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Modeling and Thermal Analysis of IC Engine's Connecting Rod by using CATIA and ANSYS Software

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ABSTRACT-

The connecting rod is a key link within a combustion engine. It connects the piston to the crankshaft and is responsible for transferring energy from the piston to the crankshaft. It should operate at high rpm. This is why it has to withstand extreme pressures, which makes its design vital to the internal combustion engine. In this research, a two-wheeler tie rod was designed analytically. On the basis of this design, a physical model is created in CATIA V5. The materials used in the connecting rod must be chosen wisely because during the manufacturing process it must undergo various production processes and subsequent heat treatment process, which is very important for strength and durability. Accordingly, the high-strength carbon fiber connecting rod will be compared to the stainless steel and aluminum alloy connecting rod. The results can be used to improve weight reduction and modify linkage design.

Keywords- Connecting Rod; Catia V5R20; Ansys 18.0.

1. INTRODUCTION

The internal combustion engine is essentially a crank-slider mechanism, with the slider being the piston in this case. The piston is moved up and down by the rotary motion of the crankshaft. The piston is encased inside the combustion chamber. Fuel combustion occurs using an oxidizing agent in the combustion chamber which is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of high-temperature, high-pressure gases resulting from combustion applies a direct force to the piston. This force moves the component a distance called the connecting rod, the crankshaft, which converts chemical energy into useful mechanical energy [1-2].

The valves at the top represent the suction and exhaust valves needed to draw in the air-fuel mixture and exhaust the chamber residue. In gasoline engines, a spark plug is required to transmit the electrical discharge to ignite the mixture. Some important components of an internal combustion engine are cylinder, piston, piston rings, connecting rod, crankshaft, etc [3].

The connecting rod forms an integral part of the internal combustion engine. It acts as a link between the piston and the crankshaft. The small end of the connecting rod is connected to the piston pin, gudgeon pin (the usual British term) or wrist pin, which today is most often pressed to fit the connecting rod but can rotate in the piston. The other end, the larger end is attached to the crankshaft [4].

The main function of the connecting rod is to transfer the translational motion of the piston to the rotational motion of the crankshaft. The function of the connecting rod also includes transmitting piston force to the connecting rod [5-6].

The connecting rods are subject to complex loading conditions. It is subject to a high cyclic load of 108 to 109 cycles, which is why it is under the influence of different types of loads during operation. Fatigue loading is one of the main reasons contributing to its failure. The maximum pressure in the connecting rod occurs near the piston end due to piston thrust [7]. Tensile and compressive stresses are caused by gas pressure.

Due to these factors, the connecting rod has become the subject of research in various aspects such as production technology, materials, performance simulation, fatigue parameters, etc. There are different types of materials and production methods used to create connecting rods. The most common materials used to connect bars are steel and aluminum. The most common types of manufacturing processes are casting, forging, and powder metallurgy [8]

Functionally, connecting rods must have the highest possible rigidity and the lowest weight. Therefore Section I connecting rods are generally designed to provide maximum rigidity with minimum weight. Based on this design, the physical model was designed in CATIA V5. The structural system of the connecting rod was analyzed using FEA. Using FEA, different stresses for given loading conditions are calculated using FEA software ANSYS WORKBENCH 14.5 [9].

ANSYS is an analysis system that stands for Advanced Numerical System Simulation. It is a CAE program, which has many capabilities, from simple static analysis to complex nonlinear dynamic analysis, thermal analysis, transient state analysis, etc. Through the solid modeling program, the geometric shape of the model is described, then the ANSYS program is used to connect the geometric shapes of the nodes and elements. In order to obtain the desired results at each point of the model, precise meshing is performed which also leads to accurate results 10].

