A Computational Analysis of Connecting Rod of Titanium Alloy Material by FEA: A Case Study

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ABSTRACT: In the present work of enhancing performance, reducing weight, and ensuring structural integrity in engineering applications, the use of advanced materials and computational analysis has become paramount. This case study delves into the intricate realm of connecting rods, crucial components in internal combustion engines, and scrutinizes their behavior under various operational conditions. Specifically, the study focuses on connecting rods fabricated from Titanium alloy, a material renowned for its exceptional strength-to-weight ratio, corrosion resistance, and high-temperature stability.The application of Finite Element Analysis (FEA) stands as a pivotal tool in comprehending the complex structural dynamics of materials, providing engineers with invaluable insights into stress distribution, deformation, and failure modes. This research aims to unravel the performance characteristics and structural integrity of Titanium alloy connecting rods through a detailed computational analysis using FEA.

Key words : Connecting Rod, Internal Combustion Engine, Ansys, FEA , Equivalent Von Mises Stress , Equivalent Elastic Strain.

INTRODUCTION

The connecting rod is a critical component in internal combustion engines, serving as the linkage between the reciprocating motion of the piston and the rotary motion of the crankshaft. The design of connecting rods plays a pivotal role in ensuring the overall performance, reliability, and longevity of an engine. It involves a meticulous process that considers various factors, including material selection, load distribution, and structural integrity.

The Connecting Rod of I .C. engine

A connecting rod is a mechanical component that connects together two other mechanical parts, such as a piston and a crankshaft. It typically consists of several different parts, including the following:

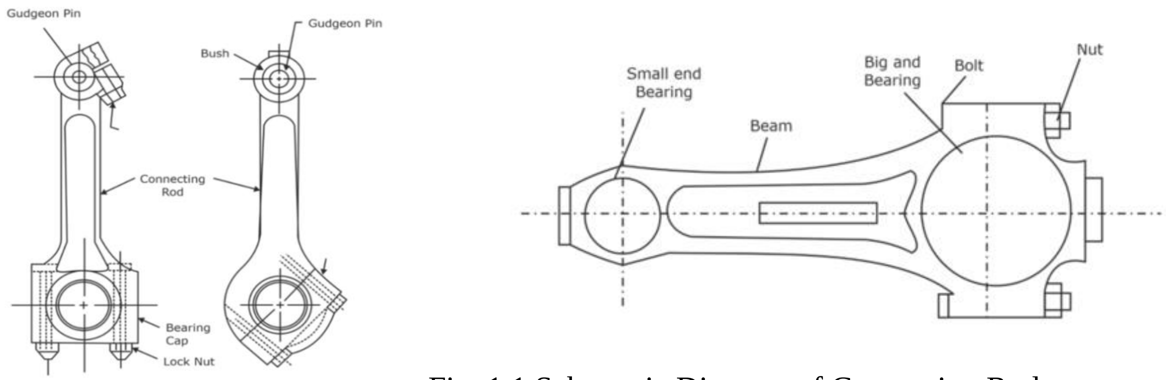


Fig. 1.1 Schematic Diagram of Connecting Rod

Rod body: This is the main part of the connecting rod and is typically made from strong, durable steel. It has a cylindrical shape with rounded ends and is designed to withstand the stresses and forces applied to it during operation.

- **The big end and small end:** The big end is the larger, rounded end of the connecting rod, which is attached to the crankshaft. The small end is the smaller, rounded end, which is attached to the piston. The rod body connects the big and small ends, designed to pivot and rotate relative to each other.
- **Crank pin:** The crank pin is a cylindrical component attached to the crankshaft and extends into the big end of the connecting rod. The crank pin allows the connecting rod to pivot and rotate relative to the crankshaft as the piston moves up and down in the cylinder.
- **Gudgeon pin:** The gudgeon pin, also known as a wrist pin or piston pin, is a small cylindrical component attached to the piston and extends into the small end of the connecting rod. The gudgeon pin allows the connecting rod to pivot and rotate relative to the piston as the crankshaft rotates.
- **Bearings:** Connecting rods typically have bearings at both the big and small ends, allowing them to pivot and rotate smoothly. These bearings may be made from various materials, such as bronze or a low-friction synthetic polymer.
- **Bolts and nuts:** Connecting rods are often held together with bolts and nuts, which allow them to be easily disassembled and reassembled for maintenance or repair. These bolts and nuts may be made from various materials, such as steel or an alloy.
- Types of Connecting Rod
- Several different types of connecting rods are used in different applications, depending on the specific requirements of the system in which they are used. Some common types of connecting rods include the following:

