PRO/E(Creo Parametric). The modeled connecting rod is imported to an analysis program called ANSYS. Analysis software ANSYS is used to determine von-mises stresses, equivalent and shear strains, shear stresses, and total deformation for given loading conditions. The analysis focuses on the analysis of three materials-Aluminum Alloy(Al-6061), Structural Steel, and Gray Cast Iron. A 6061-aluminum alloy is part of the 6xxx aluminum alloy family, which consists primarily of magnesium and silicon alloys. Aluminum 6061 has a nominal composition of 97.9% Al, 0.6% Si, 1.0% Mg, 0.2% Cr, and 0.28% Cu. A connecting rod is designed based on the results of software that compares three materials.*

Key Words: Connecting Rod, PRO/E(Creo Parametric), ANSYS, FEA(Finite Element Analysis)

1. INTRODUCTION

The connecting rod in a combustion engine is a major component. By connecting the piston to the crankshaft, it transfers power from the piston to the crankshaft and the transmission. A connecting rod can be made of various types of materials and produced in different ways. Steel and aluminum are the two most common materials used in connecting rods. Among the most common manufacturing processes are casting, forging, and powdered metallurgy. In internal combustion engines, connecting rods constitute a large portion of the production volume. Besides connecting the piston with the crankshaft, this component is responsible for transmitting power from the piston to the crankshaft. Connecting rods are made from various types of materials and are manufactured in different ways.

1.1 Stresses Experienced by Connecting Rod

As a result of the operation, the connecting rod is subjected to major axial and bending stresses. As a result of the cylinder gas pressure (only compressive) and the inertia force arising from reciprocating action (both tensile and compressive), axial stresses are produced, while bending stresses are created due to centrifugal force.

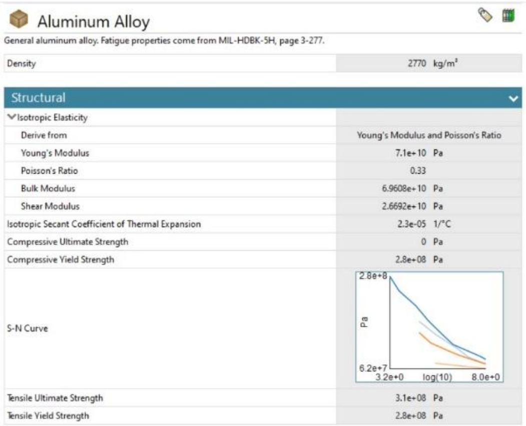
1.2 Design and Manufacturing of Connecting Rod

Connecting rod has a long shank, a small end, and a large end. The shank's cross-section can be rectangular, circular, tubular, I-section, or H-section. In general, circular sections are preferred for low-speed engines, whereas I-sections are preferred for high-speed engines. Casting, forging, and powdered metallurgy are the most common types of manufacturing processes. A complex state of loading is applied to the connecting rod. It is subjected to high cyclic loads of the order of 10^8 to 10^9 cycles, ranging from high compressive loads caused by combustion to high tensile loads caused by inertia. As a result, the durability of this component is critical. Because of these factors, the connecting rod has been the subject of research in a variety of areas, including manufacturing technology, materials, and performance.

2. SPECIFICATION OF THE PROBLEM

This work aims at analyzing and comparing connecting rods made of aluminum alloy(Al-6061), structural steel, and gray cast iron. The connecting rod model was created in Pro-E (Creo-parametric 8.0) and imported into ANSYS 2022 R1 for static analysis. Based on the analysis, an assessment is made between an aluminum alloy and a steel connecting rod regarding Equivalent(Von-Mises) stress, maximum shear stress, equivalent elastic strain, and maximum shear elastic strain, as well as total deformation.

