Tensile Strength Analysis of IC Engine Connecting Rod Under 20kN Load for Aluminum Alloy (AL2024) and Grey Cast Iron

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Abstract

The application of load acting on a connecting rod during the combustion of fuel, often leads to the failure of the connecting rod and engine case. In this study, a connecting rod was designed based on selected dimensions and material in SOLIDWORKS tool. The connecting rod structural failure analysis under tension load has been carried out using SOLIDWORKS Finite Element Analysis (FEA) tool with aluminum alloy (AL2024) and grey cast iron material. The results show that with the selected design parameters and material, higher stresses are induced in the middle region (I-section) of the connecting rod if it is made of grey cast iron. The deformation of the model made of grey cast iron is also worse than the AL2024. The elongation of grey cast iron material is higher than the Al2024 by 0.1634 mm, and 0.14947 mm in Al2024 material. This study concluded that for better connecting rod design, the aluminum alloy Al2024 is a suitable material with very light weight and high tensile strength under 20kN load.

Keywords—Connecting rod, internal combustion engine, FEM, cast iron, aluminum alloy 2024, grey cast iron

1 Introduction

The connecting rods are always subjected to various loads that induces bending, tensile and compressive stresses due to their complex working movement [1] [2]. Connecting rods can be made of various ferrous and non-ferrous metals with different grades such as structural steel, alloy steel, aluminum, aluminum alloys and titanium [3]. If the light weighted connecting rods are used in engine, they can help to reduce lead which is caused by the inertia forces because it does not require a heavy/large weight balance system on the crankshaft. The production of aluminum connecting rods reinforced with steel continuous fibers has already been started by Honda company [4].

If the connecting rods and pistons are made of light weighted material, the engine will be safe from vibrations, as vibrations also have a major impact on the failure of engine parts [5] [6]. The manufacturing of IC engine connecting rods are typically carried out by various processes such as hot forging and casting [7] [9] for automotive applications. The connecting rods are commonly made of different materials such as steel and cast iron for production engines in modern automotive IC engines, but can also be made of aluminum. Aluminum is light and at the expense of durability, it can absorb the high impact with good manufacturing abilities [10].

The connecting rods used in tractor vehicle engines are mostly made of cast iron through the metallurgy of forging or powder [11]. The connecting rods for production engines are also made of steel, high-strength aluminum, high-performance titanium and motor scooter cast iron [12]. The material properties play an important role in the final element analysis result, which is why C-70 grade steel is used in connecting rod design [13]. The AISI / SAE 4140 steel is widely used as material in the designing of the connecting rods, which basically is a low alloy medium carbon steel [14]. As connecting rod material, the cast steel grade AISI 1045 was used in [9]. Steel and aluminum are the materials used for connecting rods, whereas casting, forging and powder metallurgy are the manufacturing process followed by most manufacturers [15]. The engine connecting rods are under the forces resulting from the combustion of fuel. These types of forces

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S. No.	Source	Amount of Load
1	[3]	22.397kN
2	[4]	95kN
3	[5]	22.396kN
4	[7]	36.595kN
5	[9]	43.926kN
6	[10]	39.473kN
7	[13]	26.7kN
8	[16]	0.677kN
9	[19]	31.415kN
10	[20]	16.56kN
11	[21]	33.609kN
12	[22]	15.39kN
13	[23]	14800kN
14	[24]	39.473kN
15	[25]	95.740kN
16	[26]	4.319kN

TABLE 1: Summary of load applied on connecting rods

result in the development of stresses of axiality and bending. The bending failure may be caused by the crank shaft eccentricity, cylinder wall deformation and rotational forces [16]. The excessive burnt gas pressure results in high centrifugal forces that usually produce tensile, compressive and bending stresses [17] [19]. The connecting rods are always subjected to heavy or large stresses because of the reciprocating forces and pressure applied through engine piston, causing elongation and compression during each stroke. Whereas, increasing engine speed also results in increasing load which affects the power transmission [20] [21].

