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Design and Analysis of Connecting Rod with Abaqus

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Abstract :-In the internal combustion engine, the connecting rod connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion of the piston and crankshaft. Mostly connecting rod is the main component of the internal combustion engine because all the power is depend on it to run the engine. The purpose of a connection rod is to provide fluid movement between pistons and a crankshaft. The connecting rods mainly used in the internal combustion engine, vee engine and the reciprocating compressor also. Connection rods are widely used in vehicles that are powered by internal combustion engines. The main objective of this work is to optimize the existing design of connecting rod of changing some of the design variables. The existing design performs modelling and evaluates critical regions in the connecting rod under static, dynamic and fatigue loading. In this present work, the model is developed, designed and analysed using CATIA, and ABAQUS/CAE. Optimization of connecting rod is done under same boundary and loading conditions for variation in the few stresses and fatigue parameters. The critical regions under both static and dynamic analysis are identified and improved. The results obtained from performed analysis can be used to modify the design of existing connecting rod, so that better performance i.e. reduced inertia, fatigue life and manufacturability can be obtained under varying static and dynamic conditions.

Keywords *–Connecting rod, Analysis, Abaqus*

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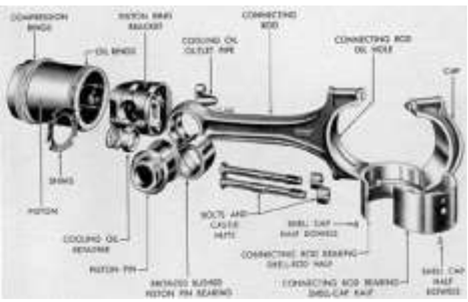
I. INTRODUCTION

In a reciprocating engine, the connecting rod connects the piston to crank or crankshaft. Together with the crank, they form a simple mechanism that converts reciprocating motion into rotating motion. Connecting rods may also convert rotating motion into reciprocating motion. A connecting rod is an engine component that transfers motion from the piston to the crankshaft and functions as a lever arm. Connecting rods are commonly made from cast aluminum alloy and are designed to withstand dynamic stresses from combustion and piston movement. The small end of the connecting rod connects to the piston with a piston pin. The piston pin, or wrist pin, provides a pivot point between the piston and connecting rod. Spring clips, or piston pin locks, are used to hold the piston pin in place. The big end of the connecting rod connects to the crankpin journal to provide a pivot point on the crankshaft. Connecting rods are produces as one piece or twopiece components. A rod cap is the removable section of a two-piece connecting rod that provides a bearing surface for the crankpin journal. The rod cap is attached to the connecting rod with two cap screws for installation and removal from the crankshaft

A. Part of Connecting Rod



1) Rod small end:

The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most Often press fit into a connecting rod but can swivel in the piston, a Floating wrist pin design.

2) Rod big end:

The big end connects to the bearing journal in the crank throw, in most engines running on replaceable bearing shells accessible via the connecting rod bolts which hold the connecting cap on to the big end. Typically there is a pin hole bored through bearing and the big end of the connecting rod so that pressurized lubricating motor oil squirts out on to the thrust side of the cylinder wall to lubricate the travel of the piston and piston ring.

3) Bottom end bolt:

Because of the stress reversal mentioned above, bottom end bolts have a limited life. This varies from engine to engine, but is generally around 12-15000 hours. If a bottom end bolt was to fail in operation, then the results would be disastrous.

B. Four Stroke Engine Connecting Rod The connecting rod in a medium speed 4 stroke engines is subject to an inertia whip loading due to the mass of the connecting rod swinging about the piston pin.

This loading of the rod influences its design, and to withstand the loading described above, connecting rods are often forged from a manganese molybdenum steel in an I or H section which reduces its mass from one made of round section steel (and thus reduces the whip loading) while maintaining strength.

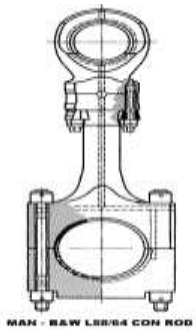


Fig.2. Cross Section of connecting rod

The advantage of using a vee engine is that the overall length of the engine is reduced for a given power output. If a normal bottom end arrangement is used then the con rods must be placed side by side which means the opposite cylinders are offset. The crankpins must be long enough to accommodate two bottom ends side by side, and of large enough diameter to resist bending. The increased length of the crankshaft means a longer engine. Two alternative arrangements are pictured (right). Both allow the cylinders to be opposite one another.

