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DYNAMICS AND TRANSIENT ANALYSIS OF DIFFERENT MATERIAL OF CONNECTING ROD OF AN IC ENGINE

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Abstract

Internal combustion (IC) engines are integral components of various modes of transportation, including cars, aircraft, and boats. Among the critical components of an IC engine, the connecting rod plays a pivotal role in converting the reciprocating motion of the piston into the rotating motion of the crankshaft, which operates at extremely high speeds. Consequently, the design and choice of material for the connecting rod become crucial in ensuring reliable engine performance and durability. In this research, a detailed investigation was conducted on the connecting rod of a 4-cylinder engine using Computer-Aided Design (CAD) software CATIA V5. Subsequently, dynamic and transient structural analyses were carried out through Finite Element Analysis (FEA) using ANSYS Workbench 19.2. The objective was to evaluate the performance of the connecting rod when fabricated from different materials, including Structural Steel, Aluminium Alloy, Titanium Alloy, and Magnesium Alloy. To assess the connecting rod's performance, a constant torque or moment of 10N-mm was applied to the crankshaft for duration of 4 seconds. The analysis aimed to elucidate the stresses experienced by the connecting rod during this operation and to study the development of forces at the junction between the connecting rod and the crankshaft. These findings were then used to determine the most suitable material for manufacturing the connecting rod in terms of strength and reliability. The results of this study provide valuable insights into the structural behaviour of connecting rods made from various materials and offer guidance to engine designers and manufacturers seeking to optimize performance while ensuring component longevity and safety.

Keywords- *Ansys, Connecting rod , Catia V5, Dynamics and Transient analysis.*

1.INTRODUCTION

The internal combustion engine essentially operates as a crank-slider mechanism, with the piston serving as the slider. In this setup, the piston moves up and down due to the rotary motion of the crankshaft. The piston is housed within a combustion chamber where the fuel combines with an oxidizer to undergo combustion. This combustion takes place within the engine's working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases resulting from combustion exerts a direct force on the piston. This force causes various engine components, such as the connecting rod and crankshaft, to move. This mechanical motion effectively converts chemical energy into useful mechanical energy.

Key components of an internal combustion engine include the cylinder, piston, piston rings, connecting rod, crankshaft, and more. The connecting rod plays a vital role as it acts as a link between the piston and the crankshaft. Its small end attaches to the piston pin (also known as the gudgeon pin or wrist pin), which is usually press-fitted into the connecting rod but can pivot within the piston. On the other end, the larger end connects to the crankshaft. The primary function of the connecting rod is to convert the piston's linear motion into the rotational motion of the crankshaft. Additionally, it handles the transfer of the piston's thrust to the connecting rod [1] .[2] In a study conducted by Mr. H. B. Ramani, Mr. Neeraj Kumar, and Mr. P. M. Kasundra in 2012, a comprehensive load analysis of the connecting rod was carried out. This analysis was followed by the application of the finite element method using Ansys-13 software. To analysis the stress levels in various sections of the connecting rod, the total forces acting on the connecting rod were calculated. Subsequently, a detailed model of the connecting rod was created, meshed, and loaded within the Ansys software. This allowed for the determination of the maximum stress points in different regions of the connecting rod through a thorough analysis. [3] In a study conducted by Vivek. C. Pathade, Bhumeshwar Patle, and Ajay N. Ingale in 2012, it was found that every vehicle utilizing an internal combustion engine requires at least one connecting rod. In terms of functionality, connecting rods must possess maximum rigidity while keeping their weight to a minimum. The primary stresses experienced by connecting rods arise from a combination of axial and bending forces during operation.Axial stresses occur due to cylinder gas pressure, primarily compressive in nature, and the inertia forces resulting from reciprocating motion, involving both tensile and compressive stress. Meanwhile, bending stresses originate from centrifugal effects. As a result, the highest stress concentrations are typically found at the fillet sections of both the big and small ends of the connecting rod.This study focuses on analyzing the stress distribution in connecting rods using the Finite Element Method, employing software like Pro/E Wildfire 4.0 and ANSYS Workbench 11.0. [4]Saharash Khare, O.P. Singh, K. Bapanna Dora, and C. Sasun in 2011, various components of internal combustion engines were examined. Subsurface cracks and pit marks were observed in the crank pin, roller bearings, and the big end surfaces of connecting rods. The primary cause of these issues was identified as high wear at the interfaces of these components. To address this problem, a laboratory test setup was developed to replicate field failures. The loads and boundary conditions obtained from these experiments were used in a finite element model of the connecting rod assembly. The results revealed high interfacial pressure and stress concentrations near the junction of the web and flange of the connecting rod.

