WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A-Review Paper and Parameter Discussion on Connecting Rod

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ABSTRACT

This review paper focuses on providing a detailed analysis of connecting rods, which are crucial components in internal combustion engines. The paper explores the design, materials, manufacturing processes, and Key parameters that influence the performance and reliability of connecting rods. It also discusses recent Advancements in connecting rod technology and highlights future trends in this field. This review paper Provides an in-depth examination of connecting rods in internal combustion engines, encompassing their Design, materials, manufacturing processes, and critical parameters. It aims to serve as a comprehensive Resource for researchers, engineers, and automotive enthusiasts. By comprehending the intricacies and Advancements in connecting rod technology, this review contributes to the development of more efficient, Reliable, and high-performance connecting rods for internal combustion engines.

Keywords- Connecting Rod, ANSYS, Optimization, Material, Review

I. INTRODUCTION

The connecting rod is a vital component in internal combustion engines, responsible for converting the reciprocating motion of the piston into the rotary motion of the crankshaft. It consists of a small end connected to the piston pin and a big end connected to the crankpin. Among the various cross-sectional shapes available, the I-section is commonly preferred due to its superior characteristics. To enhance the strength and stiffness of connecting rods, adjustments can be made to their cross-sectional shape or specific parameters. Additionally, material selection plays a crucial role in reducing weight and cost. However, ensuring the structural integrity of the connecting rod requires thorough stress analysis using advanced tools such as ANSYS. Connecting rods are manufactured through different processes. While hot forging is a widely used method, it leads to substantial material wastage (approximately 20 to 40%) due to flash formation. To address this, flashless forging in a closed cavity is employed to minimize material waste. In heavy vehicles, where optimal performance is essential, achieving superior mechanical properties of connecting rods is a priority. Traditional quenching in oil may not meet the desired requirements, but quenching in aqueous polymer water shows potential for improving mechanical properties. However, it is important to be cautious as there is a risk of developing cracks in the connecting rod. Alternatively, connecting rods can be manufactured using powder metallurgy techniques. This involves compacting metal powders and subjecting them to controlled sintering conditions. In conclusion, connecting rods play a critical role in the efficient operation of internal combustion engines. Optimizing their design, material selection, and manufacturing processes is key to achieving enhanced performance, durability, and cost-effectiveness. Thorough stress analysis and consideration of suitable manufacturing methods contribute to the production of reliable and high-performance connecting rods

Connecting rods can be classified based on various factors, including their design, application, and material composition. The following are common classifications of connecting rods:

I. Design-based classification:

a. I-Section Connecting Rod: This design features a central beam with symmetrical flanges on either side, resembling the shape of the letter "I." It offers a good balance of strength and weight and is commonly used in many internal combustion engines.

b. H-Section Connecting Rod: With an H-shaped cross-section, this design includes a thicker central beam and two flanges on each side. H-section connecting rods provide increased strength and stiffness, making them suitable for high-performance engines.

II. Application-based classification:

a. Automotive Connecting Rod: Designed specifically for use in internal combustion engines of automobiles, trucks, and motorcycles. They are engineered to withstand high levels of stress and provide reliable performance.

b. Marine Connecting Rod: These connecting rods are specifically designed for marine engines used in boats, ships, and other watercraft. They are built to withstand the unique challenges of marine environments, including corrosion and high loads.

c. Industrial Connecting Rod: Used in industrial engines for stationary power generation, pumps, compressors, and other heavy machinery. These connecting rods are designed to handle heavy-duty applications and provide long-lasting performance.

III. Material-based classification:

a. Steel Connecting Rod: Made from various steel alloys, these connecting rods offer excellent strength, durability, and resistance to high temperatures. They are commonly used in a wide range of engines.

b. Aluminium Connecting Rod: Constructed from aluminum alloys, these connecting rods are lightweight, which helps reduce the reciprocating mass in the engine. They are often used in performance-oriented engines where weight reduction is crucial.

c. Titanium Connecting Rod: Manufactured from titanium alloys, these connecting rods combine high strength with a lightweight construction. They are commonly found in high-performance engines where weight reduction is critical, such as racing engines.

d. Composite Connecting Rod: These connecting rods are made using composite materials, typically carbon fiber reinforced polymers. They offer an excellent strength-to-weight ratio and are used in high-performance and racing applications.

