Finite Element Analysis of Connecting rod for Internal Combustion Engines: A Review

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Abstract - *Connecting rod connects the piston to crankshaft and transfer follows a simple mechanism with the crankshaft that, it converts reciprocating motion into rotating motion. In modern automotive internal combustion engines, the connecting rods commonly known as 'conrod' are mostly made of steel and for motorsports industry; it is made up of aluminum alloy for more power and speed. In this paper, the study and research of various scholars have been studied and analyzed. The main objective of this study is to evaluate the problems and their solution generated from time to time with engine as mentioned by the scholars. It also provide the information about optimization and designing the connecting rod, various stresses to be considered while designing the connecting rod and different materials used and comparing their results in the CAE software's like CATIA, AUTOCAD,PRO-E and ANSYS etc. This paper also represents the review on the developments made in the field of analysis, weight and cost reduction opportunities and better materials for connecting rod.*

Key Words: *Connecting rod, crankshaft, automobile engine, CAE, CATIA, AUTOCAD, PRO-E, ANSYS.*

1. INTRODUCTION

The connecting rod is a component of an IC engine which fulfill the two main requirements: (a) to link the piston with the crankshaft and (b) conversion of the straight motion of the piston into a rotational one for the crankshaft. It is highly dynamic loaded component used for power transmission in combustion engines. They must be capable of transmitting axial tensions, axial compressions, and bending stresses between piston and crankshaft. These forces are caused by the physical processes taking place in the cylinder together with the inertia forces of the crankshaft.

It is the key part of Internal Combustion engine. The small end of the connecting rod reciprocates with the piston. The large end rotates with the crankpin. These dynamic motions make it desirable to keep the connecting rod as light as possible while still having a rigid beam section. Lightweight rods also reduce the total connecting rod material cost. There are different types of materials and production methods used in the manufacture the connecting rods.

Forged connecting rods have been used for years and have a thick parting line along the length of the rod. They are always used in high-performance engines and are generally used in heavy-duty engines. The cost of cast rods is lower than that of forged rods, both in the initial casting and in the machining. Cast rods can be identified by a thin parting line along the length of the rod. Generally, the forging method produces lighter weight and stronger, but more expensive connecting rods.

2. LITERATURE REVIEWS

The connecting rod is subjected to a complex state of loading. It undergoes high cyclic loads of the order of 108 to 109 cycles, which range from high compressive loads due to combustion, to high tensile loads due to inertia. Therefore, durability of this component is of critical importance. Due to these factors, the connecting rod has been the topic of research for different aspects such as production technology, materials, performance simulation, fatigue, etc. For the current study, it was necessary to investigate finite element modeling techniques, optimization techniques, developments in production technology, new materials, fatigue modeling, and manufacturing cost analysis. This brief literature survey reviews some of these aspects.

Webster et al. (1983)[1] performed three dimensional finite element analysis of a high-speed diesel engine connecting rod. For this analysis they used the maximum compressive load which was measured experimentally, and the maximum tensile load which is essentially the inertia load of the piston assembly mass. The load distributions on the piston pin end and crank end were determined experimentally. They modeled the connecting rod cap separately, and also modeled the bolt pretension using beam elements and multi point constraint equations.

Folgar et al. (1987)[2] developed a fiber FP/Metal matrix composite connecting rod with the aid of FEA, and loads obtained from kinematic analysis. Fatigue was not addressed at the design stage. However, prototypes were fatigue tested. The investigators identified design loads in terms of maximum engine speed, and loads at the crank and piston pin ends. They performed static tests in which the crank end and the piston pin end failed at different loads. Clearly, the two ends were designed to withstand different loads.

In a study reported by **Repgen (1998)**[3], based on fatigue tests carried out on identical components made of powder metal and C-70 steel (fracture splitting steel), he notes that the fatigue strength of the forged steel part is 21% higher than that of the powder metal component. He also notes that using the fracture splitting technology results in a 25% cost reduction over the conventional steel forging process. These factors suggest that a fracture splitting material would be the material of choice for steel forged connecting rods. He also mentions two other steels that are being tested, a modified micro-alloyed steel and a modified carbon steel.

