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Connecting Rod Deformation and Statical Stress Analysis Using Various Materials: A Review

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***Abstract:** In the world of engineering, connecting rods play a crucial role in ensuring that an engine runs smoothly and efficiently. Made from a variety of materials, these rods connect the pistons to the crankshaft, allowing for proper transfer of energy throughout the system. But with so many options available, which material is best? In this review paper, we will explore the advantages and disadvantages of various materials used for making connecting rods. From traditional steel advanced composites analysed using ANSYS FEA software, read on to discover how each material stacks up in terms of performance and durability.*

Based on previous research the objective of this review paper is "Deformation and Static Stress Analysis of Connecting Rod Using Various Materials"

***Keywords:** Aluminium alloy, Material optimization, connecting rod, Finite element analysis, Topology optimization, Ansys.*

I. INTRODUCTION

Two wheelers are one of the most popular forms of transportation in the world, and connecting rod (figure 1) assemblies are a major component of the drivetrain[1]. Connecting rods have to link the piston's linear motion to the crankshaft, and they ought to be sufficiently durable to survive heavy stress and strain[2]. Connecting rods are critical components in internal combustion engines that bear both static and dynamic loads[3], [4]. Optimization of connecting rods is important for the automotive industry in order to improve engine performance and strengthen the product[4][3]. Various materials have been studied for use in connecting rod construction, and each has its own unique properties and advantages. This review is based on the comparison of various material that suitable to make connecting rod for automobile, The rods are manufactured from different materials, including steel, aluminium, and titanium alloys[5]. Static stress analysis is performed to determine the loads exerted on the rod under various conditions. This paper will analyse the performance of different materials for two-wheeler connecting rods in terms of their strength, stiffness, weight, cost, and other properties[6].

Figure 1 (connecting rod)

1) *Strength:* Strength is an important property for two-wheeler connecting rods, given that two-wheeler connecting rods must be able to endure extreme amounts of strain and stress encountered throughout functioning, strength is an important factor[7]. The connecting rod can be made out of a variety of materials, each of which has distinct strengths. For instance, steel, which is frequently used for connecting rods and has a high strength-to-weight ratio, offers great fatigue strength[8]–[10]. Another material choice is aluminium, which has a great strength-to-weight and fatigue strength ratio. Although more expensive than steel or aluminium, other materials can also be employed, such as titanium and magnesium[11].
2) *Stiffness:* Stiffness is another important property for two-wheeler connecting rods, as they must be able to maintain their shape and strength under high levels of strain. The connecting rod can be made of several materials, and each one has distinct stiffness properties. Aluminium has a great stiffness-to-weight ratio and fatigue strength compared to steel, which has a high stiffness-to-weight ratio. Titanium and magnesium are also good options, although they are typically more expensive than steel or aluminium[12]–[14].
3) *Weight:* Weight is an important factor when it comes to two-wheeler connecting rods, as they must be light enough to handle the high levels of stress and strain during operation,The connecting rod can be made of several materials, and each has certain weight properties. Aluminium is the lightest material option, and it has excellent strength-to-weight ratio and fatigue strength. Steel is a heavier material, but it has a high strength-to-weight ratio and good fatigue strength. Titanium and magnesium are also good options, although they are typically more expensive than steel or aluminium[12], [15]–[17].In order to find the optimum solution to a problem. he technique Topology modification is the process of adding or removing material from a model based on specific constraints. TOSCA, a piece of software associated with the Abaqus Expressive finite element structure analysis utilisation, allows topology optimisation. The following needs to be specified before optimisation analysis can be performed[18]–[22]

The variables to be considered in the analysis are:
1) *Design Considerations:* It's the entity the unit in charge of design variable analysis.
2) *Objective Purpose:* The real- valuable function whose value is to be either minimized or maximized, subject to the constraint
3) *Numerical Restrictions:* These are the parameter that must be achieved to find the purpose of objective function.
4) *Geometric Restrictions:* Consistency of outcomes. relate for any furthermore, undeclared limitations on design [18], [23], [24].

For Example: The design responses, the design remedies, for illustration, are mass and stress if the aim is to lower mass while remaining over a maximum stress. Additionally, the design space can be constrained to prevent material from being taken away from any vital domains, and many objective function variables that can be weighted according to their relative significance to the issue can be introduced[25]–[29].

II. LITERATURE REVIEW

The various researches have been study for the performance of the connecting rod some of them are**:**

A. *Kumar Verma R, Kumar Jain A (2022) [1]*

The research focused on optimizing the shape and material of a connecting rod for a 125-cubic-centimeter engine. The study used simulation and analysis tools like Autodesk Inventor and ANSYS to evaluate the performance of different materials, including Alloys of Al and composites. A356-5% SiC-10% fly ash in stir-cum squeeze casting indicate the better results, with a weight reduction of 43.48% and increased stiffness. The use of fly ash as a by-product makes it an environmentally friendly option. Overall, the study provides valuable insights for designing more efficient and durable connecting rods for engines.