IV. Engine configuration-based classification:

a. Inline Connecting Rod: Found in engines with a straight or inline cylinder arrangement. Each connecting rod connects to a separate crankpin on the crankshaft.

b. V-Engine Connecting Rod: Used in V-shaped engines, where the cylinders are arranged in a V-configuration. The connecting rods are designed to connect the pistons to the crankshaft at the respective crankpins.

c. Boxer Engine Connecting Rod: Found in horizontally opposed or "boxer" engines, where the cylinders are arranged in a horizontally opposed configuration. The connecting rods are designed to work with the unique layout of these engines.

V. These classifications help categorize connecting rods based on their design, intended application, material composition, and compatibility with specific engine configurations. By considering these factors, engineers and manufacturers can select the most suitable connecting rod for their specific requirements.

In this study, two types of I-beams with different thicknesses, 3 mm and 2 mm, were produced on a foundry scale. The microstructure and compression load of the I-beams were characterized. Compression load was measured using the tensile method. Microstructure observations revealed differences between the I-beam and the end rod microstructures, except for one casting position. However, the compression load results showed similar average values between the 3 mm and 2 mm I-beams, satisfying the compression load requirement of the connecting rod.

The casting designs developed in this research demonstrate the capability to produce thin wall ductile iron (TWDI) connecting rods that can withstand similar loads as the original connecting rods. This indicates the potential for weight reduction while maintaining the necessary strength and performance characteristics.[1]

The study focused on the use of over molding techniques with thermoplastic tapes, specifically carbon/polyphenylene sulfide (C-PPS) and carbon/poly ether imide (C-PEI) tapes, in conjunction with the C-PEEK LFT. Different winding patterns and the number of tape windings around the small and big ends of the connecting rod were investigated The design optimization process involved progressively refining the geometry of the connecting rod. This included increasing the wall thickness of the small end and widening the center section. Additionally, the impact of incorporating over molded metal bushings with C/PEEK LFT at the bearing surfaces was studied. Through material and geometry optimization, the design successfully met the 14,000 N bearing requirement. However, meeting the 1 mm deflection limit constraint required several design iterations. Finite element analysis (FEA) was employed to optimize the width of the center section and the wall thickness of the small end. The optimized composite connecting rod achieved a significant weight reduction, estimated to be 78% lighter than the traditional steel incumbent connecting rod. This highlights the potential of using carbon fiber thermoplastics in composite connecting rods for substantial weight savings while meeting the necessary performance criteria.[2]

This paper focuses on the topology and structural optimization of a connecting rod suitable for diesel engine applications. The primary objective is weight optimization, aiming for weight reductions of 20%, 30%, 40%, 50%, and 60% under a static loading of 100N. This weight reduction target aims to minimize both weight and cost without compromising the reliability and durability of the connecting rod. The paper also compares the deformation, stress, strain, and factor of safety before and after a 60% weight reduction under the same loading condition. Furthermore, structural optimization analysis is conducted under a loading condition of 500N to determine an optimized structure. The analysis includes evaluating deformation, Von-Mises stress, equivalent elastic strain, and safety factor values. A comparison is made between the static structural deformation, Von-Mises stress, elastic strain, and safety factor values before and after the optimization process. Based on the results obtained from this study, it can be concluded that the use of ANSYS software can be beneficial for production companies in minimizing material wastage and maximizing profits. By employing such software, companies can maintain product quality and reliability while simultaneously reducing costs and optimizing the design of connecting rods.[3]

II. THE MANUFACTURING OF CONNECTING RODS

The economic constraint involves considering the cost of raw materials used in the manufacturing process. The choice of materials can significantly impact the overall cost of producing connecting rods. Manufacturers need to balance cost-effectiveness with the desired performance characteristics.