By implementing a modified design for the connecting rod, significant reductions in extreme pressure in the finite element model were achieved. This led to a substantial improvement in the durability and service life during laboratory tests. The study also delves into the issue of spalling and its connection to high localized interfacial pressure, which is attributed to the design of the web and flange of the connecting rod. [5] Numerous researchers have dedicated their efforts to the design of crankshafts. In a study by Farzin H. Montazersadgh and Ali Fatemi, dynamic simulation was conducted on a crankshaft from a multi-cylinder four-stroke engine.

They employed finite element analysis to assess stress variations at critical points in the crankshaft. Additionally,[6] Ankit Gupta and colleagues explored different materials for connecting rods and conducted analyses to determine Von Mises stress, Von Mises strain, and displacement under various loads. Their findings highlighted Beryllium alloy as the most suitable material compared to Aluminium and Magnesium alloy.

Furthermore, [7] K. Sudershn Kumar and his team employed ANSYS Software to analyze connecting rods, evaluating parameters like Von Mises stress, Von Mises strain, displacement, and the working factor of safety. They compared results across Aluminium, Carbon steel, and Aluminium boron carbide materials for connecting rods. [8]Puneet Agarwal and associates performed an analysis of two-wheeler connecting rods using various materials such as Forge steel, Titanium alloy, and Aluminium alloy. They also assessed Von Mises stress and Von Mises strain using ANSYS software. Notably, they conducted a comparative study and found that increasing the silicon percentage in Aluminium material resulted in stress reduction. [10]Shenoy and Fatemi – conducted dynamic analysis of loads and stresses in the connecting rod component, which is in contact with the crankshaft. Dynamic analysis of the connecting rod is similar to dynamics of the crankshaft, since these components form a slide-crank mechanism and the connecting rod motion applies dynamic load on the crank-pin bearing. Their analysis was compared with commonly used static FEA and considerable differences were obtained between the two sets of analysis.[11]Aluminium rods are popular among high rpm race engines. They are very light and strong, but they a short fatigue lift. In a limited use situation, they can last a long time and usually those types of engines see frequent tear downs anyway. High rpm is where aluminium rods offer advantages, so it can be preferred by most of the company’s .The aluminium alloys are less in weight and its expense is less than other materials. Mr.Ruchir Shrivastava [12] made modelling of two wheeler connecting rod using Cre O software also made the analysis using ANSYS software. The comparison of two materials like C70S6 Steel and Structural Steel is carried out which shows nearly similar results. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight. So the connecting rods are designed generally of I-section to provide maximum rigidity with minimum weight. On the basis of that design, a physical model is modelled in CATIA V5. Structural system of connecting rod has been analysed using FEA. With the use of FEA, various stresses are calculated for a particular loading conditions using FEA software ANSYS WORKBENCH 14.5. It is an CAE software, which has many capabilities, ranging from simple static analysis to complex non-linear, dynamic analysis, thermal analysis, transient state analysis, etc. By solid modelling software, the geometric shape for the model is described, and then the ANSYS program is used for meshing the geometry for nodes and elements. In order to obtain the desirable results at each and every point of the model, the fine meshing is done which also results in accurate results output.

