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DESIGN AND ANALYSIS OF CONNECTING ROD WITH ALUMINUM ALLOYS REPLACING CAST IRON AND STEEL FOR INTERNAL COMBUSTION ENGINES WITH THE HELP OF ANSYS

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ABSTRACT

This paper presents a comparative investigation report of effect of various parameters which affect the performance of an automobile engine. All internal combustion engines have at least one connecting rod to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight capable to withstand varying loads. It has been found that structural failure of various components results in engine missing and starts producing noise and vibration during racing, mileage gets affected and black or white smoke arise also pickup gets reduced. In automobile industry damaged or broken parts are generally too expensive to replace or repair especially in case of engine. In this concern we presented detailed analysis of causes along with preventive maintenance suggestion schedule for better engine life. Finite element modeling and analysis is to be performed using ANSYS 12.1 software package to perform a linear static and a coupled thermal-structural contact analysis of the component. A contact analysis is to be carried out to analyze the stresses arising from the interference of the connecting-rod bearing and the piston-pin bushing.

Key words: Ansys 12.1, Crankshaft, Piston, Connecting Rod, Internal Combustion Engines.

INTRODUCTION

The design and manufacture of Internal Combustion (IC) Engines is under significant pressure for improvement. The next generation of engines needs to be compact, light, powerful, and flexible, yet produce less pollution and use less fuel. Innovative engine designs will be needed to meet these competing requirements.

In order to understand the true impact, we would have to go back in time over one hundred years. A time without the simplicity of hopping into a vehicle to take us anywhere we want to go is almost unfathomable. But for the early automotive engineers, the tremendous advancements in automotive technology would be even more surprising.

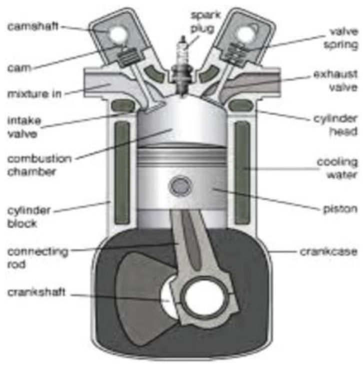

Figure 1.1: Internal combustion engine parts.

Crankshaft and connecting rods are the main components of internal combustion engines which convert reciprocating displacement of the piston to a rotary motion. A typical automotive crankshaft consist of main journals, connecting rod journals (crank-pins), counter weight, oil hole and a thrust bearing journal. During the service life, combustion and inertia forces acting on the crankshaft cause two types of loading on the crankshaft structure; torsion load and bending load.

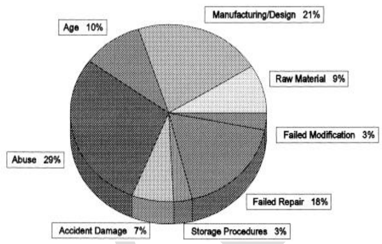

Fig.2. The distribution of causes of failure

FUNCTION OF CONNECTING ROD

The function of connecting rod is to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. It consists of a pin-end, a shank section, and a crank end. Pin-end and crank-end pin holes are machined to permit accurate fitting of bearings. One end of the connecting rod is connected to the piston by the piston pin. The other end revolves with the crankshaft and is split to permit it to be clamped around the crankshaft. The two parts are then attached by two bolts.

Connecting rods are subjected to forces generated by mass and fuel combustion. These two forces results in axial and bending stresses. Bending stresses appear due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore, a connecting rod must be capable of transmitting axial tension, axial compression, and bending stresses caused by the thrust and pull on the piston and by centrifugal force

The connecting rods 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.

FAILURE ANALYSIS OF ENGINE

One cannot correct the cause of premature failure until he first determines what causes the failure. To determine the cause of the failures, the following method was used:

- Appearance – an illustration and brief description of a component that has failed due to a specific cause.
- Damaging Action – what actually damaged the component under the conditions which were present?
- Possible Causes – a listing of those factors capable of creating the particular damaging action.
- Corrective Action – the action that should be taken to correct the cause of failure.

The major cause producing thermal stresses in engine due to

- insufficient engine cooling
- lack of lubrication or using wrong grade of lubricants

The other causes of damaging connecting rod and piston only by hydrostatic lock. Different types of other failure shown in figures.

