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Increasing the service factor of connecting rod by material and design modification of 85bhp Tractor

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ABSTRACT: *A Manufacturing world which concentrated on design, product development, production rate and profit now has to focus on tool life, human welfare and environmental issues due to the fulfillment of statutory requirements and quality aspects. This paved way for the birth of the several approaches for risk assessment and control of occupational hazards. In the metal working industry, one of the most important issues is the heat generated in cutting process. High temperature in metal cutting degrades the tool life, surface integrity, size accuracy and machining efficiency. Main objective can be achieved by maintaining the important cutting fluid parameters and operating procedures during the machining process. Detailed studies have revealed that the exposure to cutting fluid has harmful effects on human health due to inhalation and skin contacts. Also sever contamination impacts on the environment in the form of air and land pollutions resulting from vapor released during machining process and disposal of used oil. This project focused on the quality improvements of cutting fluid and the standard practices of usage during the machining operation mainly attributed on reduction in cutting zone temperature and minimize its adverse effects on human health and environment.*

I. INTRODUCTION

1.1 Introduction About I.C Engine Connecting Rod

The automobile engine connecting rod is a high volume production, critical component. It connects reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine.

The connecting rod is subjected to a complex state of loading. It undergoes high cyclic loads of the order of 10^8 to 10^9 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 our project for different aspects such as life cycle, materials cost, fatigue, etc…

For the current manufacturing condition, it was necessary to investigate finite element modeling techniques, optimization techniques, and developments in new materials, fatigue modeling, and material cost analysis for different mechanical components such as automobile, plastic, home appliances etc…, which are made by large volume production.

Due to its large volume production, it is only logical that optimization of the connecting rod for its material cost will result in large-scale savings.

Below is a picture of the fundamental parts of an engine. Surface "L" is where combustion occurs, air enters through "M", and "H" is the shaft through which power is accumulated and delivered out of the engine. The

combustion occurs against the top surface of the piston (F) and pushes the connecting rod (G) downward, causing the shaft to move in a circular motion. So, it is easy to see that the connecting rod harnesses all of the power produced in combustion and converts it into something useful, in this case a spinning shaft.

1.2 Working Principle Of Four Stroke I.C Engine

A four-stroke engine is the most common type used in automobiles. The four strokes are intake, compression, power, and exhaust. Each stroke requires approximately 180 degrees of crankshaft (or flywheel) rotation, so the complete cycle would take 720 degrees. Each stroke plays a very important role in the combustion process, and each has a different pressure surrounding it.

In the intake cycle, as the picture shows, the piston is moving downward while one of the valves is open. This creates a vacuum, and an air-fuel mixture is sucked into the chamber. This would be cause for very little pressure on the piston, so P is small.
Moving on to compression, we can see that both valves are closed, and the piston is moving upward. This creates a much larger amount of pressure on the piston, so we would have a different representation of P in our equation for this stroke.

The next stroke is the big one: power. This is where the compressed air-fuel mixture is ignited with a spark, causing a tremendous jump in pressure as the fuel burns. The pressure seems to "spike", so the most cause for concern occurs here. (This is also the area in which the dangers of engine knock or pre-detonation can occur, causing an even larger spike.)
Finally, we have the exhaust stroke. In this stroke, the exhaust valve is open, once again creating a chamber of low pressure. So, as the piston moves back upwards, it forces all the air out of the chamber. The pressure in this region is therefore considered very low.

II. STRESS STRAIN RELATIONSHIP CURVE

To understand the strength of each material in a situation like this, we need to understand a stress-strain diagram (pictured below). Each material behaves in a similar manner when placed under a load. There is a period of elastic deformation, in which the material is stretched, but it returns to its original size when unloaded. The point at which it fails to return to the original specifications is called the yield stress. Now, in an automobile, we would probably have to assume that this yield stress would be passed at some point, so most connecting rods come out of engines a different size than when they were installed

After the yield stress, another stress point can be reached called the ultimate stress point. At this point, a material has essentially reached the point of no return. Failure is imminent, and even a decreased amount of stress can cause fracture. So, naturally, this is what we concern ourselves with.
For the type of steel that a connecting rod would likely be created with, the ultimate tensile strength would be about 80 to 180 thousand pounds per in^2. If aluminum were used, the ultimate tensile strength would be closer to 70 thousand pounds per in^2. So, you can see that our connecting rod, under a stress of 880 thousand psi, would be in serious trouble. Failure would almost definitely occur, even if incredibly high strength steel were used

2.2 **Forces Acting On The Connecting Rod**

A connecting rod is subjected to the following forces.
1. Force due to gas or steam pressure and inertia of reciprocating parts and
2. inertia bending forces.

