A Review of the Connecting Rods for Static Structural Analysis

Nitish Kumar [1], N. V. Saxena [2]
[1]Research Scholar, [2]Assistant Professor
Department of ME, MIT, Bhopal, India

Abstract: The connecting rod is a critical component of an engine. The connecting rod is very important part of an engine which connects crank to piston. It forms a basic mechanism in which reciprocating motion of piston is converted to rotary motion. In an internal combustion (IC) engine, the connecting rod plays a vital role in transferring power. Connecting Rods are an important and irreplaceable part of IC Engines. It is responsible for converting the reciprocating motion of the piston into the rotary motion of the crankshaft. During this process, the connecting rod is subjected to various loads. Therefore, the materials used for connecting rod are also very important. Connecting rods are mechanical parts for producing movement from a crankshaft's piston rotating activity. The integrity, as well as efficiency of vehicles, relies on the design of the connecting rod. There have actually been various reported situations of connecting rod failing based upon the architectural style, loading as well as the sort of materials made use of in its manufacturing. For the regular requirements as well as security of the customers, an enhanced as well as the optimal connecting rod is required resulting in the requirement for optimization to accomplish greater success in auto markets by enhancing its efficiency. Cheaper and qualitative production of the connecting rod can be achieved in a short period of time as a result of optimization.

***How to cite this article**: Nitish Kumar, N. V. Saxena. (2025). A Review of the Connecting Rods for Static Structural Analysis. International Journal of Scientific Modern Research and Technology (IJSMRT), ISSN: 2582-8150, Volume-20, Issue-2, Number-1, Aug-2025, pp.1-7, URL: https://www.ijsmrt.com/wp-content/uploads/2025/10/IJSMRT-25200201.pdf*

IJSMRT-25080201

I. INTRODUCTION

An engine or motor is a machine designed to convert one or more forms of energy into mechanical energy. Available energy sources include potential energy (e.g., energy of the Earth's gravitational field as exploited in hydroelectric power generation), heat energy (e.g., geothermal), chemical energy, electric potential and nuclear energy (from nuclear fission or nuclear fusion). Many of these processes generate heat as an intermediate energy form, so heat engines have special importance. Some natural processes, such as atmospheric convection cells convert environmental heat into motion (e.g., in the form of rising air currents). Mechanical energy is of particular importance in transportation, but also plays a role in many industrial processes such as cutting, grinding, crushing, and mixing. Mechanical heat engines convert heat into work via various thermodynamic processes. The internal combustion engine is perhaps the most common example of a mechanical heat engine, in which heat from the combustion of a fuel causes rapid pressurization of the gaseous combustion products in the combustion chamber, causing them to expand and drive a piston, which turns a crankshaft. Unlike internal combustion engines, a reaction engine (such as a jet engine) produces thrust by expelling reaction mass, in accordance with Newton's third law of motion. Apart from heat engines, electric motors convert electrical energy into mechanical motion, pneumatic motors use compressed air, and clockwork motors in wind-up toys use elastic energy

Type of Engines

Internal combustion engines- Petrol engines quickly became the choice of manufacturers and consumers alike. Despite the rough start, noisy and dirty engine, and the difficult gear shifting, new technologies such as the production line and the advancement of the engine allowed the standard production of the gas automobiles. This is the start, from the invention of the gas automobile in 1876, to the beginning of mass production in the 1890s. Henry Ford's Model T drove down the price of cars to a more affordable price. At the same time, Charles Kettering invented an electric starter, allowing the car to be more efficient than the mechanical starter. The abundance of fuel propelled gas automobiles to be the highly capable and affordable.

Steam engines- The steam engine was invented in the late 1700s, and the primary method of powering engines and soon, locomotives. One of the most popular steam automobiles was the "Stanley Steamer," offering low pollution, power, and speed. The downside of these steam automobiles is the unreliability, complexity, and the frequent accidents that occurred with them. The startup time for a steam car may take up to 45 minutes, defeating the purpose of faster transportation.