1.1 Material and Load Selection

Bari et al. [23] conducted a study on the design of connecting rod using Sulphur as a design material. In other studies [17] [1], the researchers used aluminum and magnesiumm (AL-Mg) alloys for the design of connecting rods. The AL6061 Sic Flyash AL360 can also be used as connecting rod material for considering light weight material [4]. In various other studies, researchers also used steel-aluminum-titanium [5], aluminum-titanium [18], aluminum alloy [6], aluminum alloy 7075 [20], stainless steel (SS304) [22], aluminum alloy 7068, T6, T6511 [24], steel C-70 [13], and forged steel [10].

In this paper, a connecting rod for IC engine was designed and analyzed for its tensile strength under a constant tension load (20kN) acting on it due to the combustion of fuel inside the engine cylinders. The load applied on the connecting rods is different as per the type of application. Most of the connecting rods of small engine, investigated in the relevant literature, are summarized in Table 1.

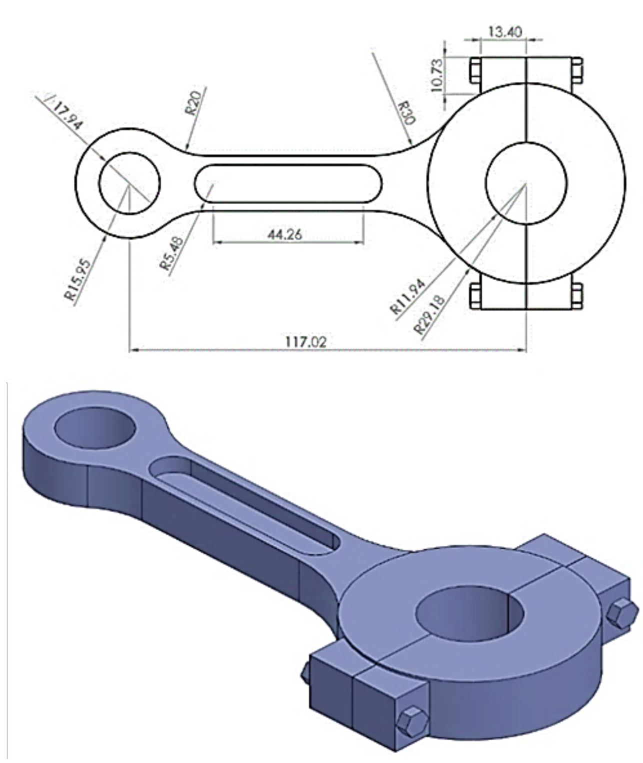

Fig. 1: 3D model of connecting rod

2 Materials & Methods

The connecting rod was designed by SOLIDWORKS tool, based on dimensions chosen from literature review as shown in Figure 1. The material selection was done through the previous study survey and in this study two type of materials, AL2024 and Grey cast iron, were used. The designed connecting rod was then simulated for its tensile strength analysis at a constant load of 20kN. This load actually acts on the connecting rod during the combustion of fuel in the cylinder of IC engine. The burnt gases produce various forces such as tension and compression. As these forces repeat in each cycle, therefore, fatigue is also one of them. These forces are considered to be the major cause of connecting rod failure. Therefore, the connecting rod should be designed according to the perspectives of safety and durability with a high strength based on suitable material selection and design parameters. The physical properties of AL2024 and grey cast iron are illustrated in Table 2. The material AL2024 has a higher tensile strength than the grey cast iron. Whereas, the elastic modulus of grey cast iron is higher than AL2024, which can save the grey cast iron form quick failure. The failure criteria of AL2024 and grey cast iron are based on maximum von-mises stress.

