Failure Analysis of Connecting rod under 10kN Compressive load using different Aluminum Alloys

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Abstract: In internal combustion (IC) engines, the connecting rods are used as mediator member in between the engine crank shaft and piston. Its main function is to transmit the power in the form of push and pull between the piston pin and the crank pin, the transformation of reciprocal motion of piston into rotating motion of the crank shaft. The failure of a connecting rod, usually referred to the application of load acts on it during the combustion of fuel, which are tension, compression and bending often cause the braking or failure of 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 has been carried out using SOLIDWORKS Finite Element Analysis (FEA) tool at a constant 10kN compressive load with different aluminum alloys material. The results show that with selected design parameters and material, the connecting rod was failed due to the maximum von mises stress induced in the connecting rod, which was 8.45×10^{7} N/m^{2} under compressive load. Whereas the deformation occurred in connecting rod at different value depends on the material. Moreover, the higher strain was observed in AL6061 and AL6063, since the lowest strain was 8.9×10^{-4} in AL2024. It was concluded that AL2024 is the most suitable aluminum alloy for the design of connecting rods.

Keywords: *Finite Element Analysis, Stress Analysis, Aluminum alloy, Automobile, Connecting rod.*

1. Introduction

The manufacturing of IC engine connecting rods are typically carried out by various processes such as hot forging and casting [1-3] for automotive applications. The connecting rods are commonly made of different materials like steel and cast iron for production engines in modern automotive IC engines, but can also be made of aluminum. The aluminum is light and at the expense of durability that can absorb the high impact with good manufacturing abilities [4].

The connecting rods used in tractor vehicle engines are mostly made of cast iron through the metallurgy of forging or powder [5]. The connecting rods for production engines are also made of steel, high-strength aluminum, high-performance titanium and motor scooter cast iron [6].

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 [7]. 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 [8]. As connecting rod material, the cast steel grade AISI 1045 was used [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 [10].

Connecting rods can be made of various ferrous and nonferrous metals with different grades such as; structural steel, alloy steel, aluminum, aluminum alloys and titanium [11]. In connecting rod design, aluminum alloy grade AA5754 was used. This material was passed through the process of annealing metal heat treatment to improve its hardness [12].

The connecting rods are always subjected to various loads that induces the bending, tensile and compressive stresses due to its complex working movement [13]. If the light weighted connecting rods used in engine that can help to reduce lead, which 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 had already begun by Honda company [14]. The engine connecting rods are under the forces resulting from the combustion of fuel. These types of forces result to develop the stresses of axiality and bending. The bending failure may cause due to the crank shaft eccentricity, cylinder wall deformation and rotational forces [15-16].

If the connecting rods and pistons are made of light weighted material then the engine will be safe from the engine vibration. Because the vibration is also having a major impact on the failure of engine parts [17-18]. Due to the excessive burnt gas pressure results the high centrifugal forces that usually produce the tensile, compressive and bending stresses [19]. The connecting rods are always subjected to the heavy or large stresses because of the reciprocating forces and pressure applied through engine piston, actually cause the elongation and compression during each stroke, whereas by increasing engine speed that also results in the load increasing to affect the power transmission [20].

In this paper, the connecting rod for IC engine was designed and analyzed for its structural failure under a constant compressive load act on it due to the combustion of fuel inside the engine cylinders.

2. Design of IC engine Connecting rod

The 3D model of IC engine connecting rod was designed in SOLIDWORKS tool, based on dimensions chosen from literature review. The material selection was done through the previous study survey. The detail of design is shown in

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Figure 1, whereas the details of dimensions are given in Figure 2.

