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Stress and Factor of Safety for Connecting Rod using Ansys

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Abstract: The primary link of an IC engine is a connecting rod. Its position is in-between the crankshaft and the piston whose key function is to convert the piston motion which is reciprocating in nature into rotary motion of the crank by transmitting the piston thrust to the crankshaft. This has entailed performing a detailed load analysis. In this paper, connecting rod's finite element analysis was done using Finite Element techniques. So firstly by using the schematic diagram the solid model of the connecting rod was created using Solid works software. Then using the Ansys R17.1 software the meshing was done and then the Finite element analysis is done to find the Equivalent (Von-Mises) stresses and the Factor of Safety under the loading conditions. Structural Steel is the material which is used for connecting rod and the loading conditions are assumed to be static. In Equivalent (Von-Mises) stress test maximum stress is found to be 1.504x108 Pa and the minimum factor of safety is 1.20765 for the connecting rod.

Index Terms: Disaster Relief, Convergent Communication Networks, Evolutionary Ad hoc Communication, Cloud based Disaster Communication

I. INTRODUCTION

The Connecting Rod is an in-between member of the piston and the crankshaft [7]. It is extensively used in an array of car engines. The primary function of the connecting rod is to convert the reciprocating motion of the piston into the rotational motion of the crankshaft by transmitting the thrust of the piston to the crankshaft [8]. They have a wide range of engines applications such as in V-engine, radial engines, line engines, opposed-piston engines and opposed cylinder engines [3]. Techniques utilized for making vehicle engines connecting rods (C/rods) are by casting, powder forging and forging methods. Forging method is the most commonly used technique, as this technique gives superior mechanical properties to the connecting rods [9]. The con-rods made by PF(Powder Forged) method has major advantages as compared to the drop forged products, as it leads to superior weight/tolerance control and reduced machining operations and hence also the machining costs [10]. Usually, several die-forging stages are used to make forged connecting rods.

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Before the geometry fabrication of the connecting rod by the die-forging method, the material received has to be pre-formed by cross wedge rolling or stretch rolling process [11]. In the contemporary automotive internal combustion engine, steel is used for the production of the connecting rods for the production engines. But for higher performance of engines made up of cast iron they can be made up of aluminium or titanium which has its application in motor scooters [2]. The flash less forging process is difficult to perform than that of the conventional closed die forging with flash. But Flash less forging offers the opportunity of producing aluminium composite connecting rods at vying costs. [12]. Fracture splitting is a mechanical method in which the crank end is fractured by splitting with both notches as the starting point of the crank end. There's no need to use processes such as abrasive finishing and also parts for positioning, such as dowels, reamer bolts or inserted pins as the uneven surface with fracture splitting connecting rod can decrease the shear stresses. After being fractured both the surfaces can be easily positioned again and assembled again as low ductile steel is used whose fractured surface shows a cleavage surface [9]. Compared to the conventional method, this technique has greater advantages. It can decrease tools investment, save energy, reduce equipment and manufacturing procedures. Hence, the overall cost of production is also significantly reduced. Additionally, this technique can also improve bearing capability and product quality and it provides a high accuracy, high quality and low-cost path for manufacturing of the C/rods [13]. There are three main parts of the connecting rod. The big end, the centre shank and the small end. The big end is the crank end, the small end is the piston pin end, and the centre shank has the shape of I-cross section. It is a pin jointed strut and in which more concentration of weight lies towards the crank end by which the location of the Centre of Gravity (CG) point of connecting rod lies more towards the big end [5]. Designing of the connecting rod is a very complex process as the engine has to work in varying complicated conditions and both pressure as well as inertia act as loads on the rod mechanism [8]. The connecting rod is in under immense pressure due to the reciprocating motion of the piston, by being compressed and stretching with each rotation the load on the rod increases to the third power with the increase engine speed [4]. In operation combination of both bending and axial stresses acts on the connecting rod. The axial stresses are generated due to the pressure of the gas (compressive only) in the cylinder and the inertia force arises due to the reciprocating action (both compressive and tensile), whereas the bending stresses are a cause of the centrifugal effects [1].

Usually, for high-speed engines, I-section is used and for low-speed engines, a circular section is preferred. It is subjected to a complex state of loading and it undergoes cyclic loads which are higher and range from higher tensile loads due to inertia and higher compressive loads due to combustion and of the order of 10^8 to 10^9 cycles. Therefore, this component durability is of critical importance [6].