2.3 **Force Due To Gas Or Steam Pressure**

It may be noted that in a horizontal engine reciprocating parts are accelerated from rest during the first half of the stroke. (When the piston moves from inner dead center to outer dead center). It is then
retarded during the latter half of the stroke. The inertia force due to the acceleration of reciprocating parts opposes the force on the reciprocating parts helps the force on the piston.

Fp = force due to pressure+ inertia force

The negative sign is used when the piston is accelerated and positive sign is used when piston is retarded.
Inertia force per unit length at the crank pin

$= m1 \times w^2 \times r$

Inertia force per unit length at the gudgeon pin

$= 0$

And the maximum bending stress due to inertia of the connecting rod

$f_{max} = M_{max} / Z$

where Z = section modulus

III. MODELLING OF CONNECTING ROD

3.1 Modelling Of Connecting Rod

There are most software packages are available for creating the 3D model of the connecting rod and some of the software's are
1. SOLID WORKS
2. UNIGRAPHICS

3. CATIA
4. UNIGRAPHICS
5. INVENTOR

Here we have chosen the unigraphics as the modeling software because of following advantages.

1. It is the feature based modeling software
2. Associativity
3. Parametric based design
4. Design indent

For analysis the model we considered the ANSYS as the CAE software and done the structural analysis on the connecting rod by changing different materials under same loading conditions and same dimensions of the connecting rod. The theory of von- mises Theory
Is used for calculating the stress induced in the connecting rod when it is in heavy loaded conditions

3.2 Introduction About Unigraphics:

In Part modeling you can create a part from a conceptual sketch through solid feature-based modeling, as well as build and modify parts through direct and intuitive graphical manipulation.

The Part Modeling Help introduces you to the terminology, basic design concepts, and procedures that you must know before you start building a part. Part Modeling shows you how to draft a 2D conceptual layout, create precise geometry using basic geometric entities, and dimension and constrain your geometry. You can learn how to build a 3D parametric part from a 2D sketch by combining basic and advanced features, such as extrusions, sweeps, cuts, holes, slots, and rounds. Finally, Part Modeling Help provides procedures for modifying part features and resolving failures.

From the above modeling concept we modeled the component and the representation of the connecting rod is as follows:

The first figure shows the schematic representation of the connecting rod with the additional elements.

Connecting Rod:

The 3D model which is developed from the AutoCAD drawing. The following 3D model is created using pro-engineer and the basic parameters are given as follows:

VOLUME = 6.3054407e+04 MM^3
SURFACE AREA = 2.3904488e+04 MM^2

Fig 3.2.1 Connecting rod

COVER:

The 3D model which is developed from the AutoCAD drawing. The following 3D model is created using pro-engineer and the basic parameters are given as follows:

VOLUME = 2.1879024e+04 MM^3
SURFACE AREA = 1.0710839e+04 MM^2

Distance Piece:

The 3D model which is developed from the AutoCAD drawing. The following 3D model is created using pro-engineer and the basic parameters are given as follows:

VOLUME = 1.0222913e+03 MM^3
SURFACE AREA = 1.0393000e+03 MM^2

M10 NUT:

The 3d model which is developed from the AutoCAD drawing. The following 3D model is created using pro-engineer and the basic parameters are given as follows:

VOLUME = 2.7745789e+03 MM^3
SURFACE AREA = 1.5837742e+03 MM^2

STUD:

The 3d model which is developed from the AutoCAD drawing. The following 3D model is created using pro-engineer and the basic parameters are given as follows:

Fig 3.2.5 Stud

VOLUME = 3.5707203e+03 MM^3
SURFACE AREA = 2.2682509e+03 MM^2

Assembly Of Connecting Rod:
The total components of connecting rod are assembled with the help of Pro-engineer software and the view is given in following diagram.**Fig 3.2.6 Assembly Of Connecting Rod**

IV. TRANSFORMATION OF MODEL

Then the model is converted in to the IGES format which is most suitable and easy access able for any other software.