Fig.3. Scratches on upper main bearing half in crank

Fig.4. Scratches on upper main bearing caps

Fig.5. Worn out piston due to overheating

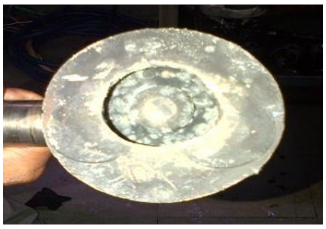

Figure 6: Consequent effects of piston can also be visualized on piston sleeves

Fig.7. Worn out cylinder surface

Fig.8. Worn out piston sleeves due to of badly overheated piston

Fig.9. Engine block assembly

CONNECTING ROD FAILURE

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.

A bent or twisted connecting rod results in misalignment of the bore, causing the bearing to be chocked so the bearing edge makes metal-to metal contact with the journal. These metal-to-metal contact areas cause excessive wear on the bearing surface. Alternating loading and flexing of the connecting rod can cause the bearing housing to become elongated. And because replacement bearing shells, when installed, tend to conform to the shape of the bearing housing, this can result in an out-of-round bearing surface.

In general connecting rod treated as individual is failed subjected to hydrostatic pressure lock. No much connecting rod failure observation is found due to overheating piston assembly (seizing), fluctuating loads and failure of main crank shaft big end bearing.

Whenever driver passes the car over the stored water on the ground and if there is chances of water coming inside in engine through exhaust pipe (silencer) then in that case hydrostatic locking of engine condition will observed. Figure 10 shows the hydrostatic lock effect on the connecting. Due to this only connecting rod is observed to be affected there is no any defect on piston is observed.

Fig.10. Hydrostatic Lock Effect

Fig.11. Cylinder in good condition

Also it was observed that it does not affect cylinder as shown in Figure 11

For avoiding hydrostatic lock it is mandatory to pass over that kind of situation by putting vehicle in first gear, press 50% of accelerator paddle without fluctuation and slowly controlling through the clutch and cross the situation

LITERATURE SURVEY

[1] P S Shenoy et.al. Studied detailed load distribution under service time loading conditions for a typical connecting rod, followed by finite element analysis (FEA) to capture stress variations over a repeated cycle of operation. It was found that even though connecting rods are typically tested and analyzed under axial loading and stress state, bending stresses are significant and a multi axial stress state exists at the critical regions of connecting rod.

[2] Thomas et.al.has done the analysis regarding the “Design of Connecting Rod for Heavy Duty Applications Produced by Different Processes for Enhanced Fatigue Life.” This studied was based on evaluating the fatigue life of a heavy duty connecting rod under 2 different conditions namely without considering the effect of shot peening and with considering the effect of shot peening. It was concluded that shot peening can significantly increase about 72% in fatigue life cycles of a connecting rod component.

[3] James R. Dale et.al.evaluated connecting rod for improved fatigue strength. In the analysis comparison was carried out between powder forging materials & C-70 materials. As a result Powder Forging materials demonstrate improved fatigue strength on the order of 25–33% over C-70 material of the same design.

[4] Prabhala et a undergone “Design And Weight Optimization Of IC Engine” by Replacing the steel components with aluminium alloy components. By observing the analysis results of two assemblies it was concluded that using aluminum alloy for both connecting rod and piston is more beneficial than using steel for piston as automatically overall weight is reduced therefore the power required to run itself by automobile is reduced resulting in the increase in the mileage.

[5] A. R. Bhagat et.al. describes the stress distribution of the seizure on piston four stroke engine by using FEA and analyzed the thermal stress distribution of piston at the real engine condition during combustion process. As a result it was observed that stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have enough stiffness to reduce the deformation.

[6] P.Brabec et.al done the analysis regarding “FEM Analysis of Connecting Rod for Stationary Engine” which addresses the computation of the strength and distortion characteristics of a stationary engine connecting rod. The results clearly indicate that the connecting rod is not significantly strength stressed and a worse variant is the stress at max. combustion pressure and as far as distortions are concerned, it is vital to avoid such distortions of the connecting rod big end which would take up the bearing clearance.

[7] T.T Mon et.al undergone the “Finite Element Analysis on Thermal Effect of the Vehicle Engine”. In this study FEM was employed to develop computational model to analyze the temperature distribution in the Vehicle Engine that utilized Spark ignition system for power generation.

[8] Vivek. C. Pathade et.al.has undergone the stress analysis of connecting rod .From the theoretical and Finite Element 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) Therefore, the chances of failure of the connecting rod may be at fillet section of both ends.

[18] Suraj Pal et al. “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.