Internal Combustion Engines

An internal combustion engine (ICE or IC engine) is a heat engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high- temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is typically applied to pistons (piston engine), turbine blades (gas turbine), a rotor (Wankel engine), or a nozzle (jet engine). This force moves the component over a distance, transforming chemical energy into kinetic energy which is used to propel, move or power whatever the engine is attached to. This replaced the external combustion engine for applications where the weight or size of an engine was more important. The first commercially successful internal combustion engine was created by Étienne Lenoir around 1860, and the first modern internal combustion engine, known as the Otto engine, was created in 1876 by Nicolaus Otto. The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar two-stroke and four- stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described

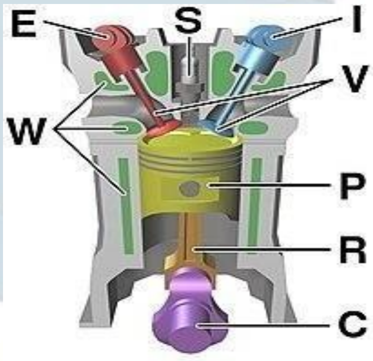

Figure 1: General setup of an IC Engine

Connecting rod

These engine parts are provided to connect the piston to the crankshaft. Just as mentioned earlier, it converts the linear motion of the piston into the rotary motion of the crank. One of its end parts is attached to the piston through a piston pin also known as a Gudgeon pin and wrist pin. Another end is attached to the crankpin journal using bolts to hold down the upper and lower bearing caps called the big end. The bearing is in the form of two half-shells placed in the crank journal by the big end connecting rod. Both ends are not rigidly fixed in order to rotate through an angle. Hence, both ends are in continuous motion and under tremendous stress from the pressure of the piston. The connecting rod is generally made from forged steel and sometimes from aluminium alloy when lightweight and high-impact absorbing ability is prioritized. The connecting rod is manufactured with a high degree of precision as it is a sensitive part that is prone to failure.

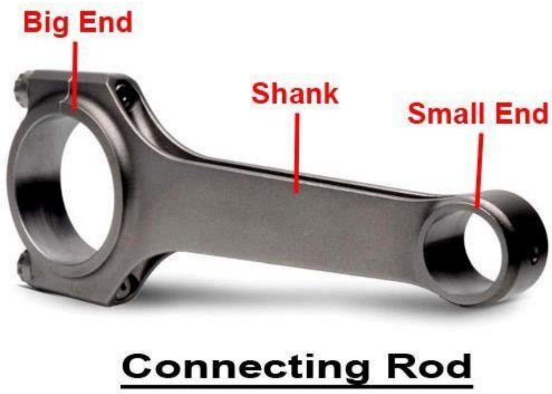

Figure 2: General form of a Connecting Rod

Structural Analysis

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

Types of Structural Analysis

One can perform the following types of structural analyses:

Static Analysis - Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Modal Analysis - Used to calculate the natural frequencies and mode shapes of a structure. Several mode extraction methods are available.

Harmonic Analysis - Used to determine the response of a structure to harmonically time- varying loads.

Transient Dynamic Analysis - Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.

Spectrum Analysis - An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

Buckling Analysis - Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

Explicit Dynamic Analysis - This type of structural analysis is available via the ANSYS LS-DYNA product, which provides an interface to the LS-DYNA explicit finite element program. Explicit dynamic analysis calculates fast solutions for large deformation dynamics and complex contact problems. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads.

A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

II. LITERATURE REVIEW

Magesh Kumar et al. (2025) Connecting rod is integral part of internal combustion engine; it acts as a linkage between piston and crankshaft. Material used to manufacture connecting rod in mass is steel, but it can also be made of Aluminium due to its lightness and the ability to absorb high impact at the expense of durability or Titanium for combination of strength and lightness at the expense of affordability for high performance engines, or of cast iron.. The main objective of this work is to optimize the weight of steel connecting rod. Titanium inserts are to be used for weight reduction without changing the original strength. Modifications are to be done by inserting Titanium at various positions of connecting rod using software UG NX7.0. Optimization is to be done by identifying the correct load conditions and magnitudes using software like ANSYS R15.0. Stress concentration is observed using modal analysis.

Dr. B. K. Roy (2024) The automobile engine connecting rod is a high-volume production, critical component. It connects reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine. As the purpose of the connecting rod is to transfer the reciprocating motion of the piston into rotary motion of the crankshaft. Connecting rods for automotive applications are typically manufactured by forging from either wrought steel or powdered metal. Various results are found out and compared with the existing results. It has been found out that the study presented here has come up with better results as well as safe design of connecting rod under permissible limits of various parameters and safe stresses.