I. Connecting Rod Design

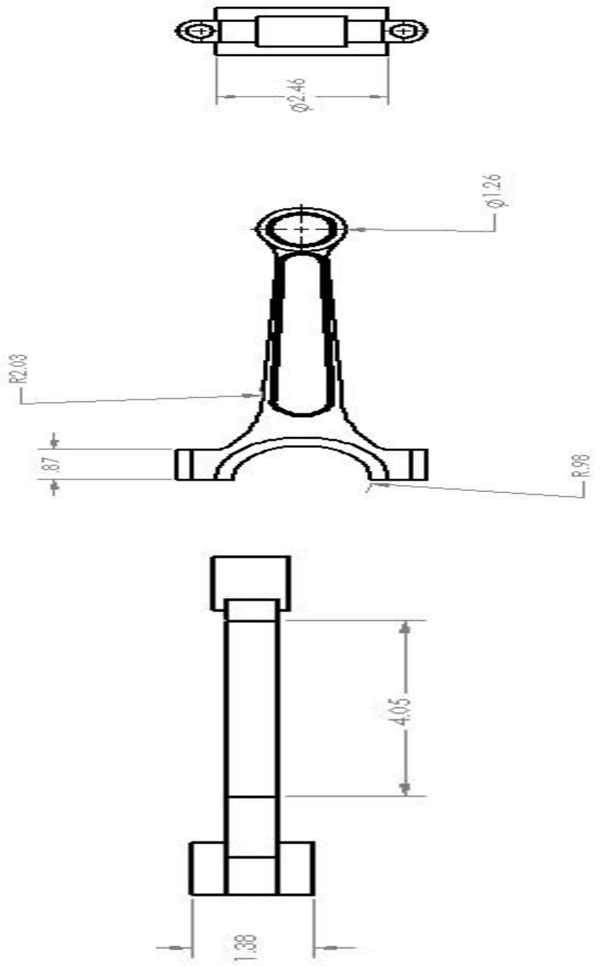

Fig 1: Drawing of Connecting Rod

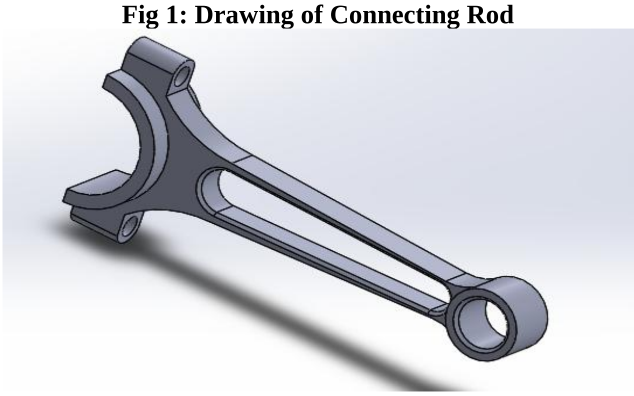

Fig 2: Solid Model of Connecting Rod

The schematic diagram of the connecting rod is shown in fig 1.The solid model of the connecting rod was developed in Solid works software and is shown in fig 2. The solid model was then imported in ANSYS R17.1 software, which is used for the analysis of the connecting rod. The dimensions of the connecting rod is Length of the connecting rod = 183 mm, Outer Diameter of the Big end/Crank end= 62.54 mm, Inner Diameter of the Big end/Crank end= 50 mm, Outer Diameter of the Small end/Piston end= 32 mm and Inner Diameter of the Big end/Crank end= 22 mm. The material selected for the connecting rod is Structural Steel. The properties of the material are as follows, density 7850 kg/m3, compressive yield strength $2.5X10^8$ Pa, tensile ultimate strength $4.6X10^8$ Pa, young's modulus $2X10^{11}$ Pa, Poisson's ratio 0.3, bulk modulus $1.6667X10^{11}$Pa, and shear modulus $7.6923X10^{10}$ Pa. The connecting rod has volume of $6.1445X10^{-4}$ m³ and the mass is 0.48234 Kg.

The next step in modelling is to create the meshing of the created model. The mesh model of the connecting rod is shown in the fig 3. The parameters which are used for the connecting rod are Number of Nodes= 14082 and Number of Elements= 7395.

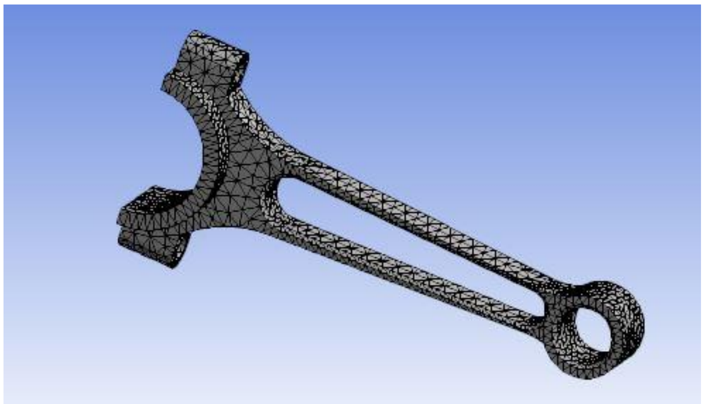

Fig 3: Mesh Model of Connecting Rod

II. RESULT AND DISCUSSION

Equivalent (Von-Mises) Stress Analysis

The von-Mises principle says that for a material under load, if the von-Mises stress is equal or greater than the yield limit under simple tension and for the same material, then the material will yield and which is also easy to determine experimentally. Its value is used to determine the yielding and fracture of a given material. It is part of the maximum equivalent stress failure theory, and it works really well for ