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A Review on Analysis of Connecting Rod Using Finite Element Method

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Abstract- In recent times, the focus of automotive engineering design has been on stress analysis and optimization of connecting rods. Designers are now paying close attention to key parameters such as deformation, stress, fatigue, strain, factor safety, and life values. The performance of a connecting rod in an automobile engine is influenced by its weight and design. Thus, there's a need for optimizing and analyzing to create a cheaper, durable, and lightweight connecting rod. This article presents a review of various researchers' work on designing and analyzing the connecting rod of an engine using Finite element analysis in ANSYS workbench. The review is accompanied by a comprehensive comparison table and graphs. This article is a valuable resource for both experienced and novice researchers in the field of automotive design.

Keywords- Connecting rod, finite element method, stress, deformation.

I. INTRODUCTION

The connecting rod belongs to the group of critical components of piston engines. The connecting rod transfers loads from the piston onto crankshaft. In modern diesel engines the large value of torque achieved at low speed of rotation causes high stresses in pistons, crankshafts, connecting rods and another engine components [1, 2]. Amplitude of operational stresses has significant influence on the fatigue life of the connecting rod. Additional factors which limit its fatigue strength are: incorrect shape (design), material defects or technological errors (defects created during the production process).

The failure analysis of the connecting rods of piston engines was described in many publications. Several typical and uncommon failure modes in connecting rods of combustion engines were reported in work [3]. The author's attention is focused on description of failure mode and the stress analysis of investigated components. The interpretation of the fractures was supported by traditional calculations and advanced analytical models.

The analyzed failures in connecting rods showed that the most common failure modes are: buckling, bending and the torsion (as a result of overloading or mechanical damage) of the engine. In damaged connecting rods the large plastic deformations were observed.

An analysis of automotive diesel engine which was damaged 6 month after revision was described in study [4]. The reason of engine failure was the fatigue fracture of connecting rod bolts. The tensile tests for remaining connecting rod bolts were performed. During this investigation another bolt with the fatigue crack was detected. In cited paper the finite element analysis (FEA) common with an analytical fracture mechanics approach were used. The aim of work was to evaluate the relation between tightening force and propagation of fatigue crack in bolts. The engine was damaged due to forming laps in the grooves of the bolt shank.

Results of an interesting research study are presented in work [5]. On the base of customer’s reports (high noise and vibration of engine) an analysis of the various components of the combustion engine was performed. In results, the following damages were detected: pit marks and subsurface cracks in crank pin, roller bearings and big end surfaces of the connecting rod.

Results of numerical analysis showed high interfacial pressure and stresses near the junction of web and flange of the connecting rod. In described work the modified design of the connecting rod was proposed. After modification of connecting rod a significant reduction of stress was obtained. As a result the increase of fatigue life was observed in laboratory test.

The work [6] presents results of the failure analysis of connecting rod from the diesel engine used in electric generator. The attention was focused on analysis of the connecting rod material and the fracture zone. In analysis the following procedures and techniques were used: fractography, visual inspection, chemical analysis, magnetic particle inspection and metallography. The connecting rod was made out of AISI/SAE 4140 low alloy steel. The connecting rod was fractured in section close to the head. The crack origin was located at the lubrication channel. The main reason of fatigue fracture was incorrect manufacturing process.

An interesting study of failure analysis of connecting rod cap and connecting bolts of the compressor was presented in study [7]. To determine the failure reason of the connecting rod the numerical analysis and material investigation were performed. Obtained results showed that the stress concentration in crack origin was observed. Performed investigations revealed that the main reason of fracture was the fatigue of the connecting rod material.

Results of stress and fatigue analysis of high loaded components of combustion engines [8–10] showed that many operational failures are related to high cycle fatigue (HCF). Results of failure analysis of the connecting rods are also presented in works [11–14].
The main research objective of this study is explanation of the failure reasons of the connecting rod. An additional aim of this work is determination of the stress state in the connecting rod during work of the engine.