B. *Buddi T, R.S. Rana (2021) [2]*

The research focuses on enhancing the mechanical properties of connecting rods used in engines by introducing Si_3N_4 ceramic reinforcement in Al7068 alloy. Different weight %ages of Si_3N_4 are added to create Al- Si_3N_4 composites through stir casting. Tensile tests reveal that as Si_3N_4 content increases, ultimate tensile strength and yield strength improve. However, %age elongation decreases due to increased brittleness. Brinell hardness numbers and density also increase with higher Si_3N_4 content. Finite element analysis is accomplished to investigate the connecting rod's stress distribution under compressive loads.

The results show the maximum stress and strain concentrations at specific locations, indicating that Si_3N_4 reinforcement enhances the mechanical performance of the connecting rod. This research open up possibilities for lightweight and durable connecting rods in engine design. The addition of Si_3N_4 increases the hardness and elasticity of the resulting Al- Si_3N_4 composites. Hardness rises by 49.8% as Si3N4's weight %age rises from 0% to 5%, and elasticity rises from 98 MPa to 140.5 MPa. finite element analysis indicates the maximum stress occurs at specific locations within the connecting rod, and The Factor of Safety, which ranges from 1.6 to 1.7, points to a secure design.

C. T. Sathish, S. Dinesh Kumar, S. Karthick (2019) [3]

In this study, the researchers analysed the performance of these various Al alloy materials (AA-2014, AA-6061, and AA-7075) in manufacturing connecting rods for high-speed engines in bikes. They conducted Finite Element Analysis (FEA) using ANSYS software to obtain stress, deformation, and shear stress results. The main focus was to compare the three materials based on their weight, stiffness, and deformation. Furthermore, AA2014 exhibited high von Mises stress, indicating its superior strength compared to the other alloys. The optimized connecting rod was determined to be made from AA2014, as it demonstrated a deformation of 0.66911 mm and a stiffness of 2312 N/mm, both of which were favourable characteristics. Overall, based on the analysis results, AA2014 was identified as the best choice for producing connecting rods, offering a balance of low weight, high strength, and reduced deformation. the study suggests that AA2014 is the best alternative material for producing connecting rods due to its favourable mechanical properties and ability to withstand high-speed engine conditions.

D. S. Seralathan, Sai Viswanath Mitnala, RV. Sahith Kumar Reddy, Inturi Guru Venkat b, Dadi Reddy Tejeswar Reddy b, V. Hariram, T. Micha Premkumar (2020) [4]

The connecting rod of a compress ignition engine will reportedly be the focus of a stress investigation in this project. The commercial finite element programme ANSYS is used to do this analysis. The four different materials for the connecting rod were Al-2024-T3, A-356, A-356-5 % SiC-10 % fly ash stir-cum squeez cast, and A-356.

Connecting Rod Accoutrements are studied in terms of Numerical Stress Analysis using a variety of materials that have been subjected to operating loads and stationary Structural Mechanics packages. A356-5-7SiC-10 is the substance. In flyash stir cum squeeze casting, the total distortion, original elastic strain, and original stress are set up to have the lowest distortion values of all the considerations.

E. A. Pandiyan, G. Arunkumar and G. Premkumar (2019) [5]

The goal of the project is to build, examine, and improve the design of a connecting rod for four-stroke, single-cylinder petrol engines using Alloy 6061-T6, Alloy LM6, and Alloy ADC12.According to the research, there is the greatest amount of stress at the tiny end, which is located within the crank end and the big end.Topology was used to optimise the weight of the connecting rod, with the shank region showing the most room for weight decrease.

The safety factor is considerably higher for the alloys LM6 and A6061-T6, while the alloy ADC12 has a little lower safety factor.With an enhanced weight of 130.02 grammes and the material choice of aluminium 6061-T6 toughened alloy, the connecting rod's weight was lowered by 4.1%.

F. Soundararajan Ranganathan, Sathishkumar Kuppuraj, Karthik Soundarrajan, and Ashokvarthanan Perumal (2019) [6]

Connecting rods, which act as a link between the piston and crankshaft, internal combustion engines cannot run without this

Press forging is used to create connecting rods, which are then treated with heat and machined.

Connecting rods can be made from a range of materials, such as carbon and alloy steels, magnesium and aluminium alloys, and titanium alloys.

The connecting rod's weight and essential strength have an impact on the material that is used.

While alloy steel is typically used in high-performance engines, lightweight magnesium or aluminium alloys also offer good performance.