Quantity	Materials	
	AL2024	**Grey Cast Iron**
Tensile strength	$4.7 \times 108\,N/m^2$	$1.51 \times 108\,N/m^2$
Elastic modulus	$72.4 \times 109\,N/m^2$	$66.17 \times 109\,N/m^2$
Poisson's ratio	0.33	0.27
Mass density	$2780\,kg/m^3$	$7200\,kg/m^3$
Shear modulus	$28 \times 109 N/m^2$	$50 \times 109\,N/m^2$
Thermal expansion coefficient	$2.32 \times 10^{-5}/Kelvin$	$1.2 \times 10^{-5}/Kelvin$
Default failure criterion	Max Von Mises Stress	Mohr-Coulomb Stress

TABLE 2: Physical properties of AL2024 and Cast iron

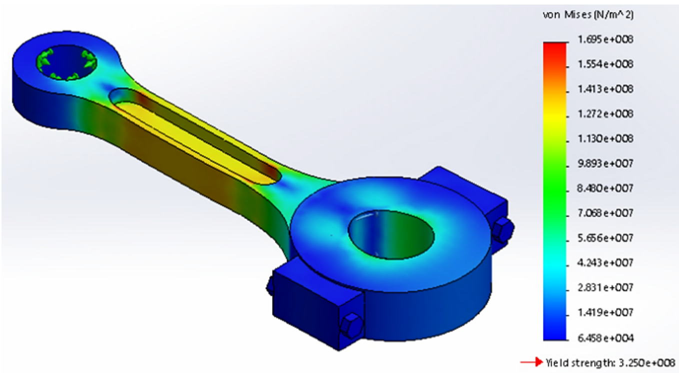

Fig. 2: Von-misses stress of AL2024

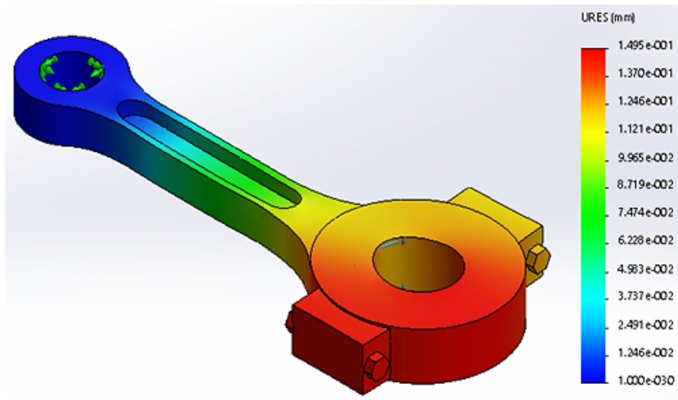

Fig. 3: Resultant displacement of AL2024

3 Results & Discussion

The designed connecting rod was simulated in SOLIDWORKS simulation tool based on the static study. The smaller end of the connecting rod is assumed to be a fixed surface with the piston pin at piston end. Whereas, the larger end is connected with crank shaft and open bearing. This end is subjected to a tension force of 20kN, which acts on the outward direction of the connecting rod. The applied load of 20kN was assumed to be the burnt gasses load due to the combustion of fuel in the engine cylinder.
The simulation was carried out based on the types of materials used for design of the connecting rod. The results are further elaborated and discussed in subsections of AL2024 and grey cast iron.

3.1 Aluminum Alloy (AL2024)

The aluminum alloy AL2024 is a light weight material and is usually used in all automobile components. AL2024 mostly fails in maximum von-mises stress criterian, where the maximum stress induced in the connecting rod of this study was $1.695 \times 108\ N/m^2$ at node 13984. Moreover, the least value of stress was induced at node 15041 with the value of $64.578 \times 10^3\ N/m2$ as shwon in Figure 2. The equivalent strain value of AL2024 with its maximum and minimum values are 0.001787 at element 6507 and 4.825×10^{-7} at element