2. LITERATURE REVIEW

Yogesh says that 50-90% of the failures of connecting rods are due to fatigue failure, so it is very important to consider fatigue failure in the design of the connecting rod and the Computer Aided Engineering (CAE) team of the company should take great care to perform fatigue analysis and come up with a reconstructive proposal. Design, if necessary. The 2016 Ford Eco Boost Mustang uses forged steel as the connecting rod member. There has always been a warlord in the automobile industry to choose the type of connecting rod material. In this thesis, steel and aluminum 7075 are used as materials for connecting rods. CAE analysis is performed to select the best materials.

The automobile engine connecting rod is a high-volume product and a critical component. It connects the reciprocating piston to the rotating crankshaft, and transmits the piston's force to the crankshaft. Every vehicle using an internal combustion engine requires at least one connecting rod depending on the number of cylinders in the engine.

Connecting rods are widely used in a variety of automobile engines. The function of the connecting rod is to transfer the force of the piston to the crankshaft, as a result of which the reciprocating motion of the piston is translated into rotational motion of the crankshaft. It consists of a pin tip, a shank section, and an elbow tip. Pin and crank end holes are machined to allow precise installation of bearings. One end of the connecting rod is connected to the piston by a piston pin. The other end rotates with the crankshaft and is split to allow it to be fitted around the crankshaft. The two parts are then connected with screws. The connecting rods are subject to forces resulting from the combustion of mass and fuel. These two forces lead to axial stresses and bending. Bending stresses appear due to eccentricity, crankshaft, case wall deformation, and rotational mass force. Therefore, the connecting rod must be able to transfer axial tension, axial stress, and bending stresses generated by push and pull on the piston and by centrifugal force (Afzaal and Fatemi, 2003).

The temperature generated inside the CC is about 300 degrees Celsius for a four-stroke IC, which is captured by the piston head, says Velevila Lakshmikanth, Dr. Amar Nageswara Rao. As we can see in the picture, the temperature effects are very high at the piston head and the temperature drops to 50 degrees Celsius at the piston edge (the piston skirt is the side part of the piston that contacts the piston bell). By the time temperature effects reach CR, they continue to decrease, which is why temperature effects are neglected.

Connecting rods operating in internal combustion engines are subjected to high cyclic loads consisting of dynamic tensile and compressive loads. It must be capable of transmitting axial tension and compression loads, as well as withstanding bending stresses generated by push and pull on the piston and by the centrifugal force of the rotating crankshaft.

A computer-aided engineering (CAE) team at a company performs analysis of all real-world problems using many different programs by applying real-world constraints to obtain solutions. Each company is equipped with a CAE team, which performs detailed analysis of the connecting rod in each automobile company by applying combustion chamber constraints such as pressure, inertia forces and suppressing the linear motion of the connecting rod which were absolutely necessary. This team draws immediate conclusions after conducting the analysis and makes suggestions for redesign, if necessary. Once the CAE team approves the design, actual production of the part begins. The connecting rod selected in this analysis is under investigation to verify the stresses and fatigue life of the component. Furthermore, if the connecting rod fails the design requirements, a new design proposal is submitted when necessary.

Connecting rods are highly aerodynamically loaded components used to transmit power in combustion engines. Connecting rod improvement actually began in early 1983 by Webster and his team. However, every day consumers are looking for the best of the best. This is why optimization is so important especially in the automotive industry. Component optimization is the process of reducing the time to produce a stronger, lighter, and less expensive product. The design and weight of the connecting rod affects the vehicle's performance. This therefore affects the credibility of the car's manufacture. The change in structural design and materials will also result in significant increases in engine weight and performance.

Since the connecting rod is a mass-produced component, it stands to reason that optimizing the connecting rod relative to its weight or size can result in significant volume savings. It can also achieve the goal of reducing engine component weight, thus reducing inertia loads, reducing engine weight and improving engine performance and fuel economy.

The connecting rod is subjected to a complex loading condition. It is subjected to high cyclic loads of 108 to 109 cycles, which range from high compressive loads due to combustion, to high tensile loads due to inertia. Therefore, the durability of this component is crucial. Due to these factors, the connecting rod has become the subject of research in various aspects such as production technology.