Titanium alloy connecting rods are suitable for high-performance turbocharged engines due to their strength and fatigue qualities. In addition to Ti3Al, popular alloy steels utilised for connecting rods include X19NiCrMo4, GX19NiCrMo4, 14NiCrMo134, 18X2H4MA, and 36NiCrMo4.

G. Kuldeep B , Arun L.R , Mohammed Faheem (2013) [7]

The study looks towards replacing the connecting rod, and SiC, fly ash, and aluminium were employed as composite materials. Composite material was created as a result of this experiment, which resulted in a weight reduction of 43.48 % and a displacement reduction of 75 %. Hybrid aerospace composites can save weight when used in place of the conventional Al360 connecting rod material. The optimised connecting rod weights 43.48 % less than the previous connecting rod.

Table 1. (Result comparison table).

Author/year	Material used	Type of system	Outcomes
Kumar Verma R, Kumar Jain A (2022) [1]	A2014, AA7068, A356, A356-5% Sic-10% fly ash, and A356	125 cc connected rod	[i] A356-5% SiC-10% fly ash exhibits the lowest total deformation and maximum principal elastic strain among the tested materials. [ii] Both analytical calculations and Ansys results indicate that A356-5% SiC-10% fly ash shows the least deformation and highest stiffness, ranking above aluminium alloys AA7068, A356, and AA2014 in terms of mechanical performance.
Buddi T, R.S. Rana (2021) [2]	Al7068 alloy and Si_3N_4.	150cc	[i] The content of Si3N4 particles in the Al-Si3N4 composites ranges from 0 wt % to 5 wt % [ii] factor of safety is between 1.6 to 1.7
T. Sathish, S. Dinesh Kumar, S. Karthick (2019 [3]	AA6061, AA7075 and AA2014	150 cc	[i] AA2014 has high strength and also high von mises stress. [i] AA2014 material is lighter then other two materials.
S. Seralathan et al. (2020) [4]	Flyash stir casting in A356-5%SiC-10,Al2024-T3 casting, flash stirs, cum squeeze casting	Deisel engine	[i] In comparison to the base material (A356), the over-all Flyash stir casting in A356-5%SiC-10, deformation of the material is reduced by 38.50%.
A. Pandiyan, G. Arunkumar and G. Premkumar (2019) [5]	ADC12, LM6, A6061	4-Stroke Petrol Single Cylinder Engine	[i] Compared to ADC12, the weight of the connecting rods was decreased by 7.98% utilising Al 6061-T6 material. [ii] rod's weight was reduced by 4.1% and optimised weight is 130.02 gm
Ranganathan et al. (2019) [6]	A-356, A356-5% SiC10% Flyash-Stir casting, A356-5% SiC-10% Flyash-Stir cum squeeze casting, and Al 6061	180 cc engine	[i] A356 with 5% SiC-10% fly ash in stir cum squeeze casting demonstrated an impressive 57 % improvement in material properties compared to similar research work conducted on A356. [ii] Based on the findings, it is recommended to use A356-5% SiC-10% fly ash in stir cum squeeze casting for automobile connecting rods.
Kuldeep B , Arun L.R , Mohammed Faheem (2013) [7]	Al360 and Al6061-9% SiC-15% fly ash	150cc engine	[1] Hybrid Alfa-SiC composites are a viable alternative to replace the current Al360 connecting rod, resulting in a significant reduction in weight. [2] The optimized connecting rod exhibits a remarkable 43.48% weight reduction compared to the existing connecting rod.

III. CONCLUSION

1) To sum it up, the choice of material for making connecting rod depends on a variety of factors such as cost, strength requirements, operating conditions, and manufacturing process. Steel has been traditionally used due to its high tensile strength, durability, and ease of manufacture. However, with advancements in technology and availability of new materials like titanium alloys and composites, there are more options available today.
2) The use of ANSYS FEA software has made it possible to accurately predict the behaviour of different materials under varying loads and conditions. This helps manufacturers make informed choices regarding the selection of material for connecting rods.
3) Research into the production of connecting rods using various materials is still ongoing, and it has enormous potential for enhancing engine performance while lowering weight and raising fuel efficiency. By utilizing advanced modelling techniques like ANSYS FEA software along with innovative manufacturing processes, we can continue to push boundaries in this field.

A. *Advantages and Disadvantages of Each Material*

1) Various materials can be used to make connecting rods, and each material has its own set of advantages and disadvantages. Let us explore some of them.
2) Connecting rods are often made from steel, favoured for its strength, durability, and cost-effectiveness, but its weight can impact engine performance
3) Titanium is a popular choice among high-performance engines due to its lightweight nature. It also has good resistance to corrosion and high temperatures. However, it comes with a hefty price tag that may not be feasible for everyone.
4) Aluminium offers excellent weight savings without compromising on strength or durability. It also dissipates heat well, making it an ideal choice for racing applications where engines run at higher temperatures. However, aluminium tends to wear out faster than other materials due to its low hardness level.
5) There are composites such as carbon fibre reinforced polymer (CFRP) that offer exceptional stiffness-to-weight ratio and reduced vibration compared to traditional metals like steel or titanium. These materials require specialized manufacturing processes that can add significant costs.
6) Each material has its own unique characteristics that can suit different needs depending on the application they are intended for; however careful consideration must be taken when selecting the best option given their benefits and limitations in order get optimal results from your engine design using ANSYS FEA software solutions".