Connecting rod is an engine component that connects the piston to the crankshaft. It converts the linear and down movement of piston into circular motion of crankshaft. The connecting rod joins the piston to the crankshaft of a reciprocating piston engine, converting the piston's reciprocating action to rotary motion for the crank. A piston pin, also known as a gudgeon pin, secures it to the piston at its small end. The crankpin journal connects the large end to the crankshaft. They form a basic mechanism with the crank that turns linear motion into rotational motion.

A connecting rod's job is to allow fluid movement between pistons and the crankshaft. During the combustion cycle, the connecting rod must be strong enough to sustain the piston force. It will be subjected to a lot of tensile and compressive loads during the course of its life. A connecting rod can be made out of a variety of materials, including carbon steel, iron base sintered metal, micro-alloyed steel, and graphite cast iron. Steel connecting rods are most typically used in mass- produced car engines. In most high-performance applications, billet connecting rods, which are machined from a solid billet of metal rather than being cast or forged, are used.

Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine. The automobile engine connecting rod is a high volume production, critical component. It is the intermediate component between crank and piston. The objective of the connecting rod is to transmit push & pull from the piston pin to the crank pin and then converts reciprocating motion of the piston into the rotary motion of crank.

The main components of a connecting rod are big shank, a small end and a big end. There are different types of materials and production methods used in the creation of connecting rods. The most common types of material for connecting rods are steel and aluminium. The most common types of manufacturing processes are casting, forging and powdered metallurgy.

Other materials include aluminium alloy, which can be used for lightweight while also absorbing heavy impact without sacrificing durability. Titanium, on the other hand, is a more expensive alternative that is found to reduce weight, whilst cast iron, on the other hand, is found to be less expensive and has extremely low performance applications such as scooters. Due to its large volume of production, it is only logical that optimization of the connecting rod for its weight or volume will result in large-scale savings.

It can also achieve the objective of reducing the weight of the engine component, thus reducing inertia loads, reducing engine weight and improving engine performance and fuel economy.

II. CONNECTING ROD

The connecting rod is a connection between the piston and a crankshaft. It joins the piston pin with the crankpin. The small end of the connecting rod is connected to the piston pin and the big end to the crank pin. The purpose of the connecting rod is to convert the linear motion of the piston into the rotary motion of the crankshaft. The connecting rod consists of an I-beam cross-section and is made of forged steel.

Aluminum alloy is also used for connecting rods. They are precisely matched in sets of similar weight in order to maintain engine balance. The lighter the connecting rod and piston, the greater the resulting in power and the lesser the vibration because the reciprocating weight is less. The connecting rod carries the power thrust from piston to the crankpin and hence it must be very strong, rigid and also as light as possible.

Fig 1. Connecting rod.

III. PARTS OF CONNECTING ROD

Following are the parts of connecting rod:

- Small End
- Big End
- Bushing
- Bearing inserts
- Bolt and Nut
- Shank
- Wrist pin
- Piston
- Bearing cap

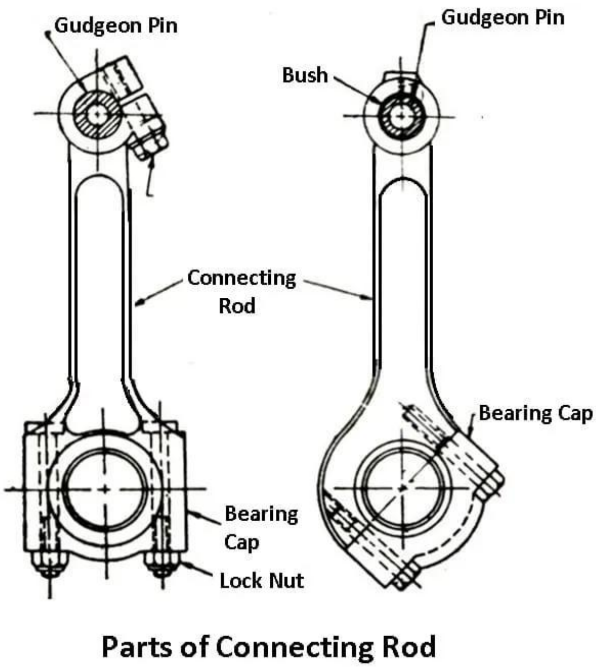

Fig. 2: Parts of connecting rod.