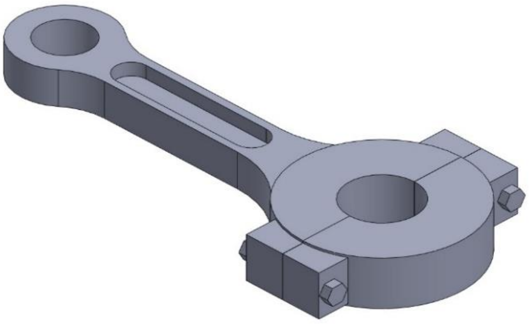

Fig. 1. Pictorial view of connecting rod

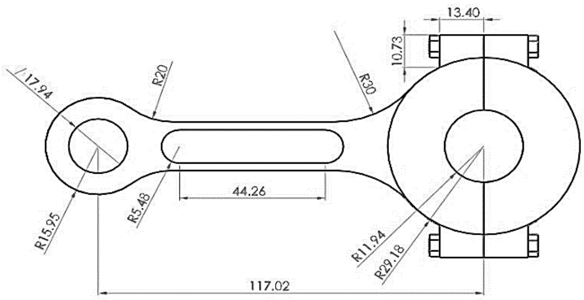

Fig. 2. Dimensions of connecting rod

3. Failure Analysis

The designed 3D model of connecting rod was simulated for its failure analysis in SOLIDWORKS FEA tool. The static structural analysis was carried out and the material for connecting rod and its parts were aluminum alloys AL2024, AL6061, AL6063, AL7050 and AL7075. The yield and tensile strength values of materials are shown in Figure 3, whereas the properties are given in Table 1. These materials are widely used in automobile applications. Through this study it was analyzed that which type of aluminum alloy material is most suitable for the design of connecting rods under some defined load condition.

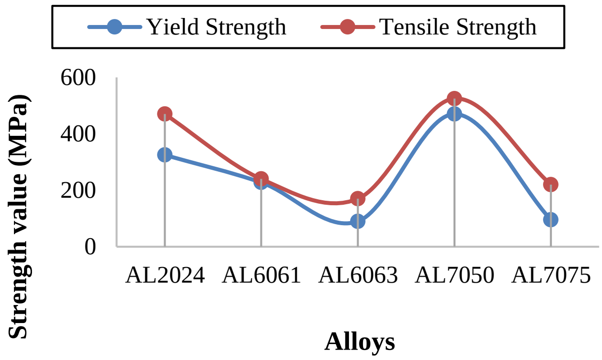

Fig. 3. Strength values of aluminum alloys

Table 1. Material properties

Quantity	Materials				
	2024	6061	6063	7050	7075
Yield strength	3.25×10^8 N/m^2	2.2752×10^8 N/m^2	9×10^7 N/m^2	4.7×10^8 N/m^2	9.5×10^7 N/m^2
Tensile strength	4.7×10^8 N/m^2	2.4×10^8 N/m^2	1.7×10^8 N/m^2	5.25×10^8 N/m^2	2.2×10^8 N/m^2
Elastic modulus	72.4×10^9 N/m^2	69×10^9 N/m^2	69×10^9 N/m^2	72×10^9 N/m^2	72×10^9 N/m^2
Poisson's ratio	0.33				
Mass density	2780 kg/m^3	2700 kg/m^3	2700 kg/m^3	2830 kg/m^3	2810 kg/m^3
Shear modulus	28×10^9 N/m^2	26×10^9 N/m^2	25.8×10^9 N/m^2	26.9×10^9 N/m^2	26.9×10^9 N/m^2
Thermal expansion coefficient	2.32×10^{-5} /Kelvin	2.4×10^{-5} /Kelvin	2.34×10^{-5} /Kelvin	2.36×10^{-5} /Kelvin	2.4×10^{-5} /Kelvin
Default failure criterion	Maximum von Mises Stress				

The solid meshing of the model was done by the simulation tool, and the details of meshing are given in Table 2. Similarly, the graphical solid mesh of model is shown in Figure 4.

Table 2. Mesh information of connecting rod model

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Jacobian points	4 Points
Element Size	0.00401217 m
Tolerance	0.0002006 m
Mesh Quality	High
Total Nodes	15314
Total Elements	9326
Maximum Aspect Ratio	12.183
% of elements with Aspect Ratio < 3	94.5
% of elements with Aspect Ratio > 10	0.0322