However, both arrangements restrict access to the crankcase, and because the design of the bottom ends are different, more spares have to be carried.

II. PROBLEM STATEMENT

Connecting rod rotates the crank shaft which helps the engine to move on or any vehicle to rotate its wheels Connecting rod is designed to withstand mechanical dynamic loads the dynamic loads are exerting from piston and crank shaft while the engine is in dynamic condition. The connecting rod cross section is induces tremendous stress while motion is transfers from the piston to crank shaft. It is necessary to develop enhancement of connecting rod performance while transfers the motion and energy from piston to crank shaft in this project is addressing in the development of most effective feature and performance of a connecting rod. The cross section of connecting rod beam design should be spread and minimize stress load over large uniformly shaped areas.

III. OBJECTIVES

The connecting rod is the main part of the engine; it can be called the Backbone of the engine. There is too much importance of connecting rod in an engine. It is designed to withstand stresses from combustion and piston movement. The connecting rod is under tremendous stress from the load represented by the piston. When building a high performance engine, great attention is paid to the connecting rods. The most effective feature of a connecting rod should be the uniform shape. The cross section of rod beam design should be spread and minimize stress load over large uniformly shaped areas

III. METHODOLOGY

A. Material Selection for Connecting Rod

Generally there are a few materials that are commonly used in the creation of connection rods. Like Steel Alloy, Aluminium and Titanium. The connecting rods are usually made of steel alloys like 42CrMo4, 43CrMo4, 44csr4, C-70, EN-8D, SAE1141, etc.

Connecting rods are usually drop forged out of a steel alloy. Aluminum and titanium are both materials that are also used in the manufacturing of connecting rods for performance vehicles.

B. Selection of Manufacturing Process

According to Ilia et al (2005), the weight of connecting rod for 1.9L engine is 545gm, and that for a 2.2 L engine is 544 gm. The minimum section is about 3.5 mm. Dimensional precision is important so that the clearances at the crankshaft end and at the piston end are assured. A lower surface roughness is necessary so as to minimize surface crack initiation. The processes that evolve are forging, die casting and pressing / sintering (powder methods). For both fracture split drop forging and fracture-split powder forging, one piece forging uses a cap that is broken off (fracture-split) the main part of the connecting rod. In the drop forging process use C- 70 crackable forging steel.