Properties of Materials Used-



Aluminum Alloy

General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

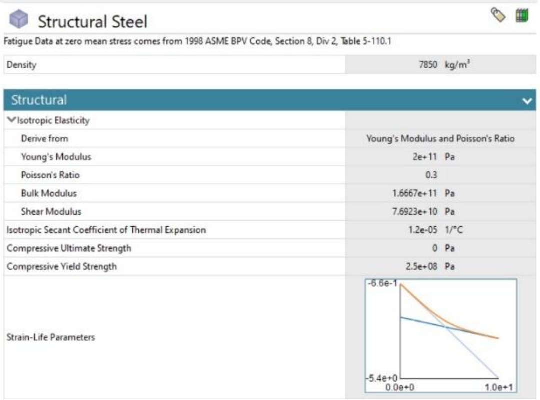
Density	2770 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	7.1e+10 Pa
Poisson's Ratio	0.33
Bulk Modulus	6.9608e+10 Pa
Shear Modulus	2.6692e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	2.3e-05 1/°C
Compressive Ultimate Strength	0 Pa
Compressive Yield Strength	2.8e+08 Pa
S-N Curve	
Tensile Ultimate Strength	3.1e+08 Pa
Tensile Yield Strength	2.8e+08 Pa

Table 1: Properties of Aluminum Alloy(Al-6061)

Gray Cast Iron

Density	7200 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.1e+11 Pa
Poisson's Ratio	0.28
Bulk Modulus	8.3333e+10 Pa
Shear Modulus	4.2969e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.1e-05 1/°C
Compressive Ultimate Strength	8.2e+08 Pa
Compressive Yield Strength	0 Pa
Tensile Ultimate Strength	2.4e+08 Pa
Tensile Yield Strength	0 Pa

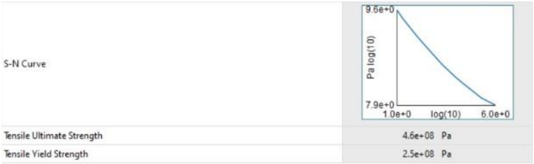
Table 2: Properties of Gray Cast Iron



Structural Steel

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Density	7850 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2e+11 Pa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+11 Pa
Shear Modulus	7.6923e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05 1/°C
Compressive Ultimate Strength	0 Pa
Compressive Yield Strength	2.5e+08 Pa
Strain-Life Parameters	



S-N Curve	
Tensile Ultimate Strength	4.6e+08 Pa
Tensile Yield Strength	2.5e+08 Pa

Table 3: Properties of Structural Steel

3. MODELLING OF CONNECTING ROD

Figure 1 illustrates a solid model of a connecting rod. Modelling the connecting rod follows the steps outlined below.

a. Reference plane selection.

b. Setting of the dimensions in mm(dimensions have been taken from reference papers).

c. Sketching circular entities at the sketcher.

d. Making the connecting rod ends by extruding these entities.

e. Redefining the reference plane for the shank of the connecting rod.

f. Entities made to be tangential to both ends.

g. Symmetrical extrusion of the entities.

h. Choosing the planes that will be used to make groove entities.

i. The shank is grooved and mirrored, resulting in grooves on both sides of the shank.

Figure 1:Model of Connecting Rod in PTC Creo Parametric

4. STRUCTURAL ANALYSIS OF CONNECTING ROD

The analysis is performed on a 3D model of a connecting rod using ANSYS 2022 R1 workbench. It is assumed that the loading conditions are static. Pressure loads are applied to both ends of the piston and the fixed crank during the analysis. Finite element analysis is carried out on structural steel connecting, cast iron as well as on aluminum alloy connecting rods. From the analysis the equivalent stress (Von-mises stress), equivalent strain, Max Shear stress, Max. Shear Strain and total deformation were determined. A connecting rod with a fixed big end is shown in fig. 2 whereas the connecting rod with pressure at the small end is shown in fig. 3.

Pressure applied:3.15 MPa

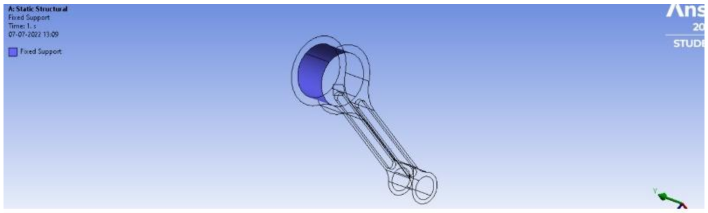


Figure 2:Connecting Rod with the fixed big end

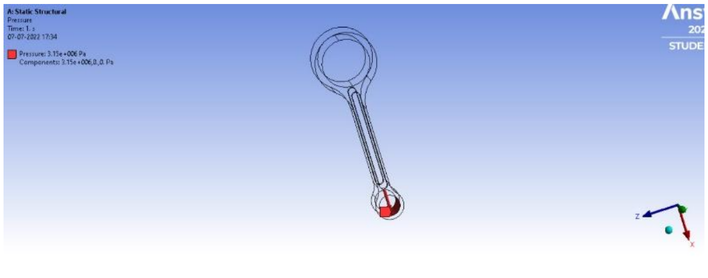


Figure 3:Connecting Rod with pressure at the small end

Fig. 4, Fig. 5, and Fig.6 show Min Equivalent stress as 60.602 Pa, 65.999 Pa, and 64.332 and max equivalent stress as 7.7714 X 10^7 Pa, 7.18617 X 10^7 Pa, and 7.8256 X 10^7 Pa for a connecting rod made of Aluminum Alloy, Cast Iron and Structural Steel respectively.

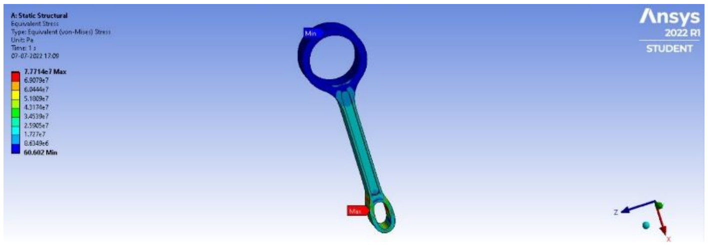


Figure 4: Equivalent Stress of Aluminum alloy Connecting rod

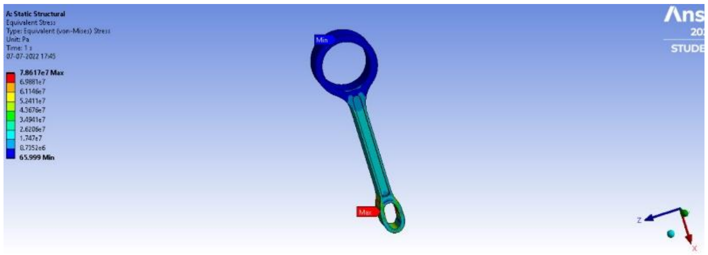


Figure 5:Equivalent Stress of Cast Iron Connecting rod

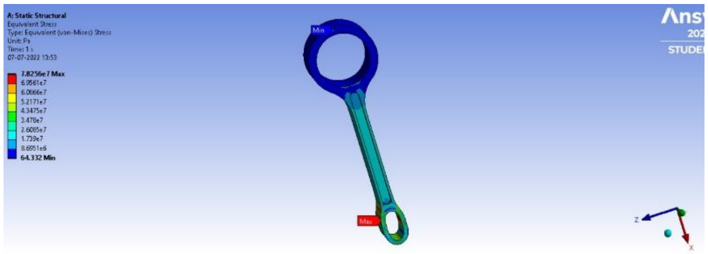


Figure 6:Equivalent Stress of Structural Steel Connecting rod

Fig. 7, Fig. 8, and Fig.9 show Max. Equivalent elastic strain as 0.0010958, 0.00071547, and 0.00039171 and Min. equivalent elastic strain as 9.9265 X 10^-10, 6.4929 X 10^-10 and 3.5605 X 10^-10 for a connecting rod made of Aluminum Alloy, Cast Iron and Structural Steel respectively.