1. Small End:
The end at which the connecting rod is attached to the face of the piston pin is known as the small end of the connecting rod.

2. Big End:
The end at which the connecting rod is attached to the side of the crank pin is known as big end of the connecting rod.

3. Bush Bearing:
Both ends of the connecting rod are fixed with a bush bearing. A phosphor bronze bush is fitted with the solid eye is attached to the small end of the connecting rod.The Big end is attached to the crankpin. The end is divided into two parts and is supported over the crank bearing shell.

4. Bearing Insert:
In the big end of the connecting rod, there is a bearing insert that is connected to the bearing cap, it is known as a bearing insert. These are made in two parts that fit together on the crankshaft. This is the position where the connecting rod travels along the reverse direction.

5. Bolt and Nut:
After the connecting rod is fitted with the crank at the bottom, both sides of the big ends are fastened by some bolts and nuts. Thus, by combining these all components the connecting rod is ready to use.

6. Shank:
Furthermore, each of the bolt and nuts are employed to connect both the connecting rod and bearing cap. And a section beam is applied it is known as shank. The section of the rod may be rectangular, tubular, and a circular section.

7. Wrist Pin:
The engine piston is connected to the connecting rod with the help of a hollow hardened steel tube called wrist pin. It is also known as gudgeon pin. Wrist pin goes through the short end of the connecting rod and pivots on the engaged piston.

8. Piston:
The piston is connected to the crankshaft with the help of a connecting rod, which is usually shortened to the rod or Conrod. The purpose of the piston is to work as a movable plug in the cylinder, which forms the bottom of the combustion chamber.

9. Bearing Cap:
Shell bearings have an adjustment for wear, but it controls the running and the side clearance allows the bearing cap to be tightened correctly.

IV. CONSTRUCTION OF CONNECTING ROD

There are two types of ends small end and big end bearings. The big end is split at right angles to its length as at (a) or at an angle as at (b), in order that it may be assembled on the crankpin. A cap is fixed to the body of the connecting rod by two bolts and nuts. Modern engines do not have bearing metal fused to the bore of a big end, but it uses separate low carbon steel bearing shells.

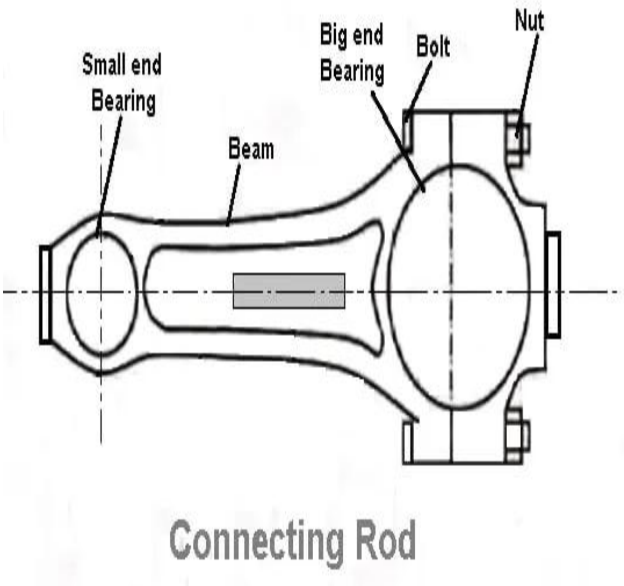

Fig 3. Construction of connecting rod.