3. DESIGN OF CONNECTING ROD

A connecting rod is a piece of metal that connects the crankshaft to the pistons. Forces generated by combustion in the cylinder push the pistons down and rotate the crankshaft through the rods. The rotation of the crankshaft is ultimately transferred to the motion in your wheels.

The vehicle's RPM is a measure of how many times the crankshaft completes a full revolution in one minute. At an average redline of 7,000 rpm, the crankshaft rotates 117 times per second. Since the rods have to be connected to move with the intake crankshaft, the connection points have to be something special. The job is outsourced to your connecting rod bearings (also called input bearings).

4. METHODOLOGIES

CATIA V5 software is used to create the connecting rod. Catia software is capable of developing different types of engineering, assembly, sheet metal works, etc. using different types of modules. To develop a 3D model of the connecting rod, a parts design package was used.

In ANSYS, a widely used software suite for engineering simulation and finite element analysis (FEA), the term “meshing” refers to the process of creating a discrete representation of physical geometry. This representation consists of small geometric elements called “finite elements” or “mesh elements”. Together, these elements form a mesh that covers the entire geometric shape. The goal of meshing in ANSYS is to break down complex shapes into simpler elements to facilitate accurate numerical analysis.

4.1 The ANSYS meshing process includes the following steps:

Geometry Preparation

Import the CAD model or geometry into ANSYS and prepare it for meshing. This may include cleaning up the geometry, simplifying complex features, and defining important areas or boundaries.

Meshing Setup

Specify the type of analysis you plan to perform, such as structural, thermal, or fluid analysis. Depending on the analysis type and geometry characteristics, you will select the appropriate meshing settings and preferences.

Mesh Generation

ANSYS provides various meshing methods and techniques to generate meshes. These methods include:

Automatic Tetrahedral Meshing

This method generates tetrahedral elements, which are particularly suitable for complex geometries. It is often used for general-purpose analyses.

Sweep Meshing

This method is suitable for parts with prismatic or cylindrical features, where the mesh elements are swept out along the geometric features.

Patch Conforming Meshing

When working with multiple bodies or assemblies, this method ensures that the mesh transitions smoothly across the different components.

Hexahedral Meshing

Hexahedral (brick-like) elements are used for more regular shapes and can be more computationally efficient for some simulations.

Mesh Control

ANSYS allows you to control mesh density and size in specific areas of interest, ensuring accurate representation where it matters most.

Quality Check

After generating the mesh, ANSYS performs quality checks to ensure that the mesh elements comply with the specified criteria. Poor quality elements, such as excessively distorted or too small, can have a negative impact on the simulation results.

Refinement and Improvement

Depending on the quality check and analysis requirements, you may need to refine the mesh in specific areas or adjust settings to improve the quality of the mesh.

Exporting the Mesh

Once the mesh is created and refined, it can be exported in the appropriate format for the specific analysis module you want to use (structural, fluidic, thermal, Etcetera).

An accurate and well-structured mesh is essential to obtain meaningful simulation results. The choice of meshing method, element type, and mesh refinement strategies depends on the geometry, analysis type, accuracy requirements, and available computational resources. ANSYS offers a variety of tools and options to ensure effective meshing for a variety of engineering simulations.

5. MESH

Any continuous object has infinite degrees of freedom, and it is not possible to solve the problem with this format. The finite element method reduces the degrees of freedom from infinite to finite with the help of differentiation or meshing (nodes and elements). So, in ANSYS, the following are the basic methods used for linking. The purpose of this analysis is to obtain an accurate output solution. In this thesis, it is designed to accurately eliminate stress and fatigue charts. The relationship between input value and output values is understood using network sensitivity analysis. The output results were studied for different input element sizes from 8mm to 2mm (element size).