[19] G. Naga Malleshwara Rao et al. "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.

[20] K. Sudershn Kumar et al. "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.

EXPERIMENTAL SETUP

DESIGN OF CONNECTING ROD

Connecting Rod consists of a long shank, a small end and a big end. The cross-section of the shank may be rectangular, circular, tubular, I-section or H-section. Generally circular section is used for low speed engines while I-section is preferred for high speed engines

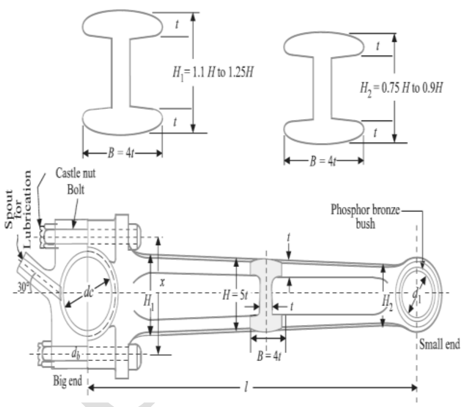

Figure 12: Sectional view of connecting rod

The length of the connecting rod (l) depends upon the ratio of l / r, where r is the radius of Crank. It may be noted that the smaller length will decrease the ratio l / r. This increases the angularity of the connecting rod which increases the side thrust of the piston against the cylinder liner which in turn increases the wear of the liner. The larger length of the connecting rod will increase the ratio l / r. This decreases the angularity of the connecting rod and thus decreases the side thrust and the resulting wear of the cylinder. But the larger length of the connecting rod increases the overall height of the engine. Hence, a compromise is made and the ratio l / r is generally kept as 4 to 5.

The small end of the connecting rod is usually made in the form of an eye and is provided with a bush of phosphor bronze. It is connected to the piston by means of a piston pin. The big end of the connecting rod is usually made split (in two halves) so that it can be mounted easily on the crankpin bearing shells. The split cap is fastened to the big end with two cap bolts. The bearing shells of the big end are made of steel, brass or bronze with a thin lining (about 0.75 mm) of white metal or Babbitt metal. The wear of the big end bearing is allowed for by inserting thin metallic strips (known as shims) about 0.04 mm thick between the cap and the fixed half of the Connecting rod. As the wear takes place, one or more strips are removed and the bearing is trued up.

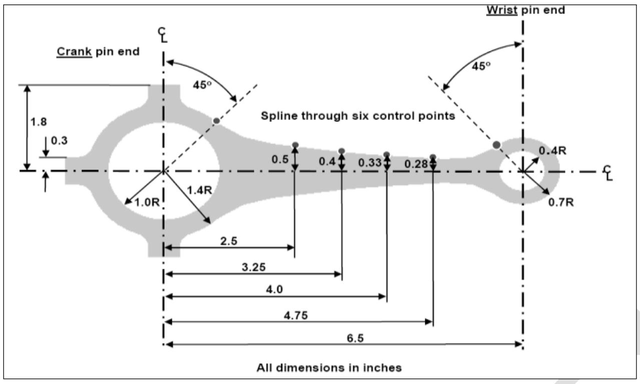

Fig.13. Specifications of the Connecting Rod

MATERIAL PROPERTIES

Connecting rod of bike's engine, which is available in market is selected for the present investigation. The dimensions of the selected connecting rod are found using vernier calipers, screw gauge and are tabulated in the table 1. According to the dimensions the model of the connecting rod is developed using CATIA design software. The modeled connecting rod is shown in figure 8.1.

TABLE1 – Dimensions of connecting rod

S.NO.	PARAMETERS	VALUES
1.	Length of connecting rod.	94.27 mm
2.	Outer diameter of big end.	39.02 mm
3.	Inner diameter of big end.	30.19 mm
4.	Outer diameter of small end.	17.75 mm
5.	Inner diameter of small end.	13.02 mm

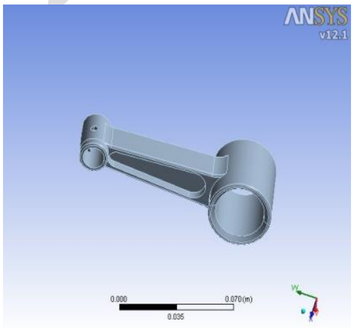

Figure 13. Model of connecting rod

MATERIAL PROPERTIES

When, the material used for selected connecting rod is structural steel and the properties of the material are presented in the table 2.