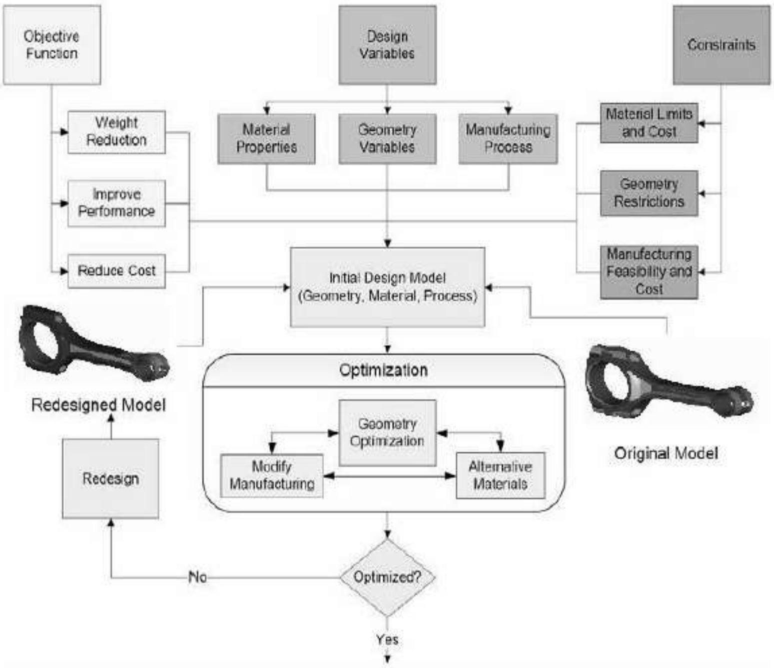


Fig.3 optimization flow chart

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V. DESIGN AND DEVELOPMENT OF CONNECTING ROD

Today, most of the development work is done with computers and sophisticated software. Engineers nowadays use finite element analysis (FEA) to analyse the compression and tension forces on a rod. The software creates 3-D images with colour coding that indicates the areas of highest and lowest stress. This allows the engineer to visualize what's actually happening to a rod at various loads and speeds. He can then tweak the design on his computer screen to add metal where extra strength is needed, and to remove metal from lightly loaded areas where it isn't needed. By repeating the FEA process over and over with each design change, he can optimize the rod to deliver the best possible combination of weight, strength and reliability in theory anyway. It still takes real world testing to validate the design. But with today's design and analysis software, most of the work is done before a prototype part is manufactured. One rod supplier said using FEA on their current rods allowed them to increase strength 12 to 15 percent with less than a 2 percent increase in overall rod weight.

Computer controlled numeric (CNC) machining also allows manufacturers to machine billets and forgings in ways that were previously too difficult, too time-consuming or too expensive. This allows manufacturers to offer a wider variety of rods in terms of rod length and beam construction. It also allows them to produce custom made-to-order rods very quickly. In fact, some rod suppliers say the majority of the rods they sell today are custom order rods rather than standard dimension rods from off the shelf stock, Rods essentially come in two basic types: I-Beam and HBeam.

Some rod suppliers only make I-Beams, others only make H-Beams, and some offer both types. I-Beam rods are the most common and are used for most stock connecting rods as well as performance rods. I-Beam rods have a large flat area that is perpendicular (90 degrees) to the side beams. The side beams of the rod are parallel to the holes in the ends for the piston pin and crank journal, and provide a good combination of light weight, and tensile and compressive strength. I-Beam rods can handle high rpm tension forces well, but the rod may bend and fail if the compressive forces are too great. So to handle higher horsepower loads, the I-Beam can be made thicker, wider and/or machined in special ways to improve strength. Rod suppliers produce a number of variants on the basic IBeam design.

The center area may be machined to create a scalloped effect between the beams, leaving a rounded area next to both beams that increases strength and rigidity much like the filets on a crankshaft journal. These kind of rods may be marketed as having an "oval-beam", "radial-beam" or "parabolic beam" design. H-Beam rods, by comparison, are typically designed for engines that produce a lot of low rpm torque. This type of rod has two large, flat side beams that are perpendicular to the piston pin and crankshaft journal bores. The center area that connects the two sides of the "H" together provides lateral (sideways) stiffness.

VI. MODELING OF CONNECTING ROD

Solid modeling tool is available to develop the concepts and initial design of any mechanical components and systems that can be analyses by using Finite Element Technique. Since the connecting rod involves several merging radii and surfaces, a classical study into this complicated problem has limitations and hence a finite element analysis is more appropriate to study the effect of combined loads due to gas pressure and inertia of reciprocating and oscillating parts of an engine.

The steps in modelling are described as below:

- Creating the 2D cross section on XY plane using two circle, line and fillets with the help of sketcher option.
- Fill material in sketch with the help of pad command.
- Creation of hole on piston end and crank end with the help of pocket command.
- The connecting rod is modeled for reduced weight.

Fig.4 modeling of connecting rod

VII. ANALYSIS OFCONNECTING ROD

The finite element an analysis for connecting rod is performed in two cases which are as follows. A. Static analysis of connecting rod