2. METHODOLOGY

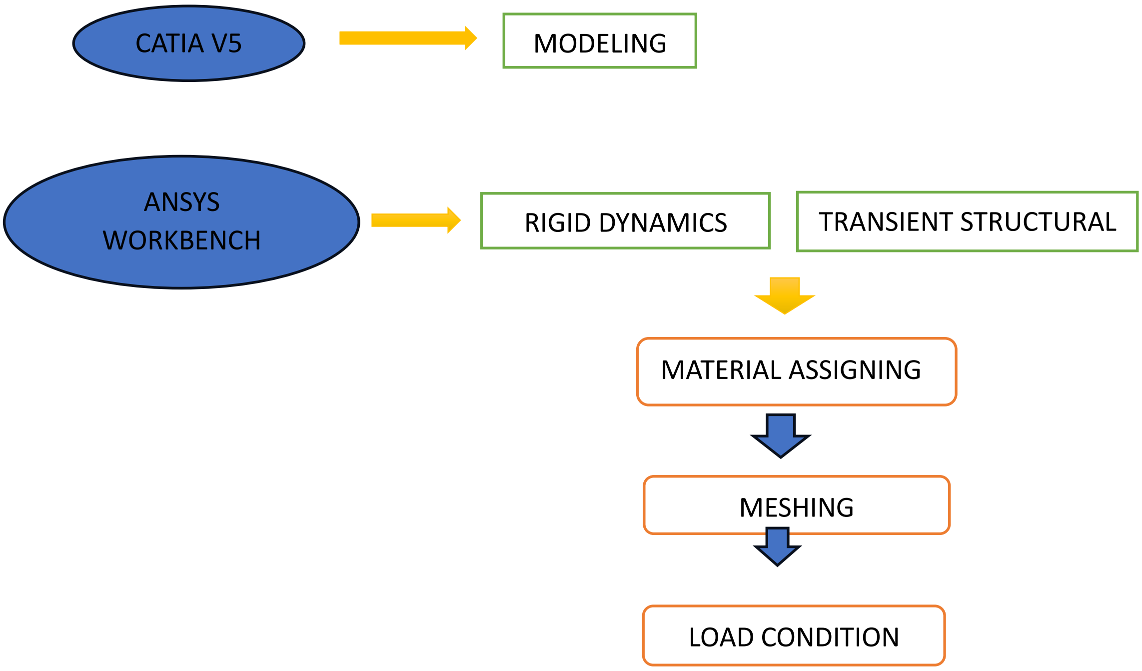


Figure: 01: Diagram for different step of methodology

2.1. MODELING

For modelling CATIA is mostly preferred software. 3D model of any complex model is easily visualized by the CATIA. Therefore the 4 cylinder internal combustion engine is modelled in Catia V5 by using part design under mechanical design. There are following parts

(1) 4 connecting rod (2) 4 piston (3)Pin (4) Crankshaft (5) Crankcase

After modelling the parts they have been assembled in assembly design under mechanical design. Assembly of parts in Catia V5

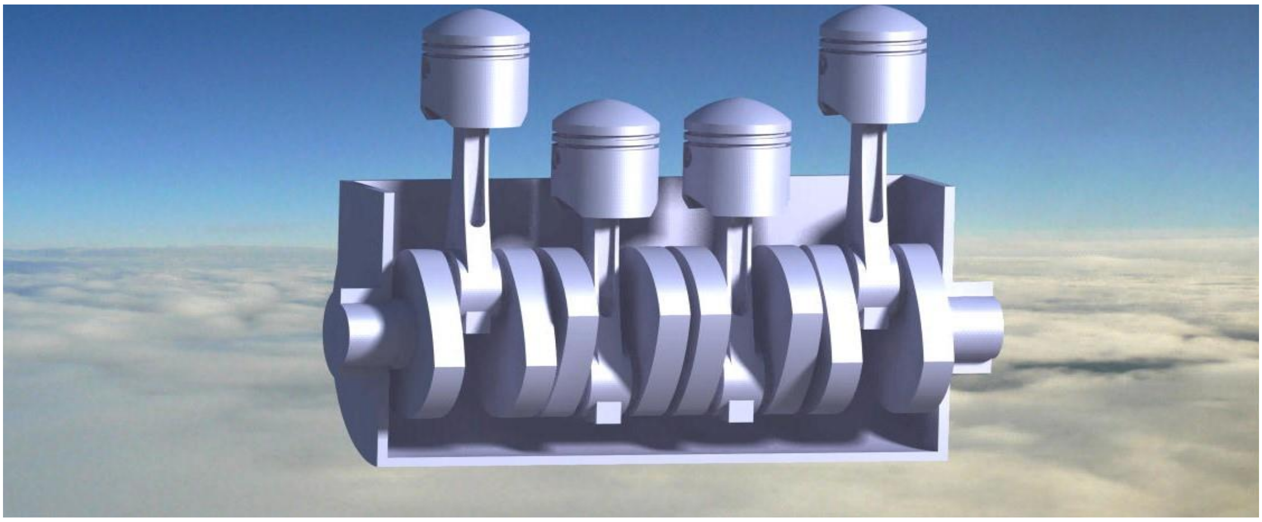


Figure:02 Assembled 4 cylinder internal combustion engine

After assembling the product is saved as stp. File extention and have been imported to Ansys workbench.