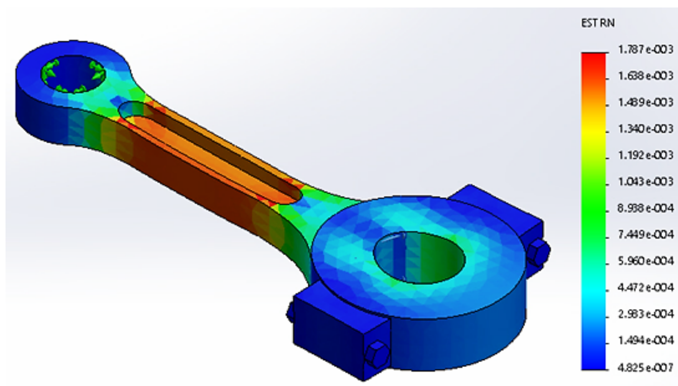

Fig. 4: Equivalent strain of AL2024

8840 respectively. The results are shown in Figure 3. The elongation taking place in the AL2024 model was measured to be 0.14947 mm at node 289, as shown in Figure 4.

3.2 Grey Cast Iron

Grey cast iron mostly fails in maximum von-mises stress criterian, where the maximum stress induced in the connecting rod of this study was $1.703 \times 10^8\ N/m2$ at node 13954. Moreover, the least value of stress was induced at node 15041 with the value of $62.8 \times 10^3\ N/m^2$, as shown in Figure 5.