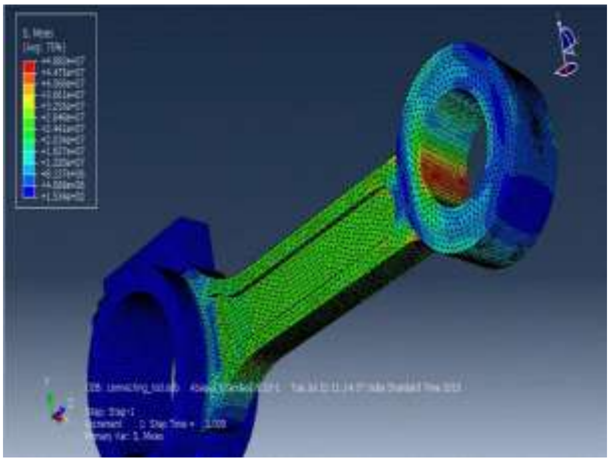

Fig.5: Finite Element Model of the Connecting Rod – Von mises Stress

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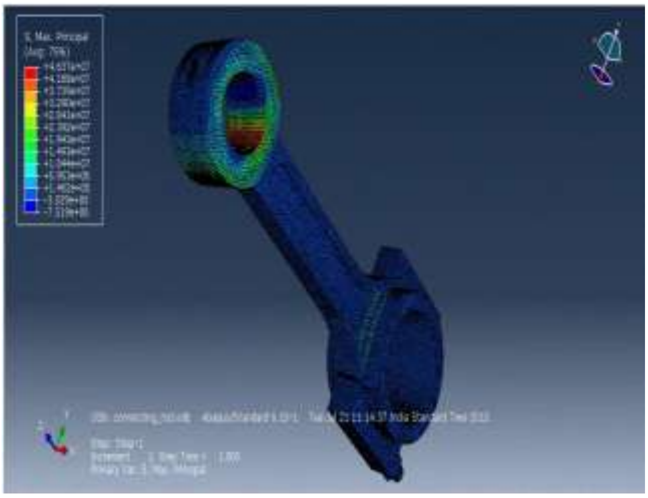