Mehmet Bulut et al. (2022 This study describes a numerical analysis of connecting rod for determining the critical stress regions. During the analysis of connecting rod, loads corresponding to different engine speeds were assumed to be statically applied, and their corresponding stress and deformation values were evaluated. The power and torque values of engine were utilized to be used as the load boundary conditions in static simulation model, other parameters those of used as input values were geometric dimensions of connecting rod and its material properties. Numerical analyses were performed for the connecting rod made of SS 304 material. A 3D CAD model was developed for the connecting rod through the SOLIDWORKS software, then drawn solid model was transferred to the ANSYS software with Workbench module.

Vaibhav V. Mukkawar et al. (2021) In this work connecting rod is replaced by aluminium based composite material reinforced with silicon carbide and fly ash. And it also describes the modeling and analysis of connecting rod. FEA analysis was carried out by considering two materials of connecting rod for 220cc engine. The parameters like von mises stress and displacement were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 17.33% of weight.

Venkatesh C et al. (2021) Connecting rod is the inter mediate link between the piston and the crank. And is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod.

M. Dineshkumar et al. (2020) Connecting rod is one of the important elements of the engine meeting, it functions as a mediator between piston assembly and crankshaft. It began from the sawmills to the motor various transmission forces. It's two endings. The small end is connected to the piston with a Gudgeon pin while others finish is connected crankshaft utilizing crank pin. This additional analysis moves towards von mises anxiety so we get the better component with decreased weight, economical and supply better result compared to other components. This paper illustrates overall research on three designs of the connecting rod along with contemporary structure.

Aisha Muhammad et al. (2019) Connecting rods are mechanical parts made use of for producing movement from a crankshaft's piston rotating activity. The integrity, as well as efficiency of vehicles, relies on the design of the connecting rod. Cheaper and qualitative production of the connecting rod can be achieved in a short period of time as a result of optimization. In this paper, Finite Element Method (FEM) using ANSYS workbench was used to carry out the weight optimization of the connection rod with target weight reduction of 20%, 30%, 40%, 50%, and 60% under a loading force of 30KN to determine the mass that needs to be remove to minimize both weight and cost. Furthermore, structural optimization is done to determine an optimized structure with new deformation, Von-misses stress, and equivalent elastic strain values followed by the comparison of these values before and after the structural optimization to verify the effect of the analysis.

Aman Shrivastava et al. (2021) The objective of this work is to carry out the structural analysis of a connecting rod made from three differing types of alloys. Connecting Rods has a wide use in all sorts of automobile engines acting as a crucial middle point between the piston and therefore the crankshaft of an engine of an automobile. It's liable for transmission of the up and down movement of the piston to the crankshaft of the engine, by converting the reciprocating motion of the piston to the rotation of crankshaft. The performance of a rod in an engine depends on its design and weight. Hence, for the assembly of a long-lasting, economical and light-weight rod, analysis and optimization become necessary.

N. Y. Kumari et al. (2013) The main objective of this study was to explore weight and cost reduction opportunities for a production forged steel connecting rod. This study has dealt with two subjects, first, dynamic load of the connecting rod, and second, optimization for weight and cost. In the first part, the relations for obtaining the loads and accelerations for the connecting rod at a given constant speed of the crankshaft were also determined. Quasi dynamic finite element analysis was performed at several crank angles. After that the component was optimized for weight and cost subject, and space constraints and manufacturability.

Amita Saxena et al. (2016) 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. Existing connecting rod is manufactured by using Carbon steel. Finite element analysis of single cylinder four stroke petrol engines is taken for the study; Structural systems of Connecting rod can be easily analyzed using Finite Element techniques. So firstly, a proper Finite Element Model is developed using CAD software. Then static and dynamic analysis is done to determine the von Misses stress, shear stress, elastic strain, total deformation in the present design connecting rod for the given loading conditions using Finite Element Analysis Software ANSYS v 16. In the first part of the study, the static and dynamic loads acting on the connecting rod, after that the work is carried out for safe design. Based on the observations of the static FEA and the load analysis results, the load for the optimization study was selected.

