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# Design and Analysis of Engine Connecting Rod

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**ABSTRACT**

Connecting rods are essential components in various types of engines, including in-line, radial, and opposed-piston engines. Structurally, they comprise a pin-end, a shank, and a crank-end. The pinholes at both ends facilitate the precise installation of bearings, ensuring optimal functionality. The top end of the connecting rod is linked to the piston using a piston pin, which may either be fixed within the piston pin bosses or allowed to float. In cases where the piston pin moves freely, a solid bronze or similar material bearing is used to accommodate high pressure and temperature variations. Conversely, the lower end of the rod rotates with the crankshaft, necessitating the incorporation of a robust bushing to withstand cyclic forces.

## 1. Introduction

The lower end of the connecting rod is divided into two parts to allow it to clamp around the crankshaft securely. The cap, which is fabricated from the same material as the rod, is fastened using bolts. Bearings positioned within the rod and cap are precisely placed using dowel pins or short brass screws. These bearings come in either precision or semi-precision variations to facilitate smooth operation.

### *1.1 Service Loads and Failures*

The primary function of a connecting rod is to convert the reciprocating motion of the piston into rotational motion of the crankshaft. Subjected to significant cyclic loads throughout its operational lifespan, the rod must be strong enough to withstand repetitive stresses. The applied forces include mass-induced inertia and gas forces. These combined forces result in axial loading, which places strain on the connecting rod. Additionally, bending moments arise due to eccentricities in crankshaft movement and deformation. Such stresses can ultimately cause failure at weak points, including the threaded holes at the crank end or along the shank section.

## 2. Materials and Manufacturing Processes

**Drop-Forging**

Forged steel connecting rods are typically manufactured through a drop-forging closed-die process. The metal undergoes various forming steps, including fullering, edging, and busting, to refine its shape. The blocking operation shapes the connecting rod through repeated hammering before undergoing final trimming. Heat treatment follows, enhancing mechanical properties and grain structure prior to machining.

**Powder Forging**

Powder forging involves compacting iron and copper-based powders before heating and forging them to achieve near-wrought steel density. This method consists of several stages:

- **Stage I:** Mixed powders are compressed in a precision die under high pressure.
- **Stage II:** The compacted component undergoes sintering in a controlled furnace environment, strengthening metallurgical bonds.
- **Stage III:** Shot peening is applied to improve fatigue resistance.
- **Stage IV:** Inspection ensures the component is free from cracks and defects before final approval.

## Stress Analysis and Finite Element Analysis (FEA)

**Finite Element Modeling**

Finite element analysis (FEA) helps evaluate stress distribution, displacement, and potential failure regions within the connecting rod. This study uses a forged steel rod for analysis, employing linear elastic modeling to simulate stresses under service loads. Parameters such as Young's modulus ($E = 207$ GPa) and Poisson's ratio ($\nu = 0.3$) define material properties. Axial loading is considered, as it represents the primary source of stress during operation.

**Geometry and Mesh Generation**

The 3D model of the connecting rod is developed using IDEAS-8 software, utilizing average dimensions obtained from multiple rod samples. Measurements are taken using precision instruments such as micrometers and coordinate measurement machines.

**Loading and Boundary Conditions**

The connecting rod experiences both tensile and compressive forces. During tension loading, pressure distributes along the inner diameter of the pin end, approximated by a cosine function. In compression, uniform pressure distributes across the bearing surfaces. These conditions help analyze potential stress concentrations and fatigue behavior.

**Life Predictions and Comparisons with Experimental Results**

## 4.0 Monotonic Testing Procedures

Monotonic tests in this study followed the ASTM E8 standard, ensuring reliable measurement of material properties. Each material type was tested using a single specimen to determine its monotonic behavior. Due to extensometer limitations, strain control was applied only up to 10% strain, after which displacement control was employed until failure. Stress-strain curves were automatically generated for each test. After extensometer removal, a displacement rate of 0.00846 in/min was maintained to ensure consistency in strain rate. Once tension tests concluded, fractured specimens were carefully reassembled and their final gauge lengths measured using a Vernier caliper with 0.001-inch divisions. The initial and final cross-sectional dimensions were assessed using an optical comparator with 10X magnification.

### *4.1 Constant Amplitude Fatigue Testing*

Fatigue tests adhered to ASTM E606 guidelines, which recommend using at least 10 specimens to establish fatigue properties. However, this study employed four forged steel specimens at strain amplitudes ranging from 0.2% to 0.5% due to limited sample availability. Additionally, twelve powder-metal specimens and thirteen C-70 steel specimens were tested across strain amplitudes from 0.175% to 0.7%. Strain amplitudes exceeding 0.7% were impractical due to buckling limitations. Instron LCF software was used for most tests, whereas long-life tests transitioned to Instron SAX software for load control. Throughout the testing process, strain data was continuously recorded.