Using the IGES format we can import the connecting rod model from UNIGRAPHICS to ANSYS. Now we can make any analysis like structural, thermal analysis etc..,

Connecting Rod As Per Design
Connecting Rod –Design Changed

4.2 Introduction About Ansys:

Ansys is the software used for commonly analysis the structural and thermal calculations. So we have taken this as calculation package for the following advantages.

1. It is powerful package for structural analysis.
2. Most accurate.
3. Reduce the manual errors during hand calculations.
4. Repetitive analysis is possible.
5. The part is divided into small elements called (quadratic, tetra-hentra elements (which produce most accurate results.

4.3 SOLID 45 Geometry

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

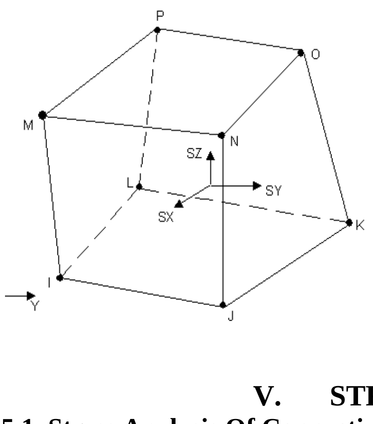
The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. A reduced integration option with hourglass control is available. A higher-order version of the SOLID45 element is SOLID95.

The geometry, node locations, and the coordinate system for this element are shown in "SOLID45 Geometry". The element is defined by eight nodes and the orthotropic material properties. Orthotropic material directions correspond to the element coordinate directions. The element coordinate system orientation is as described in Coordinate_Systems.

Element loads are described in Node and Element Loads. Pressures may be input as surface loads on the element faces as shown by the circled numbers on : "SOLID45 Geometry". Positive pressures act into the element. Temperatures and fluences may be input as element body loads at the nodes.

4.4 Three-Dimensional Finite Element Analysis

SOLID45 Stress Output



To design connecting rod, a stress analysis was performed using the finite element method done using ANSYS software. Modeling was done for every leaf with eight-node 3D brick element (solid 45) and five-node 3Dcontact element (contact 49) used to represent contact and sliding between adjacent surfaces of leaves.

Also, analysis carried out for connecting rod with bonded end joints for duralumin, C-70 and Carbon/Epoxy composite materials and the results were compared with steel connecting rod.

The maximum peel and shear stresses along the adhesive layer were measured. Figs. 5 to 14 represent FEA results for steel and connecting rod (Glass/carbon). The maximum pee land shear stresses along the bonded adhesive layer for carbon/epoxy were measured.

V. STRESS ANALYSIS OF CONNECTING ROD

5.1 Stress Analysis Of Connecting Rod

Stress analysis of connecting rod were considered when the spring is subjected to maximum load at 1729 N to determine the stress distribution and critical region of high stress which could cause failure to the spring. Maximum and von Mises stresses on each leaf, leaf 1 to leaf 5, were calculated for both linear and nonlinear techniques.

Figure shows examples of maximum principal and von Mises stresses contours plot on deformed models of nonlinear analysis. The maximum and critical region of stresses from both FE techniques are on leaf 1 and 2 at the same side and region next to the U-Bolts. Stresses on each leaf are shown in Fig. 11 and 12 for both linear and nonlinear consideration, respectively. Jerking stresses next to U-Bolts area on each leaf are the result of highly constraint by rigid elements; therefore, in practical this maximum value should be less than calculated. Moreover, the spring leaves are already prepared to encounter this high tensile stress from the bending effect by induce several hundreds MPa of compressive residual stress on surface layers during the manufacturing process. In Fig. the maximum principal and von Mises stresses distribution along leaf 1 using linear and nonlinear are compared. Though both techniques given approximately same highest stress value and the stresses distribution except for rod 1. Therefore, using linear FEA is adequate to achieve certain design guidelines for connecting rod. However, for thoroughly examine the behaviors nonlinear FEA is favorable.

VI. CONCLUSION & FUTURE WORK

Now days the Connecting rod are made up of aluminum silicon alloy, C-70 steel, Carbon epoxy Material which expands enormously due to generation of heat in the piston. This will affect clearance volume and insufficient clearance can cause the piston size in the cylinder. The ultimate aim is to reduce the expansion and increasing service factor by material and design modification and to analyze the various characteristics of Connecting rod like stress, deformation, density, Young's modules and poisons ratio in phase II .

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