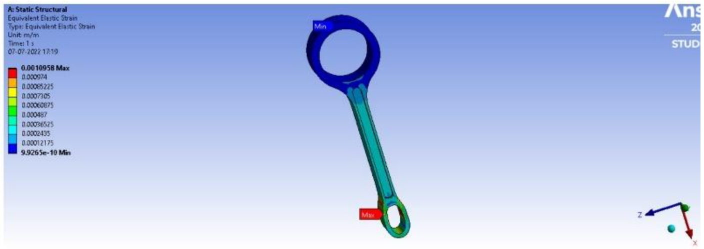


Figure 7: Equivalent Elastic Strain of Aluminum alloy Connecting rod

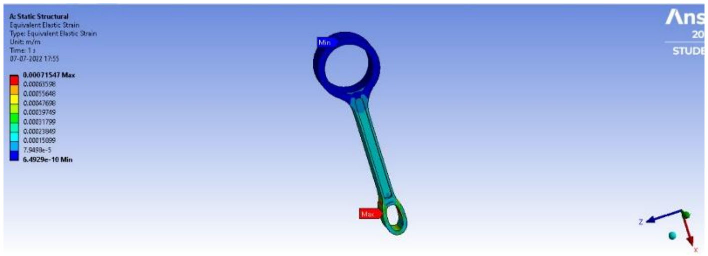


Figure 8: Equivalent Elastic Strain of Cast Iron Connecting rod

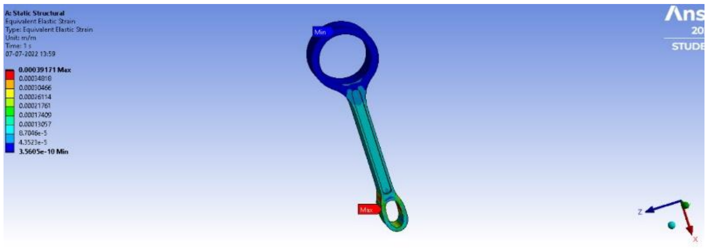


Figure 9: Equivalent Elastic Strain of Structural Steel Connecting rod

Fig. 10, Fig. 11, and Fig.12 show Min. Shear stress as 32.781 Pa, 35.388 Pa, and 34.806 and Max. Shear stress as 4.2971 X 10^7 Pa, 4.2725 X 10^7 Pa, and 4.2817 X 10^7 Pa for a connecting rod made of Aluminum Alloy, Cast Iron, and Structural Steel respectively.