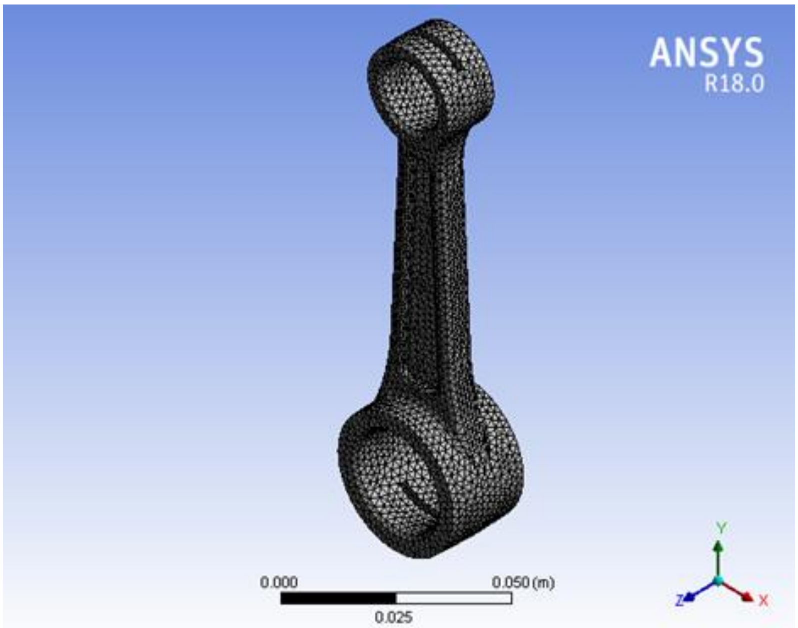

Figure 1 Mesh Generation

6. RESULTS AND DISCUSSION

CATIA V5 software is used to create the connecting rod. Catia software is capable of developing different types of engineering, assembly, sheet metal works, etc. using different types of modules. To develop a 3D model of the connecting rod, a parts design package was used. This section contains static analysis of carbon steel plates. In this study, 38,217 nodes and 6,582 network elements were selected. A node is an intersection of elements.

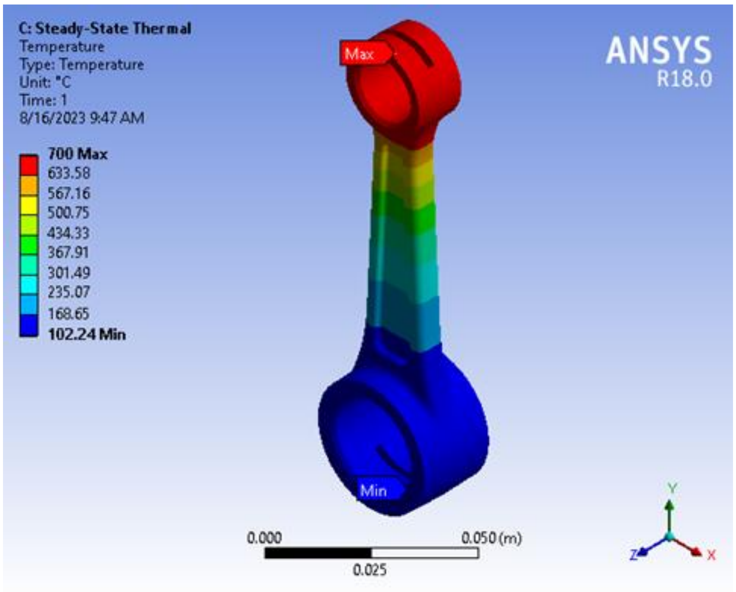

Figure 2 Temperature Distributions (Maximum 700 °C)