The shell bearing has adjustment for wear but gives the control over running and side clearance, providing the bearing cap to correct fit. Sometimes, thin pieces of metal known as shins are used when spur bearings are employed. These can be filled thinner to compensate for the wear of the bearing and also to secure the correct bearing clearance between the connecting rod and the crankshaft. The small end is usually a solid eye fitted with a phosphor bronze bush and a screw to close the eye around the pin. All the connecting rods in an engine must be of equal weight otherwise noticeable vibration may occur. In the assembly, the connecting rods and caps are individually matched to each other. It usually carries identifying numbers so that they may not be mixed if the engine is dissembled for service.

V. LITERATURE REVIEW

Sathish et al. (2020) "two separate materials such as AA2014, AA6061 and AA7075 have been analyzed. FEA review for selected three materials and for missed stress has been carried out by ANSYS tools; shear stress and overall deformation have been obtained from the software of ANSYS. The AA2014 has fewer weight and higher rigidity compared to the three materials".

Muhammad et al. (2020) determined topology for connecting a rod appropriate for diesel engine applications and structural optimization… The link rod weight optimization takes place with a 20% weight reduction goal, 30%, 40%, 50%, and 60%

under a 100N static loading to decide the weight to be removed to reduce weight and costs while affecting its strength and longevity. Comparison of structural static deformation, tension, elastic strain and protection component of Von Misses before and following optimization. Based on the outcome it can be inferred that manufacturing firms can use ANSYS Tools to mitigate waste of materials, while ensuring product consistency and efficiency at the same time.

Muhammad et al. (2020) The study of stress and the optimization of a connecting rod with strong emphasis on essential parameters including deformity, stress, fatigue and stress, factor protection, and life values, among other things. A connection rod's output in an automotive motor is dependent on its design and weight. Therefore, research and optimization are important for producing a durable, cheaper and lightweight connecting rod.

Lingaet al. (2020) An empirical tool constructed is the presented connecting rod for two wheels. A physical model is built in CATIA V5 according to the design. FEA has been used to analyze the structural rod connection mechanism. Various stresses are measured using FEA program ANSYS WORKBENCH 14.5 for specific loading conditions. Similar materials perform in the same way (forged steel and Al-360). The findings obtained are compared on the basis of different performances with considerable tension, shear stress, fatigue life based on the results achieved and we prepared the prototype part in 3d printing.

Saheb, Shaik Himamet al. (2020) researched and compare the weight and price of the connecting rod optimized reduction of certain compression ignition motors. Because the connecting rod is subject to whipping stress in order to design the rod, we can investigate multiple pressures and different forces such that connecting rods do not malfunction. In taking all these strengths into account, the review is helpful to improve design.

Bulut, Mehmet et al. (2020) a numerical rod connecting analysis for the determination of essential stress regions was identified. The load of various motor speeds was supposed to be statically implemented in the study of the connection rod and its resulting stress and deformation values were evaluated. Engine power and torque values were used in static simulation model as the load border conditions, whereas the geometric measurements of the rod connector and its material properties were other parameters used as input values. Stress and deformation tests were assessed at the various motor speeds and showed that the connecting rod did not malfunction and fractured under the external pressure.

Pani, Amiya Ranjan et al. (2020) concluded that in the event of a hydro lock failure on the connecting pin, the merchant-rankine solution is inadequate to buckling load measurement and the aluminum alloy rod buckling resistance even weaker than the steel rod forged. It will also not be used with diesel heavy duty engines. The findings of this project provide important details for the buckling failure of rod configuration in heavy diesel engines.

Abraar et al. (2020)find inducted stresses due to high capacity, examined the connector rod of the 1500 hp diesel motor in a truck. On top of the piston in a film-based system the net force operating on the gas pressure and inertia. For this study, the reaction forces produced at each eye of the main connecting rod were forecast and provided. In the static study it was noticed that the induced stress was within the allowed limit of the rated speed connecting rod. The static study for maximum speed and maximum torque conditions has also been performed.