Fig.6: Finite Element Model of the Connecting Rod – Max. Principal Stress

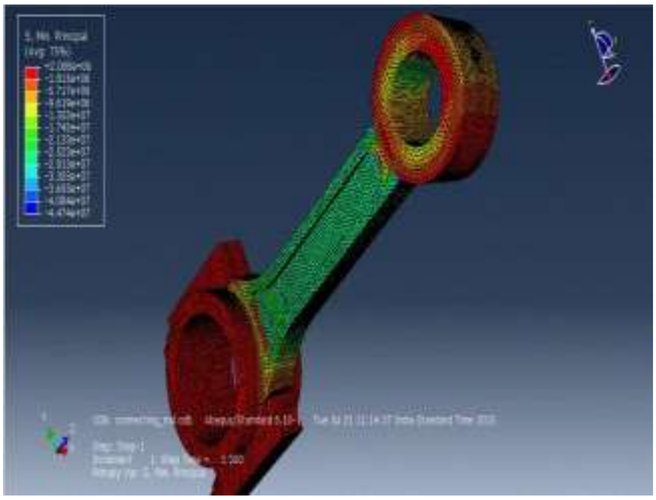

Fig.7: Finite Element Model of the Connecting Rod – Min. principal Stress

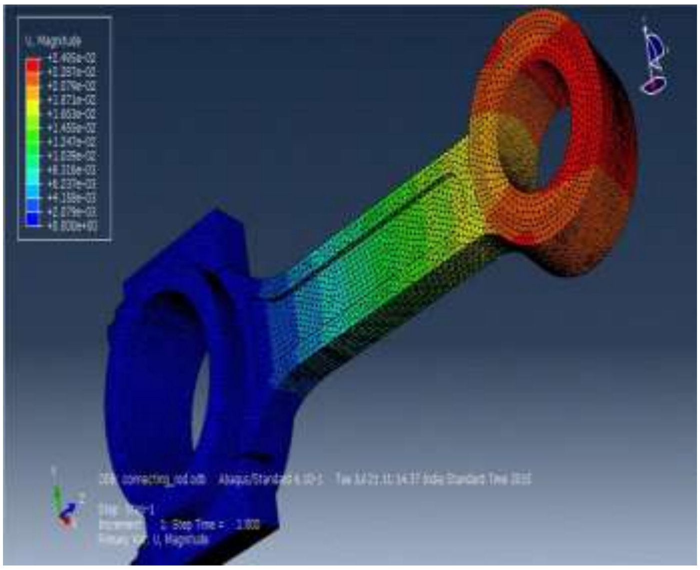

Fig.8: Finite Element Model of the Connecting Rod – Strain magnitude

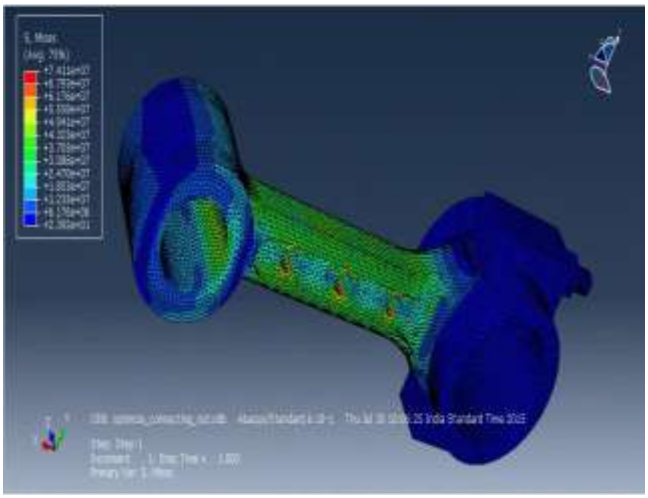

Fig.9: Finite Element Model of the Connecting Rod – Von mises Stress

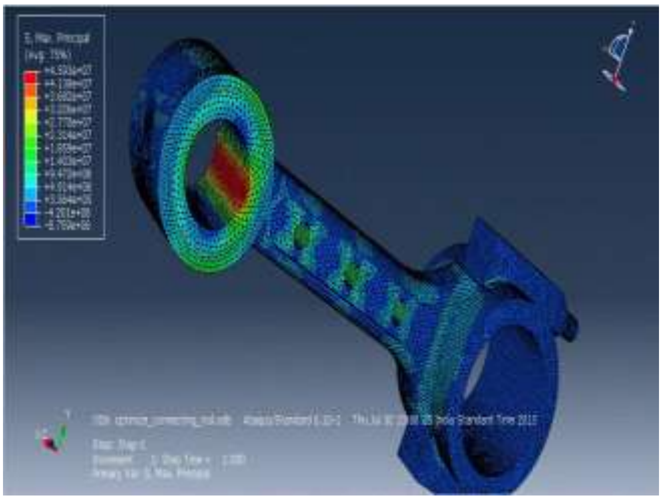

Fig.10: Finite Element Model of the Connecting Rod – Max. Principal Stress

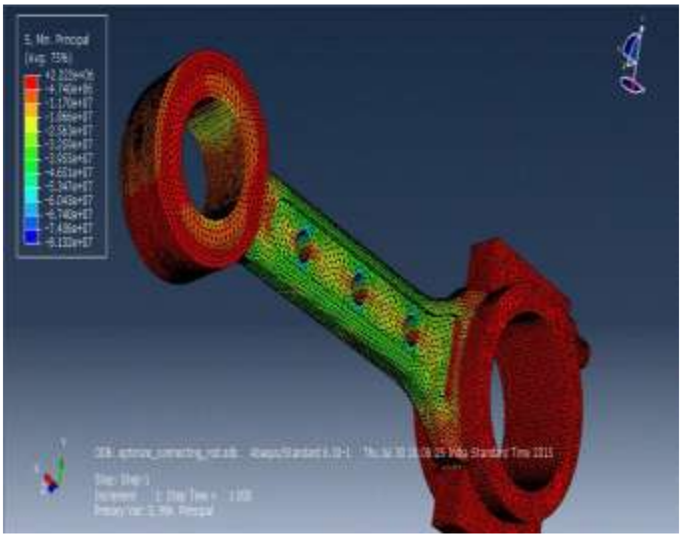

Fig.11: Finite Element Model of the Connecting Rod – Min. principal Stress

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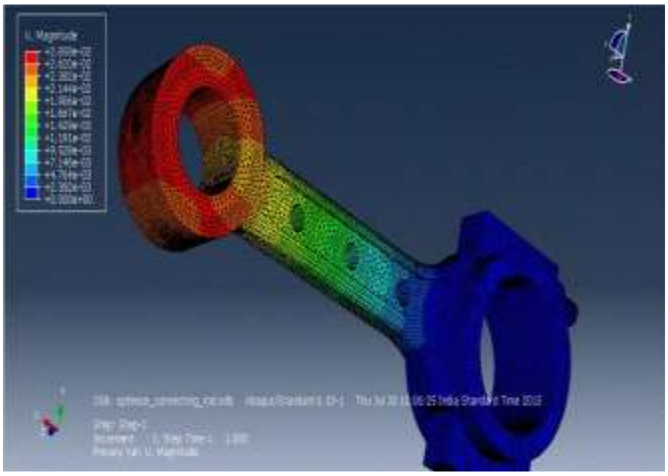

Fig.12: Finite Element Model of the Connecting Rod – Strain magnitude

Fig.9, Fig.10, Fig.11and Fig.12 are shows results for Vonmisses stresses, maximum principal stress, and minimum principal stress and strain magnitude respectively of optimized static model. From the figures it is observed that the stresses obtained from static analysis are within the acceptable limits.