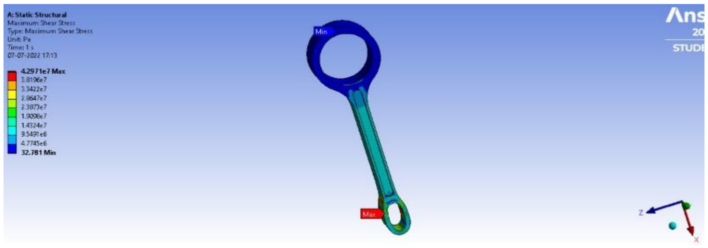


Figure 10: Maximum Shear Stress of Aluminum alloy Connecting rod

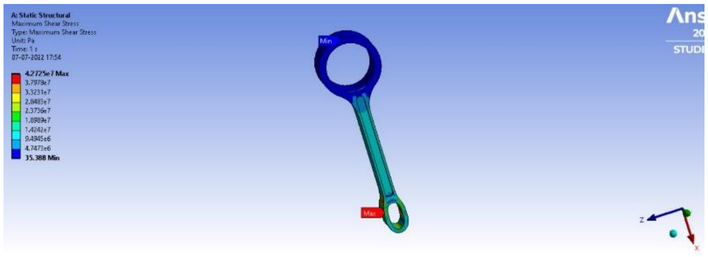


Figure 11: Maximum Shear Stress of Cast Iron Connecting rod

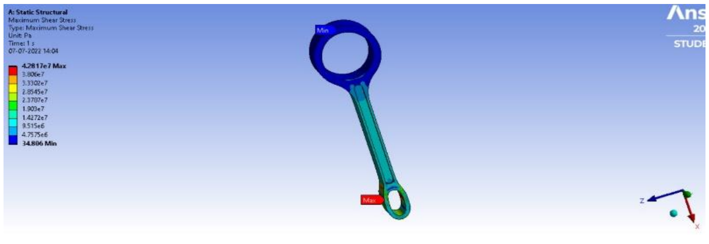


Figure 12: Maximum Shear Stress of Structural Steel Connecting rod

Fig. 7, Fig. 8, and Fig.9 show Max. Shear elastic strain as 0.0016099, 0.00099443, and 0.00055662 and Min. Shear elastic strain as 1.2281 X 10^-9, 8.2358 X 10^-10, and 4.5248 X 10^-10 for a connecting rod made of Aluminum Alloy, Cast Iron, and Structural Steel respectively.

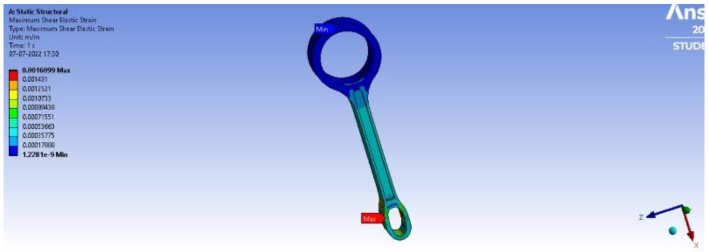


Figure 13: Maximum Shear Elastic Strain of Aluminum Alloy Connecting rod

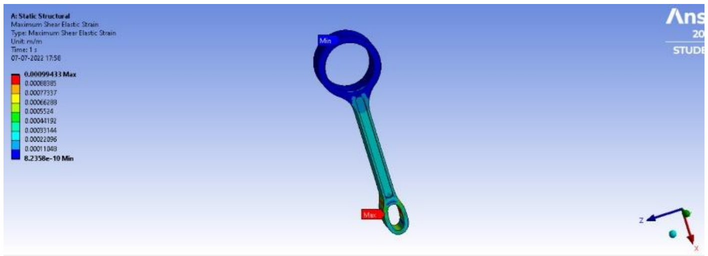


Figure 14: Maximum Shear Elastic Strain of Cast Iron Connecting rod

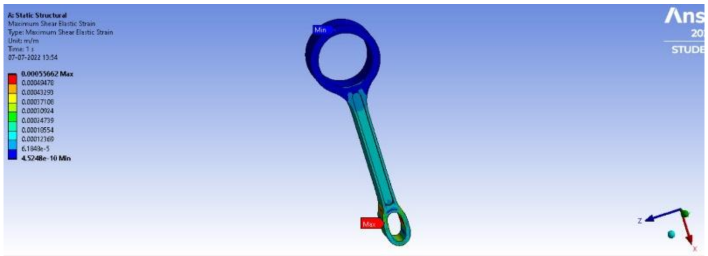


Figure 15: Maximum Shear Elastic Strain of Structural Steel Connecting rod

Fig. 16, Fig. 17, and Fig.18 show Max. Total Deformation as 0.00113159 m, 0.00073888 m, and 0.00040522 m and Min. Total Deformation as 0 m, 0 m, and 0 m for a connecting rod made of Aluminum Alloy, Cast Iron, and Structural Steel respectively.

