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Design and Development of Connecting Rod with Aluminum Alloy Replacing Iron Based Alloy Material for Reciprocating Piston Engine

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Abstract: *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. The axial stresses are produced due to cylinder gas pressure (compressive only) and the inertia force arising in account of reciprocating action (both tensile as well as compressive), where as bending stresses are caused due to the centrifugal effects. The result of which is, the maximum stresses are developed at the fillet section of the big and the small end. Hence, the project deals with the stress analysis of connecting rod by Finite Element Method ANSYS WORKBENCH 14.0 Software. The main objective in this paper to review on design evaluation and optimization of connecting rod parameters by using finite element method is to achieve suitable design for connecting rod. That can be achieved by changing such design parameters in the existing design. 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 Pro/E or Catia. Then static 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 14.In the first part of the study, the static 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. The results were also used to determine of various stress and the fatigue model to be used for analyzing the fatigue strength. Outputs of the fatigue analysis of include fatigue life, damage, factor of safety, stress biaxiality indication. Then results of present model in ANSYS are compared with the results of existing design in the reference paper.*

Keywords: *Ansys, FEA, Connecting Rod, Fatigue life, Factor of safety*

1. INTRODUCTION

The intermediate component between crank and piston is known as connecting rod. The objective of C.R. 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 components are big shank, a small end and a big end. The cross section of shank may be rectangular, circular, tubular, I- Section, + -section or ellipsoidal-Section. It sustains force generated by mass & fuel combustion. The resulting bending stresses appear due to eccentricities, crank shaft, case wall deformation & rotational mass. FEA approach deals with structural analysis along with various parameters which affects its working & define best solution to overcome the barriers associated with it. The structural analysis allows stresses &

strains to be calculated in FEA, by using the structural model. The structural analysis performed to create high & low stresses region from the input of the material, loads, boundary condition. FEA approach was adopted in structural analysis to overcome the barriers associated with the geometry & boundary condition. It is used to improve optimize design. The main objective of this work is to determine shear stresses and optimization in the existing connecting rod, which are in different cross-section as plus (+) section, I-section and ellipsoidal section. The failures of existing design suggest the minimum design changes in the existing connecting rod.

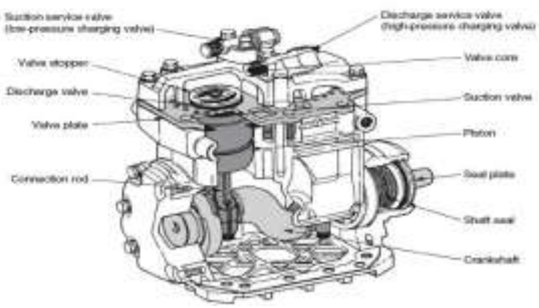

Figure 1: Overview of engine parts

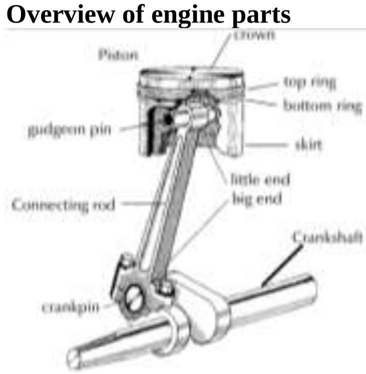

Figure 2: Connecting Rod assembly

Figure 3: Connecting Rod's parts

1.1. Small end and big end:

The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most often press fit into the connecting rod but can swivel in the piston, a "floating wrist pin" design. The big end connects to the bearing journal on the crank throw, in most engines running on replaceable bearing shells accessible via the connecting rod bolts which hold the bearing "cap" onto the big end. Typically there is a pinhole bored through the bearing and the big end of the connecting rod so that pressurized lubricating motor oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons and piston rings. Most small two-stroke engines and some single cylinder four-stroke engines avoid the need for a pumped lubrication system by using a rolling-element bearing instead, however this requires the crankshaft to be pressed apart and then back together in order to replace a connecting rod.

1.2. Engine wear and rod length:

A major source of engine wear is the sideways force exerted on the piston through the connecting rod by the crankshaft, which typically wears the cylinder into an oval cross section rather than circular, making it impossible for piston rings to correctly seal against the cylinder walls. Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore lead to longer engine life. However, for a given engine block, the sum of the length of the connecting rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the cylinder block where the cylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

1.3. Stress failures:

The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the square of the engine speed increase. Failure of a connecting rod, usually called throwing a rod is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bolts from a defect, improper tightening or over-revving of the engine. Re-use of rod bolts is a common practice as long as the bolts meet manufacturer specifications. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control.