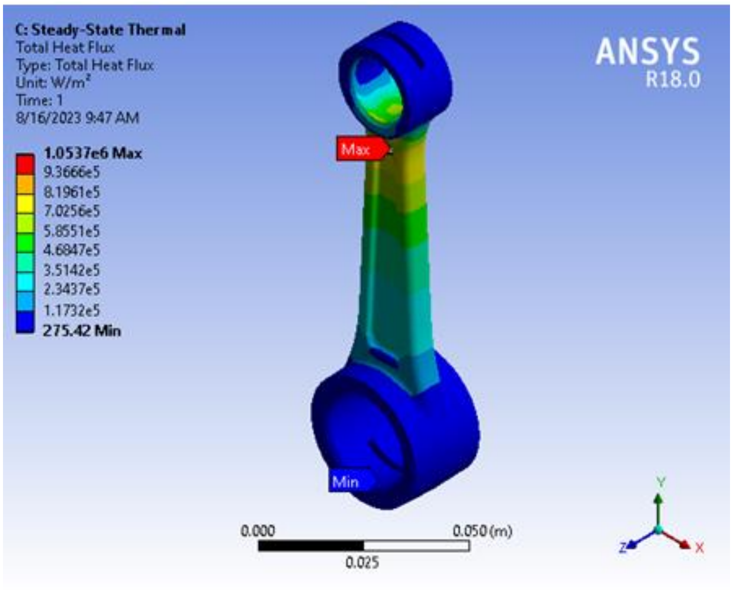

Figure 3 Total Heat Flux (Maximum 1.0537 X 10^6 W/m^2)

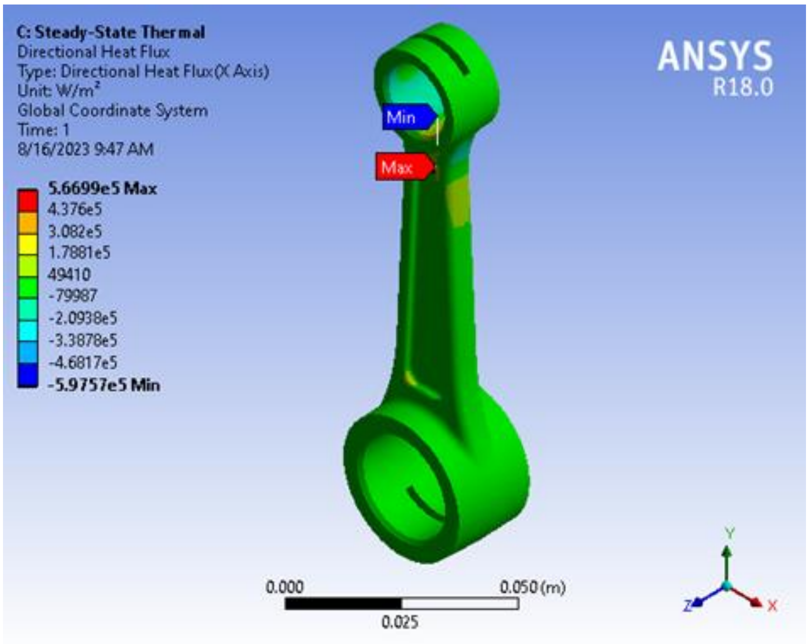

Figure 4 Directional Heat Flux (Maximum 5.6699 X 10^5 W/m^2)

Directional heat flux is relevant in cases where the properties of the material or the heat transfer mechanism itself are anisotropic, meaning they vary with direction. For example, in composite materials with different thermal conductivities along different axes, the heat transfer rate may vary depending on the orientation of the material. In these cases, understanding the direction of heat flux is essential to accurately predict temperature distribution and design efficient thermal systems.

Directional heat flux is commonly used in fields such as heat transfer analysis, materials science, and engineering design, where it is important to consider directional variations in heat transfer for accurate modeling and analysis.

7. CONCLUSIONS

Through the finite element analysis method and with the help of ANSYS software, it is able to analyze different vehicle components from various aspects such as fatigue thus saving time and cost. The way loadings were determined was effective in the results achieved. Therefore, it should fit as closely as possible to real conditions. According to this work, we change materials with different temperatures into the busbar, perform the analysis on the busbar, and compare the heat flow of the two materials at different temperatures. From the above result, it is concluded that carbon steel is better than aluminum alloy. Figures 2 to 4 show the temperature distribution (maximum 700 °C), total heat flux (maximum 1.0537 X 10^6 W/m^2) and directional heat flux (maximum 5.6699 X 10^5 W/m^2), respectively.

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