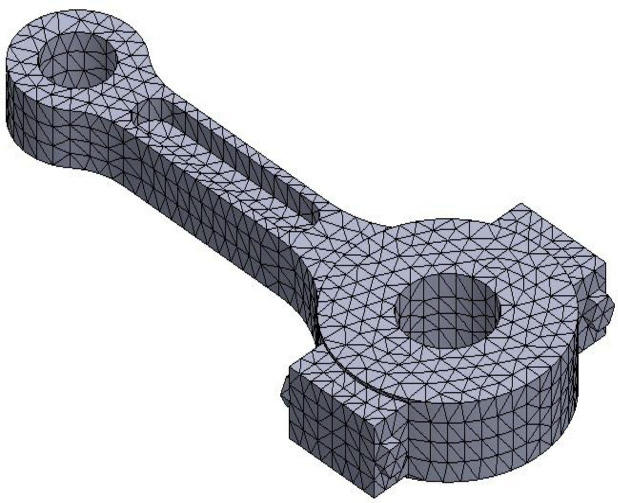

Fig. 4. Solid meshing of connecting rod

4. Results

4.1 Equivalent Strain

The connecting rod fails due to the excessive load or pressure applied due to the combustion of fuel inside the engine cylinder. The connecting rod failed under maximum von mises stress with the value of $8.75x10^3$ N/m^2, this results the strain that occurred in connecting rod at different values depends on the type of material as shown in Figure 5.

The Aluminum alloy AL6061 and AL6063 have given very poor behavior with high strain value of $9.338x10^{-4}$. In the connecting rod the red color region shows the critical or most effected region where the strain is high. The load carrying behavior of other alloys are observed as in AL2024 the strain was $8.9x10^{-4}$. Similarly, in AL7050 and Al7075 the strain value was same as $8.949x10^{-4}$.