2. LITERATURE REVIEW

The following research papers are consulted for obtaining an in-depth understanding of various aspects of the project:-

Suraj Pal et al. [1] "Design Evaluation and Optimization of Connecting Rod Parameters Using FEM" In this paper 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 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 12.In the first part of the study, the static loads acting on the connecting rod, After that the work is carried out for safe design.

G. Naga Malleshwara Rao et al. [2] "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, 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.

K. Sudershn Kumar et al. [3] "Modelling and Analysis of Two Wheeler Connecting Rod" This paper describes modelling and analysis of connecting rod. In this project connecting rod is replaced by Aluminium reinforced with Boron carbide for Suzuki GS150R motorbike. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modelled using PRO-E 4.0 software. Analysis is carried out by using ANSYS software.

B. Anusha, C.Vijaya Bhaskar Reddy et al. [4] " Modelling and Analysis of Two Wheeler Connecting Rod by Using Ansys" In this paper a static analysis is conducted on a connecting rod of a single cylinder 4-stroke petrol engine. The model is developed using Solid modelling software i.e. PRO/E (creo-parametric). Further finite element analysis is done to determine the von-misses stresses shear stress and strains for the given loading conditions.

B. Anusha, Dr.C. Vijaya Bhaskar Reddy et al. [5] "Comparison Of Materials For TwoWheeler Connecting Rod Using Ansys" The modelled connecting rod imported to the analysis software i.e. ANSYS. Static analysis is done to determine von-misses stresses, strain, shear stress and total deformation for the given loading conditions using analysis software i.e. ANSYS. In this analysis two materials are selected and analyzed. The software results of two materials are compared and utilized for designing the connecting rod.

Mr. H. B. Ramani et al. [6] "Analysis of Connecting Rod under Different Loading Condition Using Ansys Software" In this study, detailed load analysis was performed on connecting rod, followed by finite element method in Ansys-13 medium. In this regard, In order to calculate stress in Different part of connecting rod, the total forces exerted connecting rod were calculated and then it was modelled, meshed and loaded in Ansys software. The maximum stresses in different parts of connecting rod were determined by Analysis. The maximum pressure stress was between pin end and rod linkages and between bearing cup and connecting rod linkage. The maximum tensile stress was obtained in lower half of pin end and between pin end and rod linkage. It is suggested that the results obtained can be useful to bring about modification in Design of connecting rod.

Pravardhan S. Shenoy and Ali Fatemi [7] carried out the dynamic load analysis and optimization of connecting rod. The main objective of this study was to explore weight and cost reduction opportunities for a production forged steel connecting rod. Typically, an optimum solution is the minimum or maximum possible value the objective function could achieve under a defined set of constraints. The weight of the connecting rod has little influence on the cost of the final component. Change in the material, resulting in a significant reduction in machining cost, was the key factor in cost reduction. As a result, in this optimization problem the cost and the weight were dealt with separately. The structural factors considered for weight reduction during the optimization include the buckling load factor, stresses under the loads, bending stiffness, and axial stiffness. Cost reduction is achieved by using C-70 steel, which is fracture crackable. It eliminates sawing and machining of the rod and cap mating faces and is believed to reduce the production cost by 25%.

Y. Kumari, Dr. B V R Gupta [8] carried out the Dynamic Analysis & Optimization of Connecting Rod Using FEM, 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. While performing quasi-dynamic FEA of the connecting rod as shown in figure, external loads computed from the load analysis were applied to both the crank end and the piston pin end of the connecting rod. Many FE models were solved, each model with the applied loads obtained from the load analysis at the crank angle of interest. Therefore, such analysis is different from a static analysis as the time-varying dynamic nature of the loading represented by load variation at different crank angles is accounted for. It should also be noted that the dynamic load analysis step was required as a separate step, as input to the stress analysis step using IDEAS

Abhinav Gautam, K Priya Ajit [9], static stress analysis of connecting rod made up of SS 304 used in Cummins NTA 885 BC engine is conducted, It is observed that the area close to root of the smaller end is very prone to failure, may be due to higher crushing load due to gudgeon pin assembly. As the stress value is maximum in this area and stresses are repetitive in nature so chances of fatigue failure are always higher close to this region.

Ram Bansal [10] , it is noted that the The connecting rod deformation was mainly bending due to buckling under the critical loading. And the maximum deformation was located due to crush & shear failure of the big & small end bearings. So these areas prone to appear the fatigue crack. Base on the results, we can forecast the possibility of mutual interference between the connecting rod and other parts. The results provide a theoretical basis to optimize the design and fatigue life calculation.