- H-beam connecting rods: H-beam connecting rods are the most common connecting rod used in many internal combustion engines. They are named for their distinctive H-shaped cross-section, which provides a strong and rigid structure that can withstand the high stresses and forces applied to the rod during operation.
- I-beam connecting rods: I-beam connecting rods are similar to H-beam connecting rods but have an I-shaped cross-section instead of an H-shaped cross-section. This provides a slightly different balance of strength and weight, and I-beam connecting rods are often used in high-performance engines that require a lightweight and strong connecting rod.
- Forged steel connecting rods: Forged steel connecting rods are made from a single piece of steel that is heated and shaped under pressure to create the finished connecting rod. This process creates a strong and durable connecting rod well-suited for high-stress applications.
- Aluminum connecting rods: Aluminum connecting rods are made from aluminum, a lightweight and strong material. They are often used in engines that require a lightweight connecting rod, such as racing or small engines.
- Titanium connecting rods: Titanium connecting rods are made from titanium, a strong, lightweight, and corrosion-resistant material. They are often used in high-performance engines requiring a lightweight, strong connecting rod.
- Powder-metal connecting rods: Powder-metal connecting rods are made from a mixture of metal powders that are compressed and heated to create the finished connecting rod. This process allows for creation of complex shapes and designs, and powder-metal connecting rods are often used in high-performance engines.
- Piston Connecting rods: A piston connecting rod is a rod that connects the piston to the crankshaft in an engine. It is a critical component in the engine's operation, as it transfers the motion of the piston to the crankshaft, allowing the engine to generate power. The connecting rod must be strong enough to support the piston's weight and withstand the piston's forces as it moves up and down in the cylinder. It must also be able to move freely within the cylinder so that the piston can travel without obstruction. The material used for the connecting rod and its design and dimensions is important factors in the performance and efficiency of the engine.
- Bearing Connecting Rods: A bearing connecting rod is a connecting rod that has bearings installed on its ends. The bearings allow the connecting rod to rotate smoothly around the crankshaft and piston, reducing friction and improving the engine's efficiency. Two main bearings are used in connecting rods: plain bearings and journal bearings. Plain bearings are simple, low-cost bearings with a metal surface coated with a material, such as copper or lead, to reduce friction. On the other hand, journal bearings are

more complex and typically made of a metal alloy. They use a lubricating oil film to reduce friction and support the weight of the connecting rod and piston. The choice of bearing type for a connecting rod will depend on the engine's specific requirements and the design team's priorities.

Causes of Failure Of Connecting Rod

During the operation of the engine, the connecting rod undergoes is prone to tensile, compression, and buckling loading. In many cases, the major reason behind or causing catastrophic engine failure is the occurrence of the connecting-rod failure and sometimes, such a failure can be attributed to the broken connecting rod's shank especially when there is a probability of being pushed through the side of the crank-case, thereby making the engine irreparable.

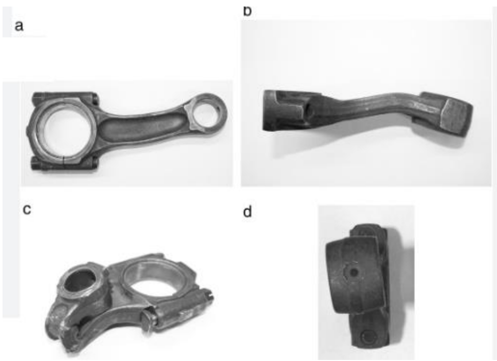


Fig. 1.2 Failure of Connecting rod

Connecting Rod Material

The material used for engine connecting rods can vary depending on the intended application and the engine's design. Common materials for connecting rods include steel, aluminum, and titanium. Each of these materials has unique properties that make it suitable for a connecting rod. For example, steel is known for its strength and durability, while aluminum is lightweight and has good thermal conductivity. On the other hand, Titanium is very strong and lightweight but also very expensive. Ultimately, the material for a connecting rod will depend on the engine's specific requirements and the design team's priorities.

OBJECTIVE

The goal of the current work is to plan and investigations of interfacing pole made of Aluminum composite 7075. Steel materials are utilized to plan the interfacing bar. In this undertaking the material (carbon steel) of associating bar supplanted with Aluminum amalgam 7075 .Associating pole was made in strong work. Model is imported in ANSYS 13.0 for examination. After examination a correlation is made between existing steel associating bar viz., Fashioned steel with regards to weight, component of security, solidifies, deformity and stress.