2.2. MATERIAL ASSIGNING

In ansys the material of different parts are assign they are as follows in tabular form.

S.No.	Part name	Material	Density
1	Connecting rod 1	Structural Steel	7.85e-06kg/mm³
2	Connecting rod 2	Aluminium alloy	2.77e-06 kg/mm³
3	Connecting rod 3	Titanium alloy	4.62e-06 kg/mm³
4	Connecting rod 4	Magnesium alloy	1.8e-06 kg/mm³
5	Pin	Structural Steel	7.85e-06kg/mm³
6	Crankshaft	Structural Steel	7.85e-06kg/mm³
7	Piston	Structural Steel	7.85e-06kg/mm³
8	Crankcase	Structural Steel	7.85e-06kg/mm³

2.3. MESHING

Meshing is very important step in the analysis process. Meshing divides the product or model in number of parts for further analysis.

Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Medium
Initial Size Seed	Assembly
Bounding Box Diagonal	422.92 mm
Average Surface Area	926.45 mm²
Minimum Edge Length	0.50521 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Statistics	
Nodes	11307
Element	5735

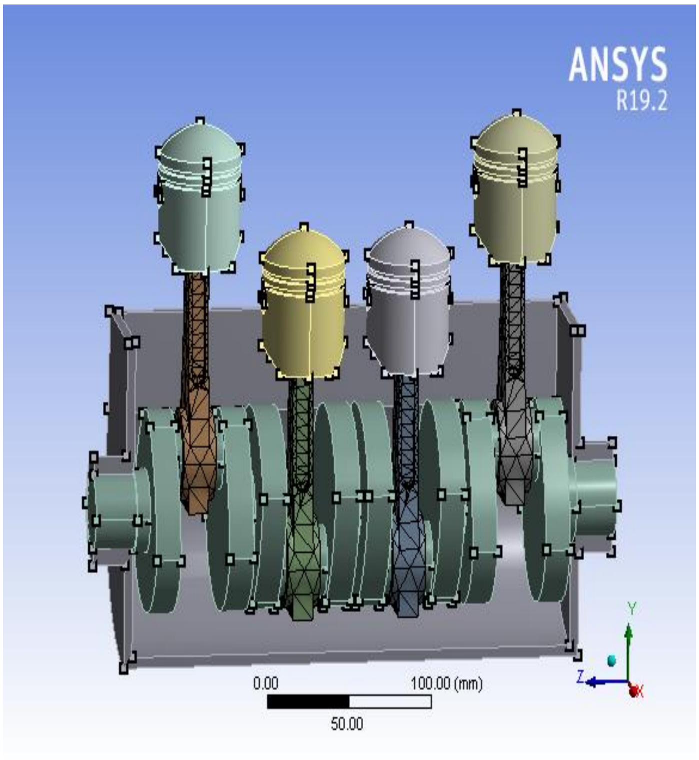
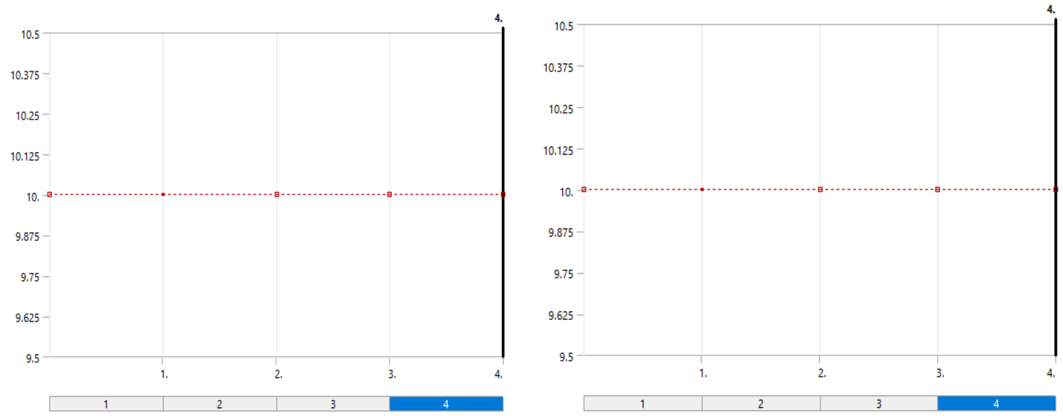