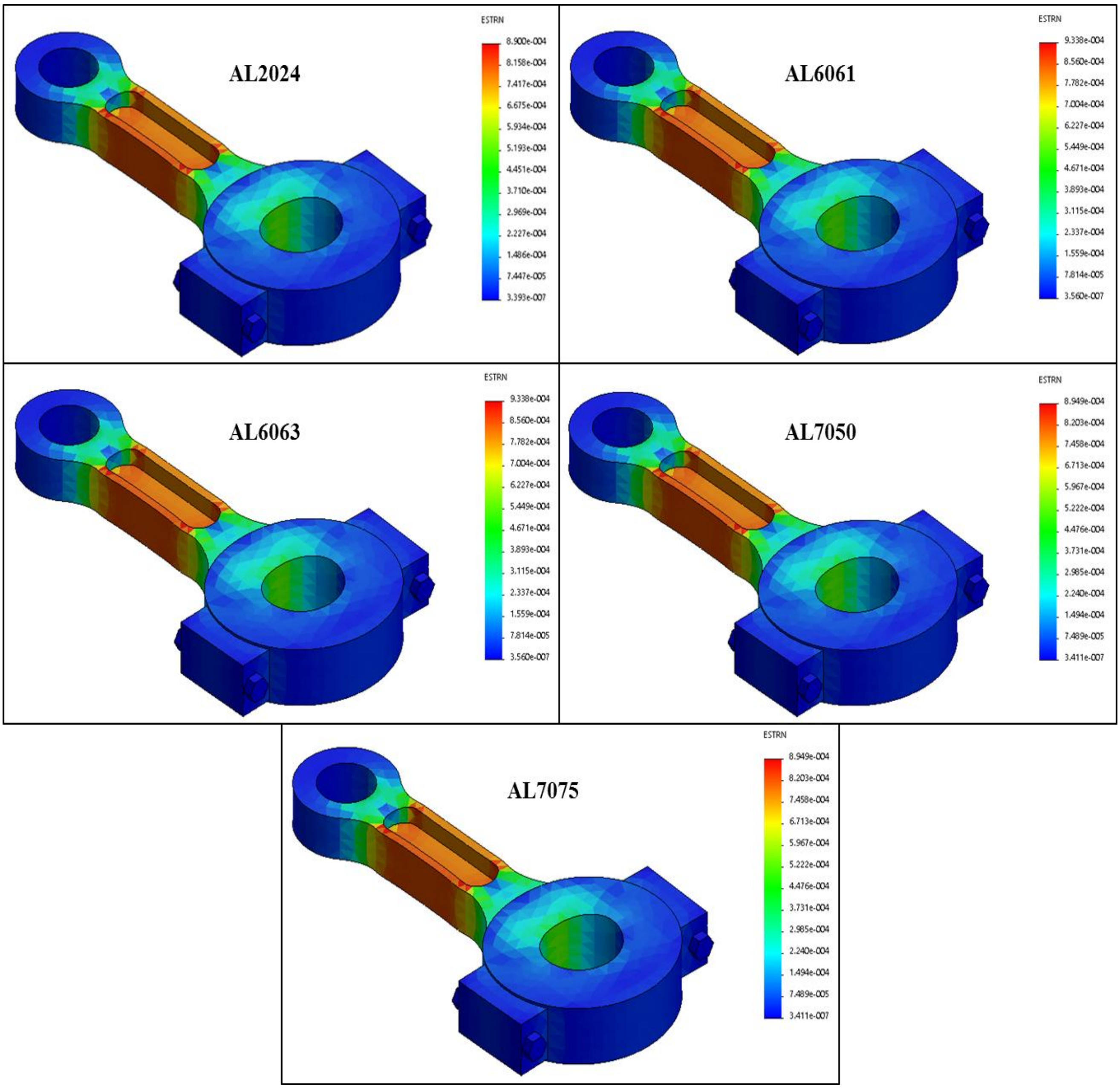

Fig. 5. Equivalent Strain at 10 kN compressive loading

4.2 Displacement

The strain or permanent deformation can cause the elongation or contraction in the model dimensions under the application of compressive load. The results of displacement for all selected aluminum alloys material are shown in Figure 6.

According to the strain graphical behavior, in the displacement graphs the red color defines the most effected or critical regions, where the elongation or contraction occurred highly. From the results it shows that AL6061 and AL6063 have the highest displacement value of $7.513x10^{-2}$ mm. Moreover, in AL7050 and AL7075 the displacement value was obtained as $7.2x10^{-2}$ mm, which are the moderate level of contraction in the connecting rod dimensions.

The lowest displacement value was observed in the AL2024 as $7.16x10^{-2}$ mm. These displacement value shows that with the highest displacement value means the material failed more, whereas on the other side lowest displacement value shows the material is strong enough to resist the failure under load condition.