Natrayan et al. (2019) based on the working of the tractor in general tie rod that does not perform overload application. Firstly, old rod designs and materials were tested and mutated designs were examined in crucial loading situations, with different stresses and deformation features, using ANSYS software.

Mahfouth et al. (2019) Performed finite element analyzes and design optimization analysis with solid works on a connecting rod. The sensitivity analysis was carried out and a convergence with standardized element duration of 1.5 mm was achieved. The maximum tension existed mainly between the pin, crank and shank regions in the transition field. The optimization thesis was carried out to examine potential to reduce weight by changing some connecting rod measurements to restrict acceptable stresses and the protection factor. The percentage decrease was achieved by optimization with a minimum protection factor of 2.2 and an overall stress of 127 MPa by Von Mises. In the static structural review the overall stress is less than the material yield power.

Muhammad et al. (2019) submitted form optimization with a reduction goal weight rate of 20 to 60% with a static load period of 10 N. A new optimized system with new deformities and stress values is often analyzed for the structural optimization respectively. The research is performed with a static structural, mechanical solver ANSYS with a tensile strength of 100N on the bigger end.

Kumar et al. (2019) examined the optimization of weight and the cost reduction of the Diesel connection rod. To get the concept of the connecting rod, different stresses are to be addressed while the connecting rod is designed. This included a systematic study of the load. Stress distribution and deflections are key variables that are focused.

Mohamed et al (2018) had done modeling and analysis of connecting rod. They had replaced the conventional material of connecting rod with aluminium reinforced with boron silicide composite, for Suzuki GSI 150R motor bike. The model of connecting rod is carried out in CATIA V5 software. The analysis is carried out using ANSYS software. In this paper good combination of parameters like von misses stress and strain, deformation, factor of safety and weight reduction of two wheeler piston were done in ANSYS software. Comparison was made between existing carbon steel connecting rod and aluminium connecting rod. They had applied 15.5MPa pressure at the small end of connecting rod and big end was fixed. Maximum and minimum von misses stress and strain, displacement, frequency were noted from the analysis.

Ramsubramanian et al (2017) presented the design manufacture and analysis of Al/SiC MMCs for connecting rod. For this study, the connecting rod was manufactured using the stir casting method. The connecting rod was designed and meshed using the solid works and hyper mesh. Then the analysis was done with the help of ANSYS workbench 14.0 software. In this study, the stress, strain, deformation and thermal analysis was carried out. The analysis was made using aluminum reinforced using SiC having ratios of Al60%/SiC40%, Al75%/SiC25%, Al70%/SiC30%. This property was done through the stir casting process. They had done proper estimation of properties with appropriate testing methods. Mechanical testing and required design analysis were discussed. Further, the Al60/SiC40 was subjected to stress, strain, deformation and thermal analysis and then compared with C70 steel.

VI. CONCLUSION

The connecting rod belongs to the group of critical components of piston engines. The connecting rod transfers loads from the piston onto crankshaft. In modern diesel engines the large value of torque achieved at low speed of rotation causes high stresses in pistons, crankshafts, connecting rods and another engine components.

Amplitude of operational stresses has significant influenceon the fatigue life of the connecting rod. Additional factors which limit its fatigue strength are: incorrect shape (design), material defects or technological errors (defects created during the production process). The failure analysis of the connecting rods of piston engines was described in many publications. Several typical and uncommon failure modes in connecting rods of combustion engines were reported in work. The author's attention is focused on description of failure mode and the stress analysis of investigated components. The interpretation of the fractures was supported by traditional calculations and advanced analytical models. The analyzed failures in connecting rods showed that the most common failure modes.

In this study the failure and stress analysis of the connecting rod of turbocharged diesel engine was performed. In order to explain the reasons of connecting rod damage, an advanced stress analysis using the finite element method (FEM) was utilized. In order to solve the problem the geometrical models of connecting rod, piston and adjacent components were created. Next the complex loads resulting from both the pressure of gas in cylinder and the inertial forces were defined.

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