C. Dynamic analysis of connecting rod

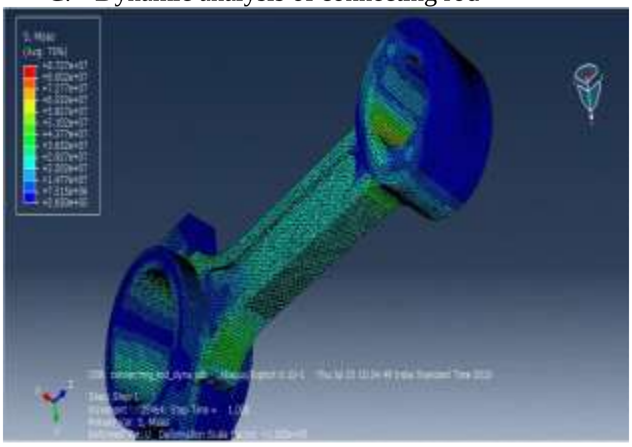

Fig.13: Finite Element Model of the Connecting Rod – Von mises Stress

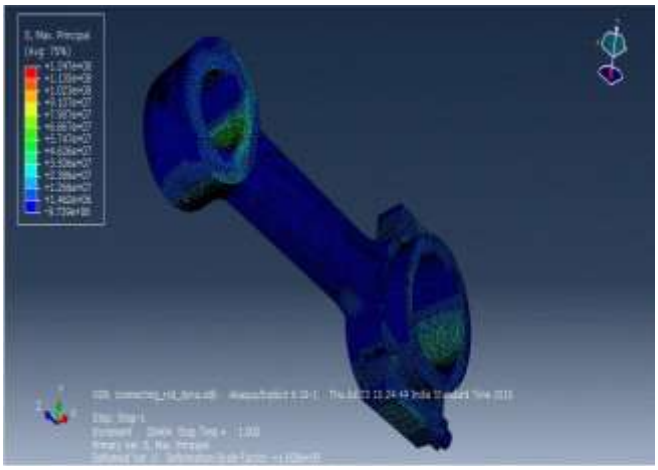

Fig.14: Finite Element Model of the Connecting Rod – Max. Principal Stress

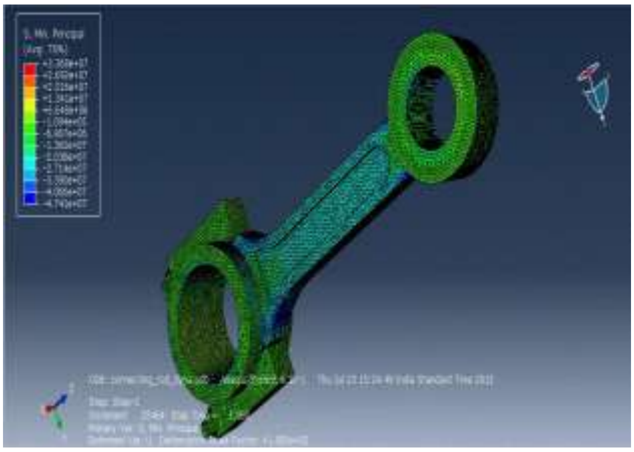

Fig.15: Finite Element Model of the Connecting Rod – Min. principal Stress

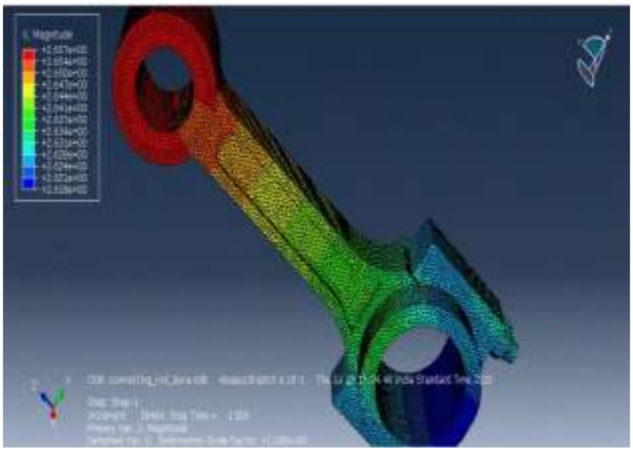

Fig.16: Finite Element Model of the Connecting Rod – Strain magnitude

Fig.13, Fig.14, Fig.15 and Fig.16 are shows results for Von-misses stresses, maximum principal stress, and minimum principal stress and strain magnitude respectively of existing dynamic model. From the figures it is observed that the stresses obtained from static analysis are generating higher stresses as normal requirement. In this case only design is to be optimizing giving fillet and hole.