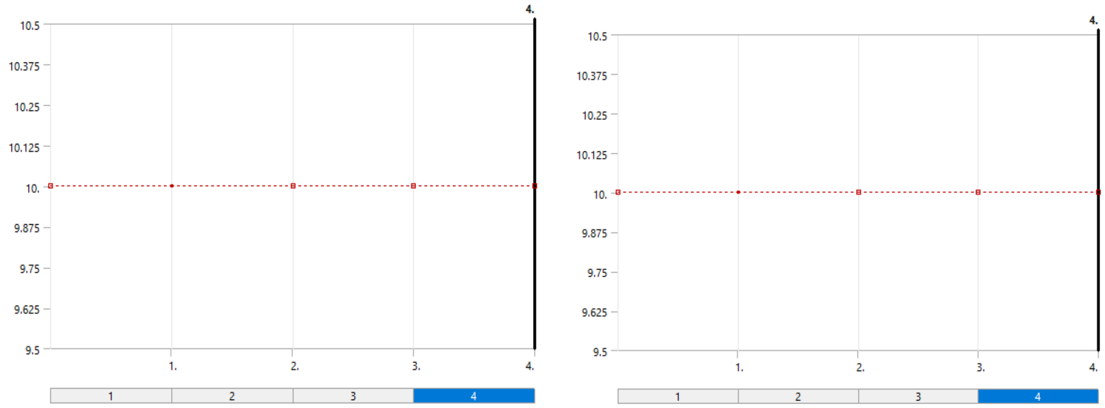
Figure: 03, Meshing Process

2.4. LOAD CONDITION

A constant Torque or moment of 10N-mm is being applied on crankshaft for 4 second.



1) Moment on connecting rod 1 and crankshaft 2) Moment on connecting rod 2 and crankshaft



3) Moment on connecting rod 3 and crankshaft 4) Moment on connecting rod 4 and crankshaft