LITERATURE REVIEW

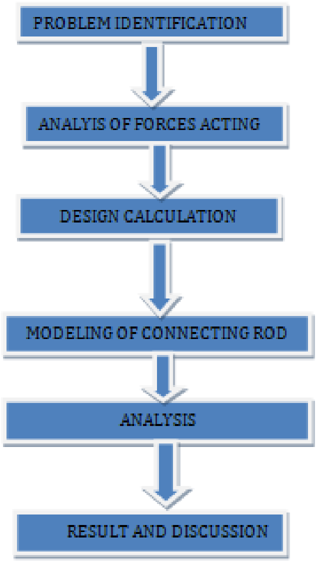
Leela Krishna Vegi, Venu Gopal Veg “Design And Analysis of Connecting Rod Using Forged steel” in this paper The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations.

G. Naga Malleshwara Rao “Design Optimization and Analysis of a Connecting Rod using ANSYS”The main Objective of this work is to explore weight reduction opportunities in the connecting rod of an I.C. engine by examining various materials such as Genetic Steel, Aluminum, Titanium and Cast Iron. This was entailed by performing a detailed load analysis. Therefore, this study has dealt with two subjects, first, static load and stress analysis of the connecting rod and second, Design Optimization for suitable material to minimize the deflection. In the first of the study the loads acting on the connecting rod as a function of time are obtained.

Mohankumar D and Rakesh L. “Design and Analysis of Connecting Rod”.This paper describe that .A connecting rod basically connects the piston to the crankshaft whilst transmitting power of the combustion from the combustion chamber to rotate the crank. It may be made of carbon steel or any other alloy. This project aims at designing a connecting rod with standard dimensions of a stock one in CREO 3.0 software and analyze the design using designing software ANSYS. The project also analyses factors such as stress, strain, factor of safety, deformation, fatigue analysis and working cycle while taking into consideration the difference in weight and design.

Mohamed AH., et al. “Design and Analysis of Connecting rod using aluminium alloy 7068 t6, t6 511”. in the present work -The connecting Rod is the main part of the internal combustion engine. Connecting rods transfer energy from pistons to crank shaft and convert the Linear, reciprocating motion of a piston into the rotary motion of a crankshaft .

METHODOLOGY



The commonly known materials for connecting rod manufacturing are; steel and its alloys, cast iron, Titanium and its alloys and aluminium alloys. Titanium and its alloys and aluminium alloys. For the purpose of this research, analysis of the connecting rod has been based on comparing connecting rod made of gray cast iron, titanium and structural steel to a connecting rod made with aluminium alloy 7075.

Table 1: Properties of the Material (Al 7075 T6).

Parameters	**Value**	**SI Unit**
Density	2.81	g/cm3
Ultimate Tensile Strength	572	MPa
Tensile Yield Strength	480	MPa
Compressive yield Strength	607.9	MPa
Poisson’s Ratio	0.33	
Young’s Modulus	71.7	GPa
Shear Modulus	26.9	GPa
Shear strength	331	MPa
Thermal Conductivity	196	W/m .K
Fatigue Strength	159	MPa

Design Procedure

Table 2 Engine specification and pressure calculations

VEHICLE MODEL	Nissan NP Pickup Double cab2.5 300 ltr
Displacement	2488 CC
Volume per cylinder	2488/4= 622cm3
Fuel type	Diesel
Max. power	98 kW at 3600 RPM
Max. Torque	304 Nm at 2000 RPM
Compression ratio	16.5:1
No. of Cylinder	4
Cylinder bore and stroke	100mm*114mm
Gearbox	5 speed, manual

Table 3: Specifications of the connecting rod.