Park et al. (2003)[4] investigated micro-structural behavior at various forging conditions and recommend fast cooling for finer grain size and lower network ferrite content. From their research they concluded that laser notching exhibited best fracture splitting results, when compared with broached and wire cut notches. They optimized the fracture splitting parameters such as, applied hydraulic pressure, jig set up and geometry of cracking cylinder based on delay time, difference in cracking forces and roundness. They compared fracture splitting high carbon micro-alloyed steel (0.7% C) with carbon steel (0.48% C) using rotary bending fatigue test and concluded that the former has the same or better fatigue strength than the later.

Anil kumar (2012)[5] He worked on the optimization in weight and reduce inertia force on the existing connecting rod, by changing some variables. The weight of the connecting rod was also reduced by 0.004 kg which was not significant but reduces the inertia forces. Fatigue strength plays the most significant role (design driving factor) in the optimization of this connecting rod. Optimization was performed to reduce weight of the existing connecting rod. This optimization can also be achieved by changing the current forged steel connecting rod into some other materials such as C-70 steel etc.

B.Anusha (2013) [6] made a comparative study on connecting rod of Hero Honda Splendor is done to determine von-misses stresses, strain, shear stress and total deformation for the given loading conditions using analysis software using ANSYS. Static analysis of two materials is carried out by ANSYS and the maximum von misses stress for cast iron is 91.593Mpa and the maximum stress for structural steel is 82.593Mpa. Maximum stress occurs at the piston end of the connecting rod. Connecting rod design is safe for both materials based on the ultimate strength.

Amit kumar (2014) [7] preformed the experiment on 42CrMo steel alloy which required less material and less dimensions to sustain required pressure generated inside the cylinder compared with 20CrMo and 30crMo materials connecting rod. For the same amount of forces acting on the connecting rod, the steel alloy 42crMo is 11.67 % less in weight with respect to 20CrMo whereas 30CrMo alloy is only 6.42 % less compared with the 20CrMo conceding rod.

Gurunath V. Shinde (2015) [8]. The paper describe the analysis of carbon steel on static stresses developed in connecting rod. Dimensions are measured from connecting rod and CAD model is developed in Pro-E 2.0 and ANSYS software is used for static analysis of connecting rod further Finite Element Analysis by Simulation in which Pro E and ANSYS Software packages are used for simulation. The main advantage of using simulation is to save time and cost involved in analysis. The input conditions like time and money. Material Properties, static load, boundary conditions etc. are given. The loads on the connecting rod were obtained as a function of crank angle.

Mahesh Nikam (2016) [9]This project is to investigate the compressive stress acting on connecting rod at different loading condition and to explore weight reduction opportunities for a production forged steel connecting rod. Firstly a proper Finite Element Model is developed using software CATIA V5. Then the FEA is done to determine the stresses in the existing connecting rod for the given loading conditions using FEA software. Based on the observations of the static FEA and the load analysis results, the load for the optimization study was selected.

K.Sudershan Kumar (2012) [10] In their project connecting rod is replaced by Aluminum reinforced with Boron carbide for Suzuki GS150R motorbike. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modeled using PRO-E 4.0 software. Analysis is carried out by using ANSYS software. As a result, the percentage of increase in stiffness in aluminum boron carbide was obtained and percentage of reducing in stress ALUMINIUM BORON CARBIDE and ALUMNUM is same than CARBON STEEL.

A.Prem kumar (2015)[11] conducted a study on connecting rod of composite material. In his work connecting rod is replaced by aluminum based composite material reinforced with Boron carbide. And it also describes the modeling and analysis of connecting rod. Pro-E solid modeling software is used to generate the 3-D solid model of Connecting rod. They concluded that the present material used for connecting rod Al6061 is high deformation when compare to Al6061+B4C. So Al6061+B4C have low deformation, the result is increasing the life time of the connecting rod.