Ramesh B T et al. (2017) Selection of connecting rod for good performance of engine is very difficult. The material used in the connecting rod should be chosen wisely because during manufacturing process it has to undergo various production processes and subsequent heat treatment process, which is very much important for strength and stiffness. Based on which the High Strength Carbon Fiber connecting rod will be compared with connecting rod made up of Stainless Steel and Aluminium Alloy. The results can be used for optimization for weight reduction and for design modification of the connecting rod. Analyses are carried out in ANSYS software.

Jaju, S. B. et al. (2009) The main objective of this study was to explore weight reduction opportunities for a production forged steel connecting rod. This has entailed performing a detailed load analysis. Based on the observations of the static Finite Element Analysis (FEA) and the load analysis results, the load for the optimization study was selected. The results were also used to determine degree of stress multiaxiality, and the fatigue model to be used for analysing the fatigue strength. Outputs include fatigue life, damage, factor of safety, stress biaxiality, fatigue sensitivity. The component was optimized for weight subject to fatigue life and space constraints and manufacturability.

G. Naga Malleshwara Rao (2013) 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, Aluminium, 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. The relations for obtaining the loads for the connecting rod at a given constant speed of crank shaft are also determined. It can be concluded from this study that the connecting rod can be designed and optimized under a comprising tensile load corresponding to 360° crank angle at the maximum engine speed as one extreme load, and the crank pressure as the other extreme load. Furthermore, the existing connecting rod can be replaced with a new connecting rod made of Genetic Steel.

Mr. Vivek T. Fegade et al. (2015) This paper describes about nonlinear static analysis and optimization of forged steel connecting rod. With the implementation of optimization approach connecting rod of stronger but equally lighter can be obtained with minimum cost. This paper focus on finite element analysis and material optimization of Titanium alloys as an alternative material for connecting rod. For comparison Finite element analysis of connecting rod is completed by considering two materials viz. structural steel & Titanium alloys.

Sharma Manojetal. (2015) Connecting rod is the important part of an IC Engine it transmits motion of piston to crank shaft and converts translating motion of piston into rotary motion and vice versa. From application point of view, it is necessary that connecting rod must be light in weight and having good strength under fatigue or reverse loading.

Ganesha Ram et al. (2014) The component is to be optimized for weight subject to constraint of allowable stress and factor of safety. A CAD model and FEA analysis of connecting rod is carried out to determine the maximum Von-Misses stresses for the given loading conditions using software SOLIDWORKS. The percentage weight reduction obtained was 13% by Optimization.

Yogesh Kumar Bharti et al. (2013) Design is process by which human desired fulfil. Design of connecting rod is very complex because the connecting rod works in very complicated condition. To obtain a best & suitable design of connecting rod to sustain various stress & forces, finite element analysis suggests the minimum design specification with the help of ANSYS.

Prakash Shanker Kumar et al. (2015) In a reciprocating engine, the connecting rod is one of the most critical components that are bear static and dynamic fluctuation of various loads. Every vehicle that uses an IC engine requires, at least one connecting rod depending upon the number of cylinders in the engine This has entailed performing equivalent stresses which are generated at the surface of the connecting rod. Firstly, the two geometric models were developed using CATIA V5 for difference analysis. Therefore, this study has dealt with two subjects, first, gradually changing the cross-sectional area of the connecting rod to perform stress analysis at varying load and stress conditions. Second, static load stresses analysis of the connecting rod for four materials.

Sahil Guleria (2014) The main aim of the project is to analyze various stresses and fatigue parameters acting on connecting rod, Optimize shape and weight. Connecting rod is an intermediate & important engine component which connects piston & crankshaft. It is subjected to multiple compressive & tensile forces. Major consideration in this case is gas force. The high magnitude gas force is responsible for many kinds of failure. These failures need to be prevented & for this purpose analysis was needed to be done. In this project, connecting rod of Tractor is chosen as a model for study. This project considers two cases, first, static load stress analysis of the connecting rod, and second, optimization for weight. In this project analysis is done on four stroke single cylinder petrol engine connecting rod. The model was developed in PRO-E software, saved in IGES format and then imported to ANSYS workbench. Using ANSYS workbench 14 model was analyzed for various stresses by applying suitable boundary conditions & using different modules of ANSYS workbench 14.

III. GAPS IN LITERATURE

Several previous researches have been studied in the current research for identifying the possible knowledge gaps which can be filled in the current research. Some of the identified knowledge gaps are presented here for reference-

Several researches have been conducted for material optimization in the previous researches but none have accommodated a comprehensive comparison among several materials. All of the reviewed researched have compared mostly 3-4 materials that too only metals have been compared. In the current age of several new composite materials & additive manufacturing related materials are also needed to be compared with already available metals for the current application.