TABLE 2- Property of the structural steel

Material selected	**Structural steel**
Young's modulus (E)	2.0e+005 MPa
Poisson's ratio	0.3
Density	7.8e-006 Kg/mm^3
Tensile ultimate strength	460 MPa
Tensile yield strength	250 MPa
Compressive yield strength	250 MPa

When, the material used for selected connecting rod is cast iron and the properties of the material are presented in the table 3.

TABLE 3- property of the cast iron

Selected material	Cast iron
Young's modulus (E)	1.78e+05 MPa
Piossion's ratio	0.3
Density	7.197e+06 Kg/mm^3
Tensile yield strength	110 MPa
Tensile ultimate strength	110 MPa
Compressive yield strength	400 MPa
Compressive ultimative strength	0 MPa

TABLE 4- Property of the aluminum

Selected material	Aluminum
Young's modulus (E)	60000 MPa
Piossion's ratio	0.3
Density	2800 Kg/mm^3
Tensile yield strength	414 MPa
Tensile ultimate strength	414 MPa
Compressive yield strength	485 MPa
Compressive ultimate strength	0 MPa

MESHING

The next stage of the modeling is to create meshing of the designed model. Parameters used for meshing are given below. The mesh model of connecting rod is shown in figure 14.

Types of element: Tetrahedron

Number of nodes: 16076

Number of element: 8373

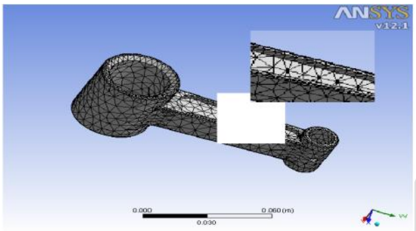

Fig.14 meshing model of the connecting rod

RESULT AND ANALYSIS

LOAD ANALYSIS OF THE CONNECTING ROD

A CATIA V5 model of connecting rod is used for analysis in ANSYS Workbench. Analysis is done with the pressure of 3.15MPa load applied at the piston end of the connecting rod and fixed at the crank end of the connecting. It is shown in fig.

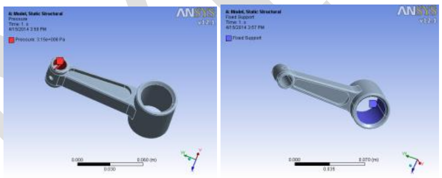

Fig. 15 Load Analysis of the Connecting Rod

TOTAL DEFORMATION

When, the material used for selected connecting rod is structural steel and the result of the total deformation is shown in the fig.

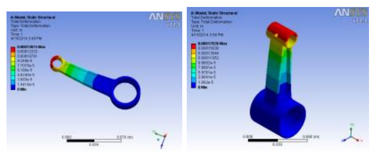

Fig.16 Total deformation in structural steel

When, the material used for selected connecting rod is cast iron and the result of the total deformation is shown in the fig.

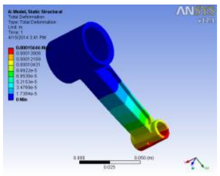

Fig.17 Total deformation in cast iron

When, the material used for selected connecting rod is aluminum and the result of the total deformation is shown in the fig.

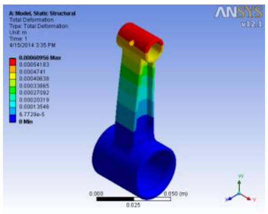

Fig.18 Total deformation in aluminium

Table 6 comparison of four materials

S.No.	NAME OF THE MATERIAL	FACTOR OF SAFETY		TOTAL DEFORMATION	
		MAX.	MIN.	MAX.	MIN.
1	STRUCTURAL STEEL	15	1.0416	0.000138	0
2	STRUCTURAL STEEL EN45	15	0.433	0.000179	0
3	CAST IRON	15	0.981	0.000156	0
4	ALUMINUM	15	0.0011982	0.00040153	0

CONCLUSION

It's been found that most of the connecting rod of IC Engine are made of Cast iron.But on comparison of different materials for similar boundary conditions & loading conditions it's been observed that out of the three materials Aluminum alloy is the most suitable material on the basis of Stress, Safety factor, Life, Thermal Resistivity, fatigue & damage because such connecting rod does not fails even at varying loads unlike Cast iron rod. And by using aluminum alloy we can also reduce the weight of the connecting rod. Hence optimizing the design of the connecting rod.

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