Figure: 04: Moment on different connecting rod and crankshaft

3. RESULT AND ANALYSIS

3.1. Equivalent Stress

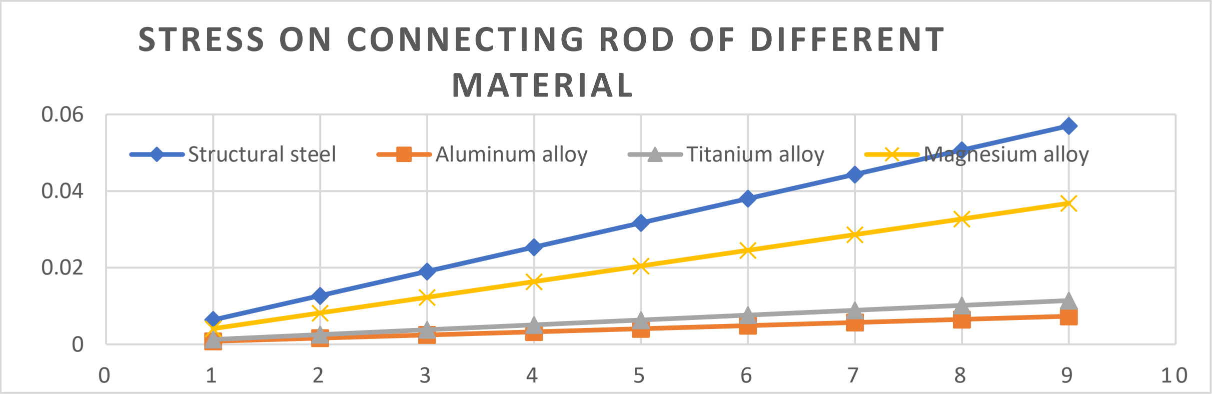
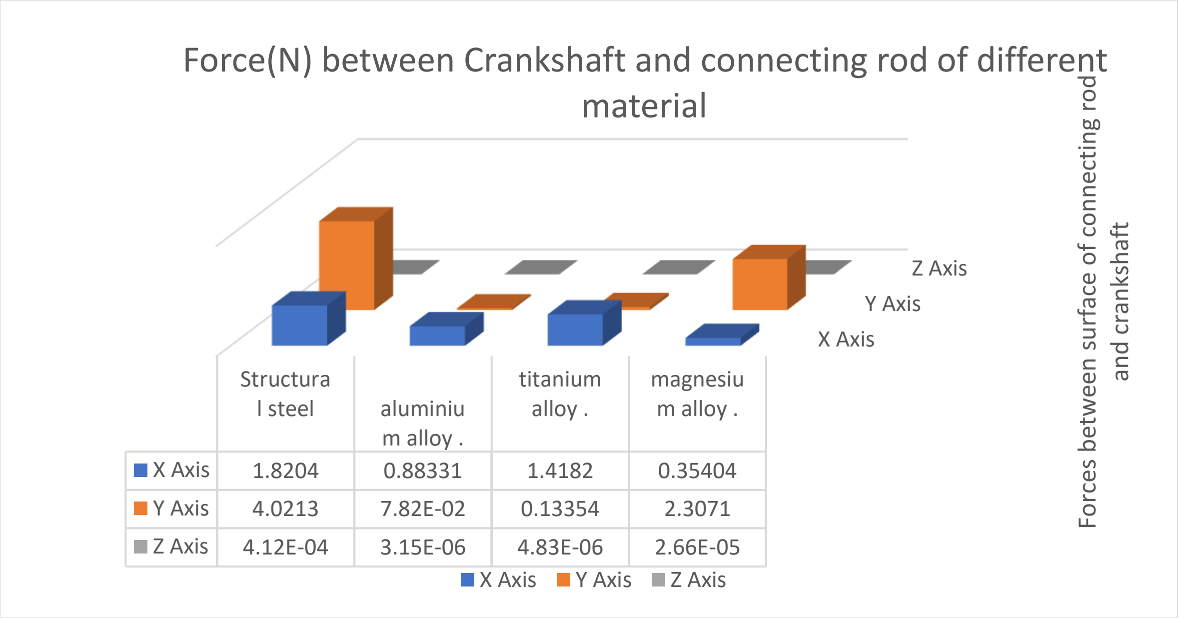


Figure: 05: Stress(Mpa) on connecting rod of different material

The figure 05: indicates that the aluminium alloy connecting rod experiences the least maximum stress, specifically 0.0073384 MPa, when subjected to a torque of 10 Nmm on the crankshaft. Therefore, it can be concluded that among the four different materials considered, aluminium is the most suitable material for a connecting rod in an internal combustion engine, especially when stress is the primary concern. Aluminium alloys offer several advantages, such as lower weight and high impact absorption capabilities. The reduced weight of the connecting rod decreases the overall mass of the reciprocating assembly, enabling the engine to achieve higher revs with reduced stress. Additionally, aluminium alloys exhibit a superior strength-to-weight ratio when compared to the other materials under consideration. For instance, aluminium has a tensile strength of 276 MPa and a density of 2.81 g/cm^3, resulting in a remarkable strength-to-weight ratio of 98.22, which surpasses that of structural steel, titanium alloy, and magnesium alloy.

3.2. Total Force at the joint between connecting rod and crankshaft

Figure 06: shows the force applied between the crankshaft and the larger end of the connecting rod, each connecting rod made from different materials, while maintaining a constant torque of 10 Nmm given to crankshaft. From the data in figure (06), it becomes evident that connecting rods constructed from aluminium alloy exhibit the lowest forces in the x, y, and z directions. This implies that there will be reduced stress, friction, and heat generation between the aluminium alloy connecting rod and the crankshaft, consequently leading to less wear and tear on the connecting rod's surface that comes into contact with the crankshaft. As a result, aluminium alloy connecting rods are expected to have a longer lifespan. Moreover, there will be more smoother movement between the aluminium alloy connecting rod and the crankshaft, in comparison to crankshafts and connecting rods made of structural steel, titanium alloy, and magnesium alloy.