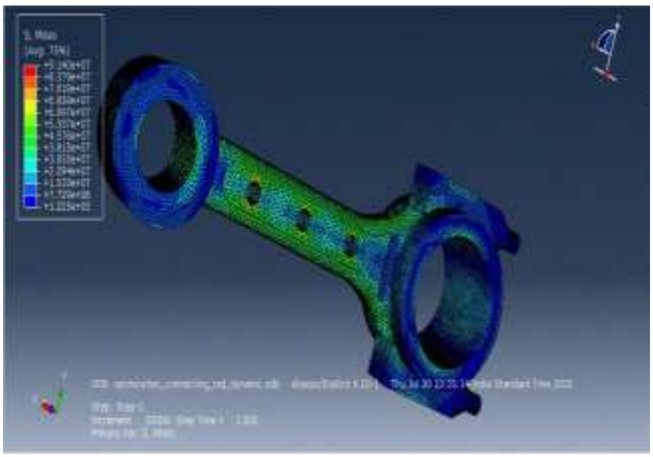

Fig.17: Finite Element Model of the Connecting Rod – Von mises Stress

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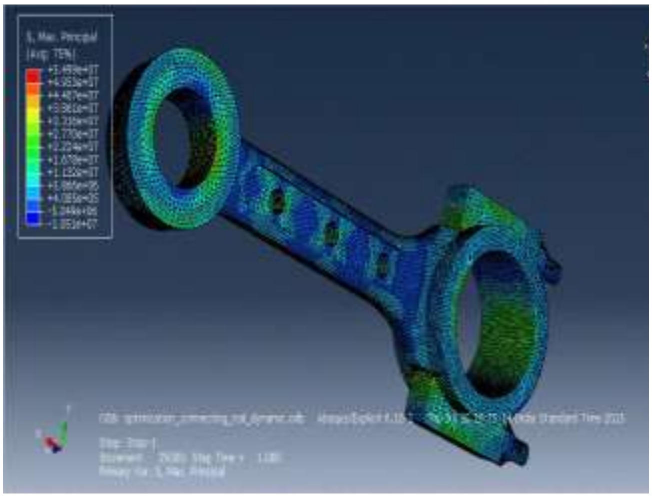