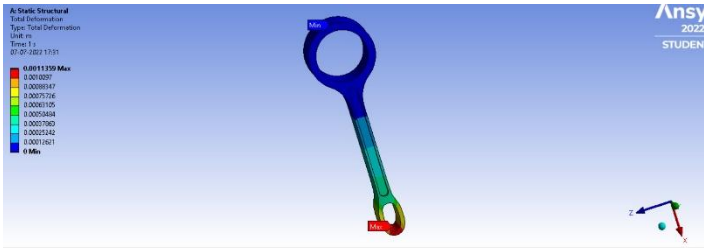


Figure 16: Total Deformation of Aluminum Alloy Connecting rod

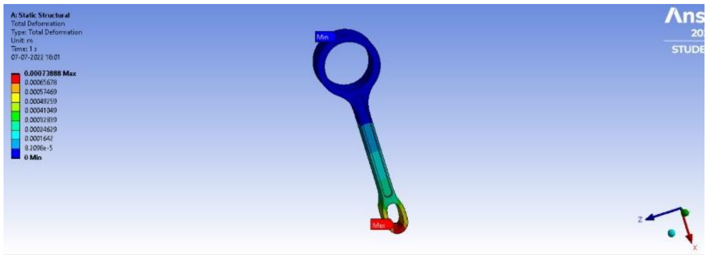


Figure 17: Total Deformation of Cast Iron Connecting rod

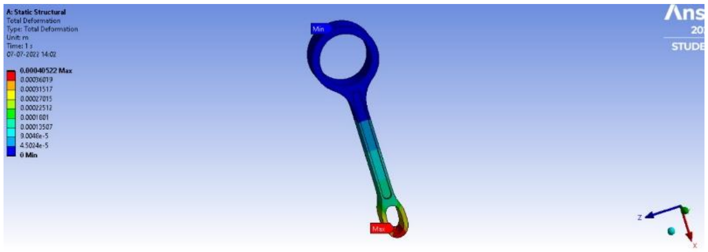


Figure 18: Total Deformation of Structural Steel Connecting rod

5. CONCLUSION

- All connecting rods had the highest and lowest physical quantities at the piston and fixed ends, respectively.
- Connecting rods made of Aluminum Alloy(Al-6061) exhibited the highest equivalent elastic strain, shear elastic strain, shear stress, and total deformation followed by the ones made of Gray Cast Iron and Structural Steel respectively.
- Connecting Rod made of Gray Cast Iron exhibited the highest Equivalent(Von-Mises) Stress followed by the ones made of Structural steel and Aluminum Alloy(Al-6061) respectively.
- As a result of the ultimate strength of the connecting rod, all of the materials are safe to use.
- The equivalent(Von-Mises) stress, equivalent elastic strain, shear elastic strain, shear stress, and total deformation induced in structural steel for the current investigation are less than that in cast iron, based on the comparisons obtained from the analysis.
- Since cast iron is a brittle material, structural steel can be used for manufacturing connecting rods with long durability.
- Compared to structural steel connecting rods, aluminum is lighter. Consequently, when the rod is lighter, the piston pressure will be lower, and the fuel will be burned less.
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- By using lightweight connecting rods, we can increase fuel economy directly or indirectly. Weight is another factor that affects the cost of the connecting rod. In comparison to heavy connecting rod materials, lighter connecting rods will be less expensive.

6. SCOPE FOR FUTURE WORK

In this sector, much has been done, and much remains to be done. Finite element analysis of static structural components is the only focus of this dissertation. It may therefore be necessary to conduct further research on dynamic loading and operating conditions of the connecting rod. Because of the oil holes provided on the connecting rods, CFD analysis can be used to improve the thermal behavior of the connecting rods by using thermal analysis. In addition, Experimental Stress Analysis (ESA) can be used to evaluate the performance of existing models based on the behavior of connecting rods. Today, vibration analysis of mechanical components is widely discussed as it plays an important role in the failure of these components. It is therefore possible to extend the study to include an analysis of the vibration of the connecting rods.

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