Ramanpreet Singh (2013)[12] The main objective of this study is to replace the conventional material of connecting rod i.e. steel with the Composite material (E-Glass/Epoxy). In this study von misses stresses, deformations and other parameters areas certained which has been done by doing the FEA of the connecting rod. On comparing the von-misses stresses in the two materials it was found that there is reduction of 33.99% of stresses when convention steel was replaced with the orthotropic E-Glass/Epoxy. For connecting rod it is suggested to replace Conventional steel with E-Glass/Epoxy.

Manoj Sharma (2015)[13] In this work we take connecting rod of a Mahindra Jeep CJ-340 and change its material from Al360 to PEEK. The modeling of the connecting rod is done on Pro-E wildfire 4.0 and analysis work is done on ANSYS 11.0. On the basis of this study, the results obtained were that the weight of connecting rod was reduced to 46.7% approximately and strength was improved to 23.7%.

G.M Sayeed Ahmed (2014)[14], In his thesis, a broken connecting rod made of forged steel was replaced with Aluminum alloys and Carbon Fiber. The materials are changed so that the weight of the connecting rod get reduced, when aluminum alloys and carbon fiber were used over Forged Steel. The connecting rod was analyzed using materials aluminum 6061, aluminum 7075, aluminum 2014 and carbon fiber 280 GSM bidirectional. After analysis, it was found that the yield strength of aluminum 6061, aluminum 7075, Aluminum 2014, and carbon fiber was found to be 71.5632N/mm2 as72.2133N/mm2 as 71.5869N/mm2 as 72.5887N/mm2, respectively. The obtained values were less than the maximum yield strength values.

Prateek Joshi (2015)[15], The study aims to carry out for the load, strain and stress analysis of the crank end of the connecting rod of different materials. Based on which the High Strength Carbon Fiber connecting rod will be compared with connecting rod made up of Stainless Steel and Aluminum Alloy. As a result the displacement, Stress and Strain Intensity induced in the Connecting Rod made up of Carbon fiber is comparatively slightly greater, thus more advancement in the field of Carbon Fiber is required to be as equivalent and efficiently used as Stainless Steel. The composite material like carbon fiber has good strength and also being lighter than both Stainless steel and Aluminum Alloy 7075.

S.Aishwarya (2015)[16] This paper describes about a real time problem of using Cast Iron connecting rod in Hero Honda Splendor + motorbike it's modeling and analysis and optimization of connecting rod. The paper also describe the comparative study of material like Cast iron, Aluminum 360, Stainless steel grade 304 and C70 Carbon steel. Weight reduction can be clearly viewed in the comparison graph between the solid and truss design. The obtained design life cycle for modified design is103 cycles, which is same as that of the existing design.

Mahesh Nikam (2016)[17] investigate the compressive stress acting on connecting rod at different loading condition and to explore weight reduction opportunities for a production forged steel connecting rod. As a result it is found that stress generated at shank is well below allowable limit. Based on numerical analysis with finite element analysis it is also observed that maximum stress is generated at piston end of connecting rod.

3. CONCLUSIONS

Above all researchers gives the idea about designing and the optimization of the connecting rod. It explains about the various stresses to be considered while designing the connecting rod and different materials used and comparing the result of all material. Also most of the researchers had used the CATIA software for the modeling and ANSYS software as analysis. These are the common tools which were used for designing any automobile element. Connecting rod can be designed for weight and cost reduction also to increase the life time of connecting rod. Up-to certain level, the efforts have been made to provide high strength at optimized design. Today, the things are designed with 2-3future decade's consideration with present working needs.

4. FUTURE SCOPE OF STUDY

Designing an optimizing a connecting rod will contribute in the increase in overall efficiency of engines. The connecting rod can be further modified with suitable alternate material for weight optimization, power increase and friction reduction technologies. While selecting a substitute of non-ferrous material like composites, alloys, carbons fibers etc, will decrease the dependency on ferrous materials. And a complete non-ferrous engine could be developed in the near future. It's an effort to move towards unconventional methods of connecting rod manufacturing and designing.

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BIOGRAPHY

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