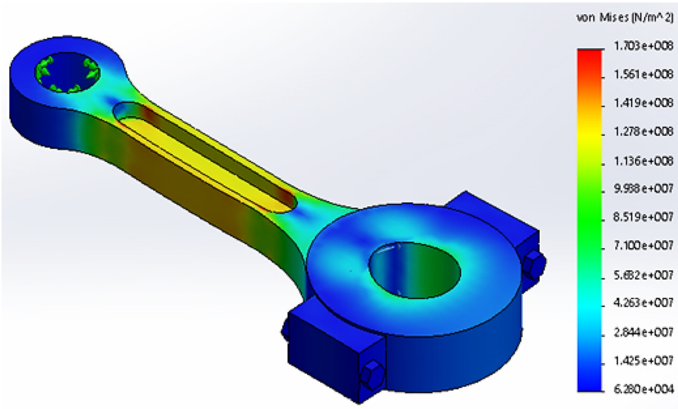

Fig. 5: Von-mises stress of Grey cast iron

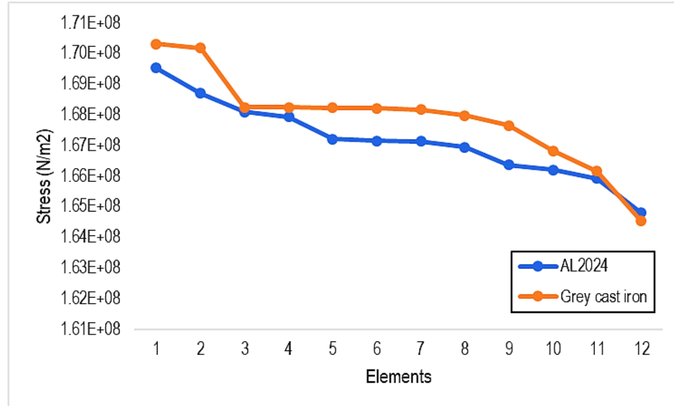

Fig. 8: Comparative results of Stress

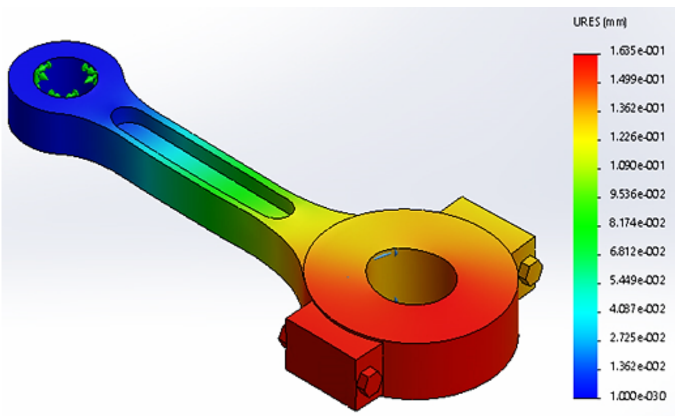

Fig. 6: Resultant displacement of Grey cast iron

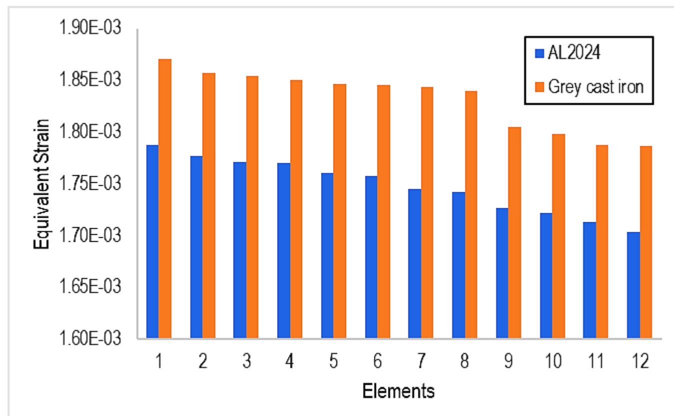

Fig. 9: Comparative results of Equivalent Strain

Similarly, the maximum deformation is observed in the element 6507 with the value of 0.00187, and the lowest deformation was observed to be 5.52×10^{-7} at the element of 8840. The simulation results are shown in Figure 6. In this material, the maximum elongation was observed at node 289 to be 0.1634 mm, as shown in Figure 7. The comparative results of stress for AL2024 and grey cast iron are shown in Figure 8. The results show that in grey cast iron the induced stress level was higher as compared to AL2024 in all elements of the model. This is because the tensile strength of AL2024 is higher than the grey cast iron, therefore, the results show that AL2024 was safe from the failure. On the other hand, the results of strain in both materials show that the deformation taking place in grey cast iron is more than that in AL2024, as shown in Figure 9.

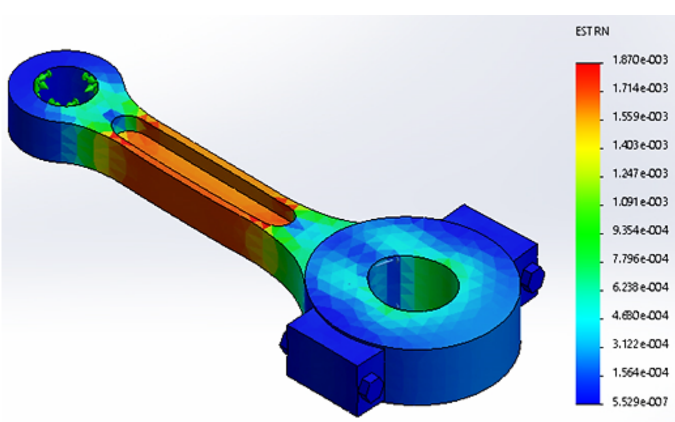

Fig. 7: Equivalent strain of Grey cast iron

4 Conclusion

The aim of this study was to design a connecting rod with most suitable material selection based on the constant load of 20kN application. The load acts on the connecting rod in the form of tension at the piston and crank ends. The two materials were selected through literature review and the model was analyzed for both material tensile strengths based on the design parameters of the connecting rod. This study concluded that the higher stresses are induced in the middle region (I-section) of a connecting rod if it is made of grey cast iron.

The deformation of model made of grey cast iron is also found to be worse than that in AL2024. The elongation of grey cast iron material is higher than AL2024 with values of 0.1634 mm, whereas, 0.14947 mm in AL2024 material. This study concluded the for better connecting rod design, AL2024 is a suitable material with very light weight and high tensile strength under 20kN load.

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