	Structural steel	aluminium alloy .	titanium alloy .	magnesium alloy .
🟦 X Axis	1.8204	0.88331	1.4182	0.35404
🟧 Y Axis	4.0213	7.82E-02	0.13354	2.3071
⬜ Z Axis	4.12E-04	3.15E-06	4.83E-06	2.66E-05

Figure: 06: Force between crankshaft and connecting rod of different material

4. CONCLUSION

This research strongly supports the utilization of aluminum alloy for connecting rods in internal combustion engines, especially when stress is a primary concern. The analysis of the data reveals that aluminum alloy connecting rods experience the least maximum stress. This pivotal observation establishes aluminum as the most suitable material among the four considered. The advantages offered by aluminum alloys further underscore this recommendation. Notably, they exhibit a superior strength-to-weight ratio compared to structural steel, titanium alloy, and magnesium alloy. With a tensile strength of 276 MPa and a density of 2.81 g/cm^3, aluminum boasts a remarkable strength-to-weight ratio of 98.22. This lightweight characteristic reduces the reciprocating assembly's overall mass, enabling the engine to achieve higher revs with reduced stress. Moreover, aluminum alloys excel in impact absorption capabilities. The forces acting between the crankshaft and the connecting rod's larger end, reaffirming aluminum's superiority. Connecting rods made from aluminum alloy consistently exhibit the lowest forces in the x, y, and z directions. This implies reduced stress, friction, and heat generation at the crucial interface between the aluminum alloy connecting rod and the crankshaft. Consequently, these results in decreased wear and tear, contributing to a longer lifespan for aluminum alloy connecting rods.

Additionally, the smoother movement observed between aluminum alloy connecting rods and crankshafts, when compared to structural steel, titanium alloy, and magnesium alloy counterparts, promises enhanced engine performance and durability. Taken together, these findings present a compelling case for the adoption of aluminum alloys in the design and construction of connecting rods for internal combustion engines.

REFERENCE

[1]Suraj Pal and Sunil kumar, “Design evaluation and optimization of connecting rod parameters using FEM,” *International Journal of Multidisciplinary Educational Research, Vol. 2, Issue 6, pp. 21-25, 2012.*

[2] Mr. H. B. Ramani, Mr. Neeraj Kumar, Mr. P. M. Kasundra. Analysis of Connecting Rod under Different Loading Condition Using Ansys Software. *Vol. 1 Issue 9, November- 2012.*

[3] Vivek. C. Pathade, BhumeshwarPatle, Ajay N. Ingale. Stress Analysis of I.C.Engine Connecting Rod by FEM. *Volume 1, Issue 3, March 2012.*

[4] Saharash Khare, O.P. Singh, K. Bapanna Dora, C. Sasun. Spalling investigation of connecting rod. *Engineering Failure Analysis 19 (2012) 77–86.*

[5] Burrell, N. K., 1985, “Controlled Shot Peening of Automotive Components,” *SAE Technical Paper No. 850365, Society of Automotive Engineers, Warrendale, PA, USA.*

[6] AnkitGupta1, Mohd. Nawajish, design and analysis of two wheeler connecting rod using different materials, *International Journalof Advance Research In Science and Engineering http://www.ijarse.com ijarse, vol. no.3, special issue (01), september 2014.*

[7] Kumar, K. Sudershn, Dr K. Tirupathi Reddy, and Syed Altaf Hussain. "Modeling and analysis of two Wheeler connecting rod.*" International Journal of Modern Engineering Research2.5 (2012): 3367-3371.10).*

[8] Agarwal, Puneet, Ankit Gupta, and Vishal Saxena. "Modeling and Analysis of Two Wheeler Connecting Rod using Finite Element Method."*MIT International Journal of Mechanical Engineering, 6(1) (2016): 21-27*

[9] S. S. Rattan, “*Theory of Machine*”, McGraw Hill Education; Fourth edition.

[10] Shenoy, P. S. and Fatemi, A., 2006, “Dynamic analysis of loads and stresses in connecting rods,” *IMechE, Journal of Mechanical Engineering Science, Vol. 220, No. 5, pp. 615-624*

[11] Anand. R, S. Raghukumar,”Design and Analysis of Connecting Rod Using Different Materials” *International Journal for Research in Applied Science and Engineering Technology,2022-05-02.*

[12] Ruchir Shrivastava,Finite Element Analysis of Connecting Rod for Two Wheeler and Optimization of Suitable Material Under Static Load Condition‖ *International Research Journal of Engineering and Technology (IRJET), 4(2) (2017):537-543.*