Kuldeep B, Arun L.R, Mohammed Faheem [11], it is concluded that Weight can be reduced by changing the material of the current al360 connecting rod to hybrid ALFASiC composites. The new optimised connecting rod is comparatively much stiffer than the former.

Pravardhan S. Shenoy and Ali Fatemi [12], Optimization was performed to reduce weight and manufacturing cost of a forged steel connecting rod subjected to cyclic load comprising the peak compressive gas load and the peak dynamic tensile load at 5700 rev/min, corresponding to 360o crank angle.

GVSS Sharma and P Srinivasa Rao [13], Statistical process control is an excellent quality assurance tool to improve the quality of manufacture and ultimately scores on end-customer satisfaction. SPC uses process monitoring charts to record the key quality characteristics (KQCs) of the component in manufacture. This paper elaborates on one such KQC of the manufacturing of a connecting rod of an internal combustion engine.

K. Sudershn Kumar, Dr. K. Tirupathi Reddy, Syed Altaf Hussain [14], for considering the parameters, the working factor of safety is nearer to theoretical factor of safety in aluminum boron carbide. Percentage of reduction in weight is same in Aluminum 360 and aluminum boron carbide. Percentage of increase in stiffness in aluminum boron carbide is more. Percentage of reducing in stress ALUMINIUM BORON CARBIDE and ALUMNUM is same than CARBON STEEL.

Suraj Pal, Sunil kumar [15], Finite Element analysis of the connecting rod of a Hero Honda Splendor has been done using FEA tool ANSYS Workbench. It is concluded that the weight of the connecting rod is also reduced by 0.477g. Thereby, reduces the inertia force. Fatigue strength is the most important driving factor for the design of connecting rod and it is found that the fatigue results are in good agreement with the existing result.

Prof. Vivek C. Pathade , Dr. Dilip S. Ingole [16], From the theoretical , Finite Element Analysis and Photoelastic Analysis it is found that i) The stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end. ii) Form the photoelastic analysis(from the fringe developed in the photoelastic model of connecting rod) it is found that the stress concentration effect exist at both small end and big end and it is negligible in the middle portion of the connecting rod. iii) Therefore, the chances of failure of the connecting rod may be at fillet section of both end.

Priyank D. Toliya, Ravi C. Trivedi, Prof. Nikhil J. Chotai [17], the objective of this research is to investigate the failure analysis of the connecting rod of the automotive engine. Apart from conventional material of connecting rod I choose the connecting rod of FM-70 Diesel engine which is made of Aluminium 6351. static analysis is done to determine the von Misses stress, elastic strain, total deformation in the present design connecting rod for the given loading conditions using the FEM Software Ansys 12.1 .In the starting of the work, the static loads acting on the connecting rod, After that the work is carried out for safe design and life in fatigue. Fatigue Analysis is compared with the Experimental results.

S. Shaari, M.M. Rahman [18], it is concluded that the modeling of connecting rod and FE Analysis has been presented. Topology optimization were analyzed to the connecting rod and according to the results, it can be concluded that the weight of optimized design is 11.7% lighter and maximum stress also predicted lower than the initial design of connecting rod. The results clearly indicate that the new design much lighter and has more strength than initial design of connecting rod.

Bhuptani K. M [19], it is well known fact that connecting rod is the important 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 Bearing of connecting rod is manufactured by using nonferrous materials like Gunmetal, Phosphor Bronze etc.. This paper describes modeling and analysis of connecting rod bearing for small end using ProE Wildfire 4.0.A two dimensional drawing is drafted from the calculations. A parametric model of bearing is modeled using PRO-E 4.0 software. Analysis is carried out by using Pro-mechanica software. Static structural analysis of Bearing for small end of connecting rod is done by considering three different materials. The best combination of parameters like Von misses stress; Maximum shear stress and weight reduction for Four stroke diesel engine were studied in ProE software.

Tukaram S. Sarkate, Sachin P. Washimkar, Sachin S. Dhulekarsssss [20], it is concluded that The stress analysis of connecting used in engine has been presented and discuss in this paper. The results obtain by FEA for both Aluminum 7068 alloy and AISI 4340 alloy steel are satisfactory for all possible loading conditions. By using Aluminum 7068 alloy instead of AISI 4340 alloy steel can reduce weight up to 63.95%. Also equivalent stresses for Aluminum 7068 alloy is less by 3.59%. The factor of safety of connecting rod will reduce by 9.77% in case tensile load applied at crank end but it will increase in all other load conditions if Aluminum7068 alloy is used instead of AISI 4340.

3. MATERIAL FOR CONNECTING ROD

The C-70 materials have been widely present in culture. Alloying elements in the material enables hardening of forged connecting rod when they undergo controlled cooling after forging. The properties of material are initial input for optimization task thus it play a very important role in optimization task. Connecting rod was design & modelled by using Pro/E 4.0 v. It was then imported to ANSYS for analysis.