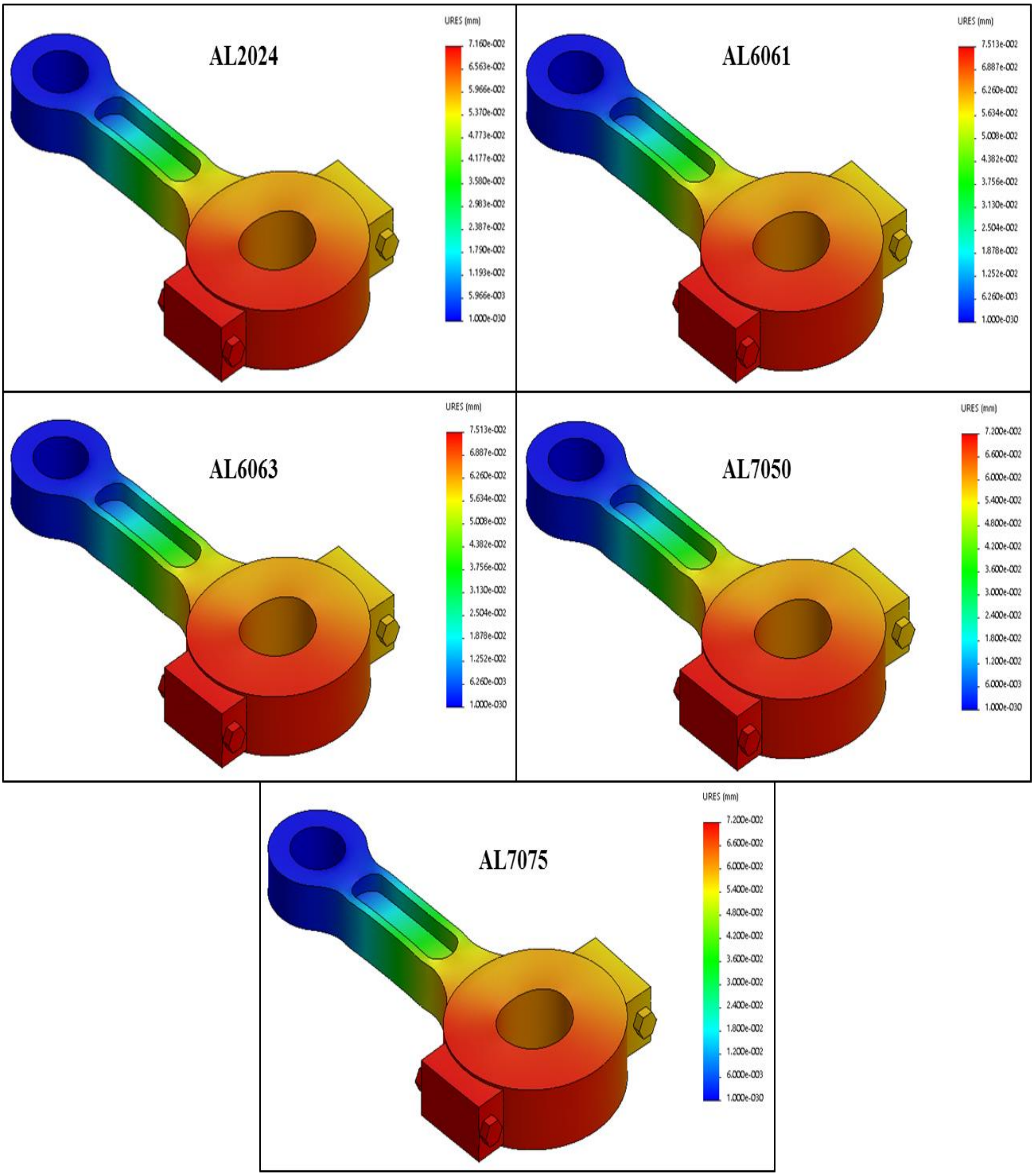

Fig. 6. Resultant displacement for AL6061-T0

5. Comparative study

The comparative study was carried out among the various aluminum alloys such as AL2024, AL6061, AL6063, AL7050 and AL7075 materials. The graphical results are plotted as shown in Figure 7. The type of material can fail under the constant load of 10kN was observed through the results of comparative study.

The highest strain or permanent deformation value was obtained in AL6061 and AL6063 materials. Whereas, the lowest deformation value was obtained in AL2024 material. These results highlight that the material AL6061 and AL6063 are not suitable for the design of connecting rods.

Furthermore, the comparison of the displacement values is shown in Figure 8. The graph shown that material AL2024 has very small displacement value 0.0716 mm as compared to the other four aluminum alloys.