Most of the previous researches have focused on general connecting rods not emphasizing on any specific vehicle category. Hence the vehicle category to be considered in the current research study is four-wheeler cars.

REFERENCES

[1] Ramesh B T, Vinayaka Koppad, Hemantha Raju T. "Analysis and Optimization of Connecting Rod with Different Materials", World Journal of Research and Review (WJRR) ISSN:2455-3956, Volume-4, Issue-1, January 2025 Pages 33-39.

[2] Charkha, Pranav G.; Jaju, Santosh B. (2024). *International Conference on Emerging Trends in Engineering &Technology- Analysis & Optimization of Connecting Rod, 86–91.*

[3] Mula Mahender, C. Venkatesh, G Radhakrishna, K Jagadeeshwar Raju, M Shiva, T Teja. "Analysis and Optimization of Connecting Rod with Different Materials", IJARIIE, Vol-8 Issue-4 2022, pp. 435-453

[4] Biradar Akshay datta Vinayak rao, Prof. Swami M. C. (2022). "Analysis and Optimization of Connecting Rodused in Heavy Commercial Vehicles", International Journal of Engineering Development and Research, Volume 5, Issue 3, pp. 684-707.

[5] Magesh Kumar, Prof. Ankush K Biradar (2021). "Design, Analysis and Optimization of Connecting Rod", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Special Issue 11, May 2021, pp. 25-33

[6] G. Shanmugasundar; M. Dharanidharan; D. Vishwa; A. P. Sanjeev Kumar; (2021).Design, analysis and topology optimization of connecting rod. Materials Today: Proceedings

[7] G. Naga Malleshwara Rao. "Design Optimization and Analysis of a Connecting Rod using ANSYS", International Journal of Science and Research, Volume 2 Issue 7, July 2023, pp. 225-229.

[8] Yogesh Kumar Bharti, Vikrant Singh, Afsar Hussain, Dipanshu Singh, Shyam Bihari Lal, Satish Kumar Dwivedi. "Stress analysis and optimization of connecting rod using finite element analysis", International Journal of Scientific & Engineering Research, Volume 4, Issue 6, June-2020, pp. 1796-1803.

[9] Ganesha Ram, Dr. P. K. S. Nain, Mr. Pramod Kumar. "Static Finite Element Analysis and Optimization of Two-Wheeler Connecting Rod", International Journal of Engineering Research & Technology (IJERT), Vol. 3, Issue 6, June – 2029, pp. 1875-1878

[10] Mr. Vivek T. Fegade, Dr. Kiran S. Bhole, 2015, Nonlinear Static Finite Element Analysis and Material Optimization of Connecting Rod, International Journal of Engineering Research & Technology (IJERT) ICNTE – 2018 (Volume 3 – Issue 01),

[11] Sharma Manoj, Shashikant, Optimization of Connecting Rod with help of FEA. International Journal of Mechanical Engineering and Technology, 6(7), 2017, pp. 53-59.

[12] Aisha Muhammad, Ibrahim Haruna Shanono. "Static Analysis and Optimization of a Connecting Rod", International Journal of Engineering Technology and Sciences (IJETS), Vol.6 (1), June 2019, http://dx.doi.org/10.15282/ijets.6.1.2019.1003

[13] Mr. Ajit Lonkar. "Analysis and Optimization of Connecting Rod by FEA", Journal of Emerging Technologies and Innovative Research, November 2016, Volume 3, Issue 11, pp. 33-42

[14] Adnan Ali Haider, Akash Kumar, Ajinkya Chowdhury, Moin Khan, P. Suresh. "Design and Structural Analysis of Connecting Rod", International Research Journal of Engineering and Technology (IRJET), e-ISSN:2395-0056, Volume: 05, Issue: 05, May- 2018, pp.282-285

[15] Vaibhav V. Mukkawar, Abhijit P. Kadam, Abhijit N. Ingole, Mangesh D. Chopade. "Design, Analysis and Optimization of Connecting Rod using ANSYS", International Journal of Advances in Mechanical and Civil Engineering, Volume-2, Issue-2, April-2015, pp. 38-41