IV. FUTURE SCOPE

1) After examining various connecting rod selection criteria, it was discovered that this study activity offers a large research Potential.
2) Connecting rod can be created with increasingly sophisticated hybrid components, which will make them lighter and cheaper.
3) Manufacturing technologies may also be developed to speed up production and facilitate the design of some crucial rod components.
4) It will boost the life of the connecting rod and be used in business vehicles.

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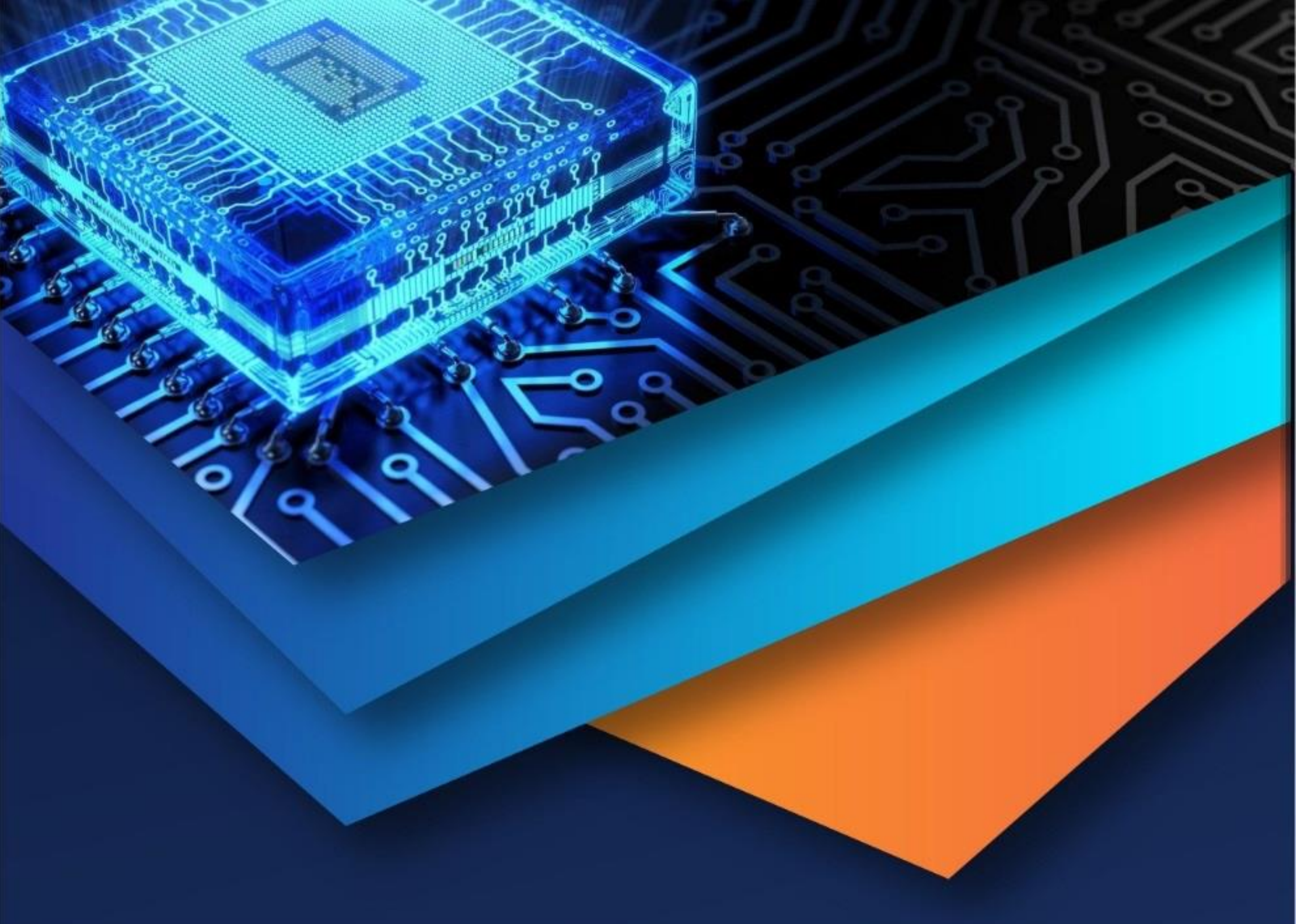

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