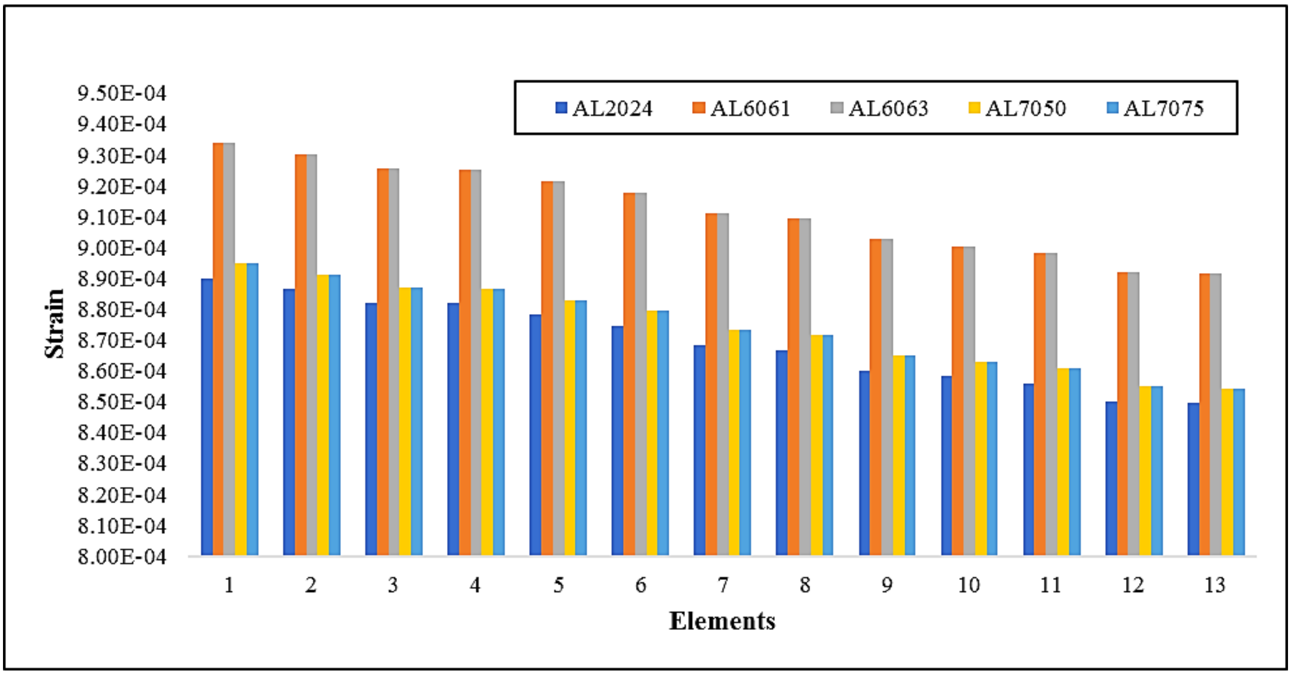

Fig. 7. Comparative results of strain for all materials

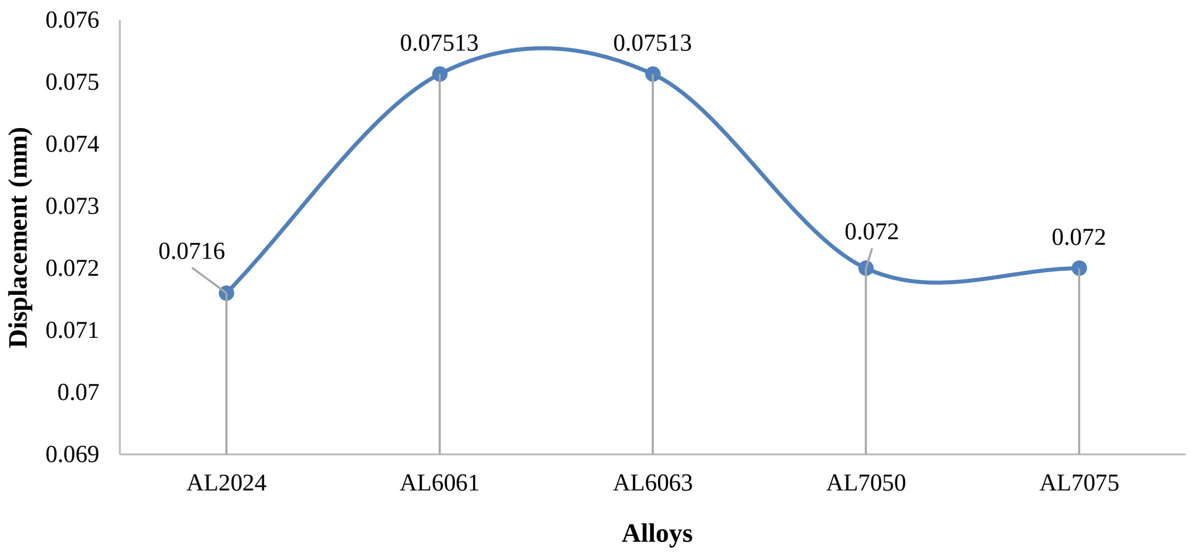

Fig. 8. Comparative results of displacement for all materials

6. Conclusion

The connecting rod for IC engines was designed in SOLIDWORKS whereas, its structural failure analysis was carried out in SOLIDWORKS FEA tool. The piston end of connecting rod was selected as rigid side fixed with piston pin, whereas the crank end side was considered to be subjected in compressive load imparted due to the combustion of fuel. The 10kN compressive load applied on connecting rod, which is made of different aluminum alloys material. The model was analyzed and results show that model goes into permanent deformation. The maximum von mises stress was induced in the connecting rod at the weakest region and which was 8.45×10^7 N/m^2 under compressive loading. Moreover, the highest deformation occurred during compression with value of 0.713 mm for material AL6061 and AL6063. Since, the lowest deformation observed in AL2024. The study concluded that the aluminum alloy AL2024 is the most strong and suitable material among other aluminum alloys for the design of the IC engine connecting rods.

References

[1] B. A. Vinayakrao, M. C. Swami. Analysis and optimization of connecting rod used in heavy commercial vehicles. International journal of engineering development and research, Vol. 5, No. 3, pp. 684-707, 2017.

[2] C. V. Vazhappilly, P. Sathiamurthi. Stress analysis of connecting rod for weight reduction-A Review. International Journal of Scientific and Research Publications, Vol. 3, No. 2, pp. 1-5, 2013.

[3] R. A. Savanoor, A. Patil, R. Patil, A. Rodagi. Finite Element Analysis of IC Engine Connecting Rod by ANSYS.