3.1. Chemical composition of c-70

Table 1: Chemical Composition of C-70

Name of element	% of element
C	0.61%
Al	0.095%
Mn	0.82%
Br	0.00097%
Co	7.8%
Fe	75.56%
Mo	3.25%
Cr	0.145%

3.2. Some important features & mechanical properties of C70 steel

1. Cost, durability, and longevity
2. The weight below the wrist pin is not as big of a concern as the weight above it
3. By using a high-strength steel rod, larger cam bores can be utilized without interference.

Table 2: Mechanical properties of C -70

S. No.	Mechanical Properties	C -70 steel values
1	Density (g/cc)	7.9
2	Modulus of elasticity (GPa)	225
3	Yield Strength, Sy (MPa)	445
4	Tensile Strength,Su (MPa)	675.5
5	Poison ratio	0.30

3.3. Engine specification:

Table 3: Engine specification of 4 stroke engine

Engine type	Air cooled 4- stroke Bore
Stroke (mm)	58.6

Displacement	149.5cc
Maximum power	13.8 at the rate of 8500rpm
Maximum torque	13.4Nm at the rate of 6000rpm
Compression ratio	9.35/1
Density of petrol	737.22kg/m3
Temperature	60F

4. METHODS GENERALLY USED FOR MANUFACTURING THE CONNECTING ROD

4.1. Wrought Forged

Connecting Rods It is unclear when the first wrought forged connecting rod was produced but the wrought forged connecting rod has long been the “standard” for the automotive industry. Plain carbon steel forgings were the initial material of choice. Since a finished connecting rod cannot be formed in one blow, the forging dies for connecting rods have several impressions, each step moving progressively toward the final shape. The metal billet, or starting material, is transferred from one impression to another between successive blows a set of forging dies and the main steps in forging a connecting rod. Often, the cap part and lower rod part are forged separately, or forged slightly oblong and sawed in two pieces. After the part has been forged it must be heat treated to reach the desired properties and then straightened after the heat treating operation. To ensure proper weight and balance of the finished rod, the rod is forged with extra weight in the form of balancing pads on both ends of the rod These balancing pads are then machined during10 the finishing operation to obtain a well balanced connecting rod. The rod and cap are finish machined using several operations including broaching, milling, boring, honing, fringing and other finishing steps.

4.2. Fiberglass Spray Lay-up Process

Is very different from the hand lay-up process .The difference comes from the application of the fiber and resin material to the mold. Spray-up is an open-molding composites fabrication process where resin and reinforcements are sprayed onto a reusable mold. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam, or other core material may then be added, and a secondary spray-up layer embeds the core between the laminates. The part is then cured, cooled, and removed from the mold.

4.3. Hand Layup Method For Composite Material

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after Perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribedhardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, daises board, deck etc.

5. CAE TOOLS AND SOFTWARE

Computer-Aided Engineering (CAE) is the broad usage of computer software to aid in engineering tasks. It includes computer aided design (CAD), computer aided analysis (CAA), computer integrated manufacturing (CIM), computer aided manufacturing (CAM), material requirements planning (MRP) and computer-aided planning (CAP).CAE embraces the application of computers from preliminary design (CAD) through production (CAM). Computer Aided Analysis includes finite element and finite difference method for solving the partial differential equations governing solid mechanics, fluid mechanics and heat transfer, but it also includes diverse program for specialized analyses such as rigid body dynamics and control system modeling. Recently, manufactures have been asked to design their products for eventual recycling, and this aspect of engineering will undoubtedly fall under the umbrella of CAE, but as of yet it doesn't have its own acronym. CAE tools are being used, for example, to analyze the robustness and performance of components and assemblies. The term encompasses simulation, validation, and optimization of products and manufacturing tools. In the future, CAE systems will be major providers of information to help support design teams in decision making.CAE areas covered include:

1. Stress analysis on components and assemblies using FEA (Finite Element Analysis);
2. Thermal and fluid flow analysis Computational fluid dynamics (CFD);
3. Kinematics;
4. Mechanical event simulation (MES).
5. Analysis tools for process simulation for operations such as casting, molding, and die press forming.
6. Optimization of the product or process.

6. CONCLUSION

Above all researchers gives the idea about designing 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 used the CATIA software for the modeling and ANSYS software for analysis. These can be used for designing the any connecting rod in Automobile. Connecting rod can be designed for weight and cost reduction also to increase the life time of connecting rod. Up to some level of extent the weight of the connecting rod is lighter and having more strength as compared to the original design.

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