### *4.2 Experimental Findings and Comparative Analysis*

#### *4.2.1 Fatigue Behavior Under Constant Amplitude Loading*

Strain-controlled fatigue tests were conducted to develop strain-life curves. The fatigue life equation, correlating true strain amplitude with durability, is expressed as:

Δε/2=σfE(2Nf)b+ef(2Nf)c\Delta \varepsilon /2 = \frac{\sigma_f}{E} (2N_f)^b + e_f (2N_f)^c

## 5. Geometric Modeling and Finite Element Analysis (FEA)

### *5.1 CAD Software: CATIA V5 R15*

CATIA V5 R15 serves as an advanced computer-aided design (CAD) and manufacturing (CAM) software. It automates engineering design tasks while facilitating numerical control (NC) programming for machining processes. The software integrates multiple applications, all supported by CATIA V5 R15 Gateway. Its robust three-dimensional modeling capabilities enable precision representation of complex geometries.

### *5.2 User Interface Elements*

The CATIA interface includes:

- **Menu Commands** for navigating design functionalities
- **Specification Tree** displaying component hierarchy
- **Active Document Window** for model interaction
- **Toolbar Sets** specific to various workbenches

- **Standard Toolbar & Compass** for geometric manipulation

**Figures**

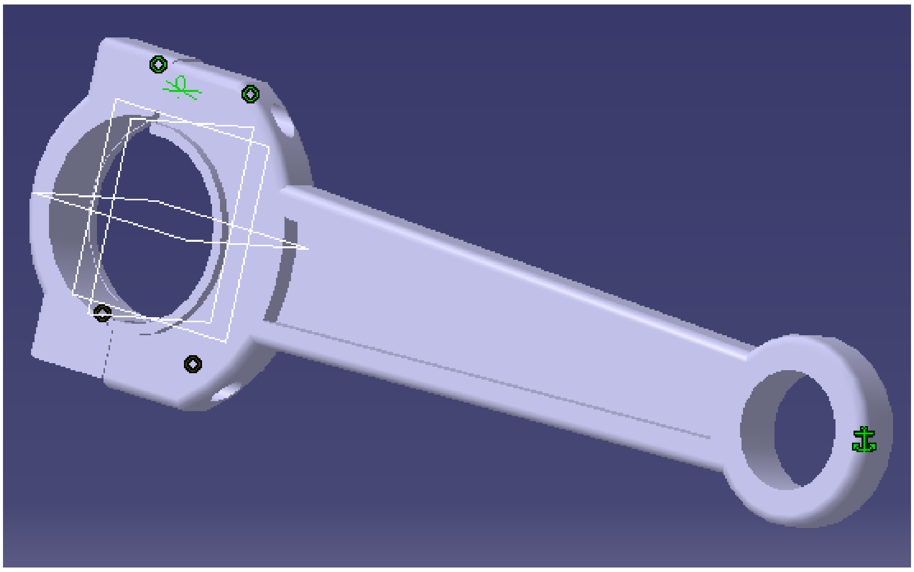

Fig 5. Assembly of connecting rod

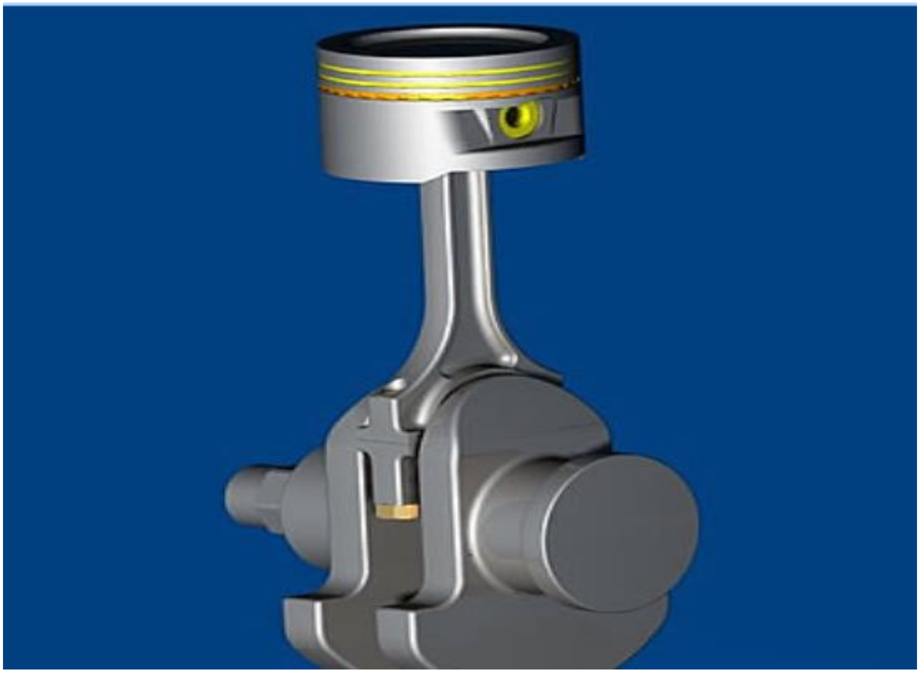

Fig 6. Assembled Piston And Connecting Rod

## Conclusions

Both existing and modified designs were modeled using CATIA software. Various engineering parameters were derived, analyzed, and compared. A truss-type connecting rod was developed, yielding feasible design characteristics. Further advancements could involve manufacturing the optimized design through forging or incorporating composite materials. Selection of various material grades, coupled with chemical composition and mechanical property assessments, can aid in optimizing stress, strain, displacement, and efficiency in machined components.

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