International Journal of Mechanical Engineering and Robotics Research, Vol. 3, No. 3, pp. 510-516, 2014.

[4] L. K. Vegi, V. G. Vegi. Design and Analysis of Connecting Rod using Forged Steel. International Journal of Scientific and Engineering Research, Vol. 4, No. 6, pp. 2081-2090, 2013.

[5] A. Mirehei, M. H. Zadeh, A. Jafari, M. Omid. Fatigue Analysis of connecting rod of universal tractor through finite element method (ANSYS). Journal of Agricultural Technology, Vol. 4, No. 2, pp. 21-27, 2008.

[6] G. M. S. Ahmed, S. E. Khany, S. H. Shareef. Design, Fabrication and Analysis of a Connecting rod with Aluminum alloys and carbon fiber. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, No. 10, pp. 16674-16687, 2014.

[7] M. S. Shaari, M. M. Rehman, M. M. Noor, K. Kadirgama, A. K. Amirruddin. Design of Connecting rod of Internal Combustion Engine: A Topology Optimization Approach. National Conference in Mechanical Engineering Research and Postgraduate Studies, pp. 155-166, 3-4 December 2010.

[8] C. Juarez, F. Rumiche, A. Rozas, J. Cuisano, P. Lean. Failure Analysis of a Diesel Generator Connecting Rod. Case Studies in Engineering Failure Analysis, Vol. 7, pp. 24-31, 2016.

[9] P. K. Samal, B. Murali, Abhilash, T. Pasha. Finite Element Analysis of Connecting Rod of IC Engine. MATEC Web of Conferences, Vol. 34, pp. 02004 (1-2), 2015.

[10] R. Shrivastava. Finite Element Analysis of Connecting Rod for Two Wheelers and Optimization of Suitable Material Under Static Load Condition. International Research Journal of Engineering and Technology, Vol. 4, No. 2, pp. 537-543, 2017.

[11] A. A. Haider, A. Kumar, A. Chowdhury, M. Khan, P. Suresh. Design and Structural Analysis of Connecting Rod. International Research Journal of Engineering and Technology, Vol. 5, No. 5, pp. 282-285, 2018.

[12] J. P. Fuertes, O. Murillo, J. Leon, C. Luis, D. Salcedo, I. Puertes, R. Luri. Mechanical Properties, Analysis of an Al-Mg alloy Connecting Rod with Submicrometric Structure. Procedia Engineering, Vol. 132, pp. 313-318, 2015.

[13] J. D. Roamani, S. Shukla, P. K. Sharma. FE Analysis of Connecting rod for C.I Engine by using ANSYS for Material Optimization. Journal of Engineering Research and Applications, Vol. 4, No. 3, pp. 216-220, 2014.

[14] N. U. Thakare, N. D. Bhusale, R. P. Shinde, M. M. Patil. Finite Element Analysis of Connecting Rod using ANSYS. International Journal of Advances in Science Engineering and Technology, Vol. 3, No. 2, pp. 82-86, 2015.

[15] M. Kumar, A. K. Biradar. A Review paper on Design Analysis of Connecting rod. International Journal on Recent and Innovation Trends in Computing and Communication, Vol. 5, No. 6, pp. 479-481, 2017.

[16] D. S. Bedse, Design Evaluation of Connecting rod. International Journal of Recent Engineering Research and Development, Vol. 2, No. 7, pp. 203-213, 2017.

[17] P. Singh, D. Pramanik, R. V. Singh. Fatigue and Structural Analysis of Connecting rod's Material due to C.I Engine using FEA. International Journal of Automotive Engineering and Technologies, Vol. 4, No. 4, pp. 245-253, 2015.

[18] S. Wable, D. S. Galhe, R. L. Mankar. A Review on Design and Optimization of connecting rod. International Journal on Applied Research in Industrial Engineering, Vol. 2, No. 1, pp. 261-270, 2016.

[19] D. M. Kumar, L. Rakesh. Design and Analysis of a Connecting rod. International Journal of Pure and Applied Mathematics, Vol. 116, No. 15, pp. 105-109, 2017.

[20] A. H. Khan, D. R. Dolas. Design a, Modelling and Static Structural Analysis of Connecting rod. Imperial Journal of Interdisciplinary Research, Vol. 3, No. 1, pp. 400-408, 2017.