From a technical perspective, minimizing the weight of the connecting rod is important. Lighter connecting rods reduce the overall mass of the engine, leading to improved fuel efficiency and performance. Therefore, selecting manufacturing processes that allow for the production of lightweight connecting rods is crucial. Quality aspects also play a vital role in connecting rod manufacturing. This involves ensuring that the connecting rod meets specified tolerances and dimensional requirements. Tolerances affect the fit and function of the connecting rod within the engine assembly, and maintaining high-quality standards is crucial for optimal performance and longevity. Overall, the manufacturing process for connecting rods involves careful consideration of economic factors, technical requirements (such as weight reduction), and quality constraints (including tolerances) to produce cost-effective, lightweight, and high-quality connecting rods for optimal engine performance.

2.1 Casting

In the powder metallurgy process for titanium connecting rods, the manufacturing steps typically involve sintering of the titanium alloy in a furnace at 1300°C. This is followed by die forging at 1000°C to shape the connecting rod. Excess flash is then removed from the die, and annealing is conducted at 600°C for 2 hours. Structural examination of the connecting rod is performed using fluorescent detection methods, followed by another annealing process at 600°C. Finally, machining of the connecting rod is carried out to achieve the desired specifications. The mechanical properties of the titanium alloy connecting rods produced through powder metallurgy are compared with those made of PF-11C50/60 material. It is concluded that the yield strength of the powder metallurgy connecting rods is greater than that of the PF-11C50/60 material, indicating the superior performance of the powder metallurgy process. Overall, the powder metallurgy process offers an economical approach to manufacturing lightweight connecting rods, particularly using titanium alloys. The process involves sintering, die forging, annealing, structural examination, and machining, resulting in connecting rods with excellent mechanical properties and performance characteristics compared to conventional materials.[4]

2.2 Forging

The forging process involves the flow of metal in three dimensions, creating stress and strain. The connecting rod is designed using the forging method, and separate 3D analyses are performed on different parts of the connecting rod. The results indicate that optimizing the design of the connecting rod is particularly challenging due to its complex geometry. However, it is observed that the small end section of the connecting rod can be formed relatively easily. In conclusion, the manufacturing process of the connecting rod using flashless forging and aluminum composites offers an economically viable option. Although the complex geometry presents challenges, the use of FEM analysis helps optimize the design. This research demonstrates the feasibility of manufacturing connecting rods with lighter materials and highlights the importance of considering both the material properties and the manufacturing process to achieve successful outcomes.[5]

Fig .1 die-forging

2.3 Powder metallurgy

The powder forging process offers advantages such as reduced material wastage, elimination of re-heating steps, and lower temperature requirements compared to conventional forging. This process is particularly suitable for manufacturing connecting rods that require high strength and durability.[6]

3. MATERIAL USED IN CONNECTING RODS

- Alloys

The use of aluminum alloys as an alternative to steel in connecting rod manufacturing offers the potential for weight reduction and enhanced performance. However, careful consideration should be given to the specific properties and limitations of the chosen material to ensure optimal durability and reliability in the given application.

- Composites

Based on these results, it can be concluded that the conventional steel material can be replaced with E-Glass/E-Poxy for the connecting rod. The use of E-Glass/E-Poxy offers a significant reduction in stresses and a slight improvement in displacement, suggesting its potential for improved performance and reliability in the connecting rod application. It's worth noting that the selection of the material and the results obtained should be evaluated in the context of specific design requirements, load conditions, and cost considerations to ensure the suitability and effectiveness of the chosen material for connecting rod manufacturing.[8]

4. CONCLUSION

The material selection depends on the specific requirements of the engine, including power output, RPM range, intended use (such as street or racing applications), and cost considerations. Engineers and manufacturers carefully analyse these factors to choose the most appropriate material for the connecting rod to ensure reliable and efficient engine operation. It's worth noting that advancements in materials science and engineering continue to drive the development of new materials with enhanced properties. Therefore, it's important to consider the latest research and technological advancements when selecting materials for connecting rods.

Replacing traditional materials with alloys or composites can enhance the strength, stiffness, and stress distribution of the connecting rod while potentially reducing weight. This substitution can also be cost-effective. However, material selection should consider the specific engine requirements and cost considerations. Overall, the proper selection of cross-section, design modifications, and material choices play a significant role in optimizing the performance, durability, and cost-effectiveness of connecting rods in IC engines

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