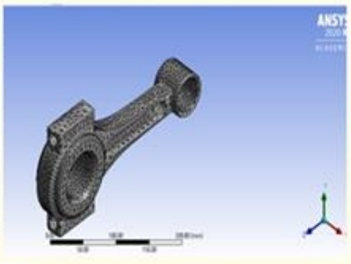
Serial No.	**Connecting Rod Parameters (mm)**
1	Thickness of the connecting rod (t)=7
2	Width of the section (B=4t)=28
3	Height of the section (H=5t)=35
4	Height at the Big End (H_1=1.2H=42
5	Height at the small end(H_2)=0.85H=30
6	Inner diameter of the Small End=43
7	Outer diameter of the Small End =55
8	Inner diameter of the Big End=58

9	Outer diameter of the Big End=104
10	Diameter of the bolt=17
11	Thickness of the big end cap=17
12	Length of connecting rod=228
13	Crank pin diameter=56
14	Length of crank pin=73
15	Piston pin diameter=41
16	Length of piston pin=81

CAD MODEL AND ANALYSIS

Finite element analysis

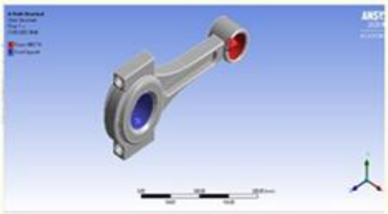
Finite Element Analysis (FEA) is a computational technique used in engineering to analyze and simulate the behavior of structures and components under various conditions. It is widely employed to predict how a structure will respond to different physical effects such as forces, heat, vibration, and fluid flow. FEA breaks down complex structures into smaller, more manageable elements, allowing engineers to simulate and analyze their behavior with numerical methods**.**



Connecting rod Meshed in Ansys

Results for Ti Alloy material

Presentation of Results and Discussion Titanium alloy material



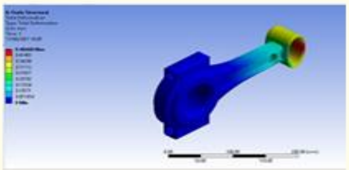


Figure 2: The boundary condition for the analysis.

The Total maximum deformation induced in the Ti alloy connecting rod when a compressive load of 49637.2N was applied is 0.46668 mm. Titanium has a percentage reduction of 23% which is far greater than the induced deformation when the load was applied.

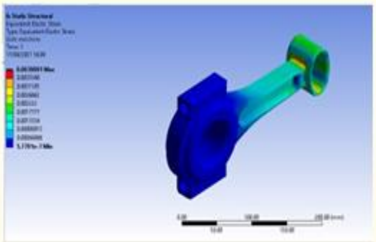


Figure 4: Equivalent Elastic Strain of Titanium Alloy Material.

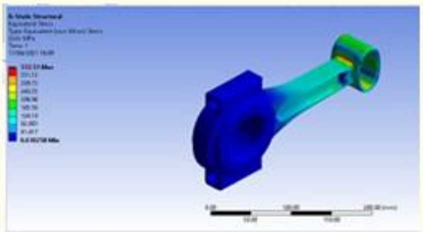


Figure 5: Equivalent (Von Mises) Stress of Titanium Alloy Material.

The maximum equivalent (Von Mises) stress induced in the Ti alloy connecting rod has a magnitude of 372.57 MPa for the given loading condition. The compressive yield strength of Ti alloy is 848 MPa. The stress distribution in the titanium alloy connecting rod was observed to be high at the piston end of the connecting rod and reduces gradually towards the big end of the connecting rod. The big end of the connecting rod was observed to have the minimum induced Von Mises stress as shown in figure 5.

Table 1

Parameters	Maximum	Minimum
Total deformation Equivalent	0.46668 mm	0.051854 mm
Elastic Strain Equivalent	0.0039991 mm	5.779×10-7 mm
Von Mises Stress	372.57 MPa	0.030258 MPa
Factor of Safety	15	2.4966

CONCLUSIONS

In the realm of high-performance engineering, the computational analysis presented in this case study has provided invaluable insights into the behavior of Titanium alloy connecting rods under diverse operational conditions. The meticulous application of Finite Element Analysis (FEA) has allowed us to scrutinize the structural integrity, stress distribution, and deformation patterns of these critical components, offering a comprehensive understanding of their performance characteristics.The study showcased that Titanium alloy, with its remarkable strength-to-weight ratio and resistance to corrosion, holds immense promise for applications in connecting rods. The FEA simulations elucidated stress concentrations in specific regions, aiding in the identification of potential failure modes. The observed deformation patterns under various loading scenarios contributed to a nuanced comprehension of how Titanium alloy responds to real-world mechanical stresses.The significance of this research extends beyond the confines of a single case study. The results serve as a foundation for informed decision-making in materials engineering, particularly in industries where weight reduction and structural integrity are paramount concerns. The aerospace and automotive sectors, in particular, stand to benefit from the knowledge gained in this study, with implications for the development of more efficient and resilient systems.

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