Fig.18: Finite Element Model of the Connecting Rod – Max. principal Stress

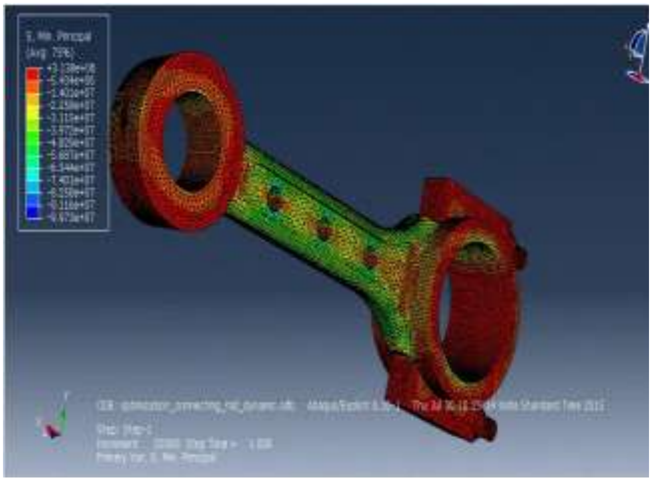

Fig.19: Finite Element Model of the Connecting Rod – Min. principal Stress

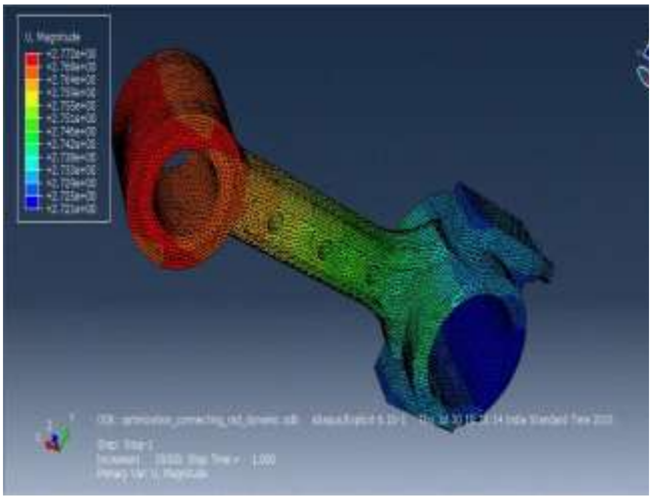

Fig.20: Finite Element Model of the Connecting Rod – Strain magnitude

Fig.17, Fig.18, Fig.19 and Fig.20 are shows results for Von-misses stresses, maximum principal stress, and minimum principal stress and strain magnitude respectively of optimized static model. From the figures it is observed that the stresses obtained from dynamic analysis are within the acceptable limits.

VII. RESULTS AND DISCUSSION

A. Static analysis of optimize connecting rod

In this analysis design is to be optimizing by changing the design of connecting rod. For equal stress distribution we are provided fillet at outer edges of middle portion and also providing circular hole due to that whatever the stresses induced on the middle portion of connecting rod are reduced and mass of the connecting rod should be reduced by providing the holes on that portion. After the analysis of existing connecting rod and optimized connecting rod following results are calculated by applying the the tool as abacus/CAE for static condition.

TABLE I COMPARISON UNDER STATIC ANALYSIS

Sr. No.	Result Parameter	Optimized Result	Existing Result
1	Von mises Stress	74.11 Mpa	48.82Mpa
2	Max. principal Stress	45.93 Mpa	46.37Mpa
3	Min. principal Stress	2.22 Mpa	2.08Mpa
4	Strain magnitude	0.0285	0.0249

Dynamic analysis of optimize connecting rod In this case only design is to be optimizing by giving fillet and hole for the middle portion of connecting rod to reduce the stresses which are introduced on that portion due to that fillet and holes which are provide on middle portion of connecting rod maximum stresses are to be reduced and also the mass of connecting rod should be reduced. After the analysis of existing connecting rod and optimized connecting rod following results are calculated by applying the tool as abacus/CAE for dynamic condition and results are as shown in below.

TABLE II COMPARISON UNDER DYNAMICANALYSIS

Sr. No.	Result Parameter	Optimized Result	Existing Result
1	Von mises Stress	91.40 Mpa	87.27 Mpa
2	Max. principal Stress	54.99 Mpa	124.7 Mpa
3	Min. principal Stress	3.138 Mpa	33.68 Mpa
4	Strain magnitude	2.77	2.657

B. Hand calculation cross-check Material considered:

Alloy steel Yield strength = 550 MPa
Tensile strength = 680MPa

Permissible stress = 550*0.30 =156 MPa
Permissible stress = 680*0.18 =122.4 MPa
By maximum distortion energy theory
Von mises stress =122.4 *0.57 = 69.76 MPa
Dynamic correction factors for connecting rod =1.25
Effective stress = 1.25*69.76 =87.21 MPa
With stress concentration at average level with reduced area = 87.21 * 1.05 =91.57 MPa
This perfectly matches with the values from table.
Hence validate. Hence analysis results through ABAQUS are acceptable.

VIII. CONCLUSIONS

1. Connecting rod has been optimized properly.
2. Stress overshoots by some level as compared to existing results.
3. But with weight reduction this is justified.
4. Design stresses (von-mises stress) increases and so also strains amplitude but other stresses drops which are ok.

IX. SCOPE OF PROJECT

The connecting rod is major and main component of the engine which provides the motion for the engine it can convert the reciprocating motion into the rotary motion at the piston end. In the engine there is high temperature should be there due to that most of the stresses are to be done on that component and due that highest stresses the life of connecting should be decrease and strength should be weaker. The connecting rod is the moving component so have to consider the weight of it also. In future by applying the advanced optimization techniques again ne research will be done for the connecting rod. The Scope of developed method lies in the following.

1. Development of new techniques in simulation package.
2. Development of new simulation strategy.
3. Extending the developed technique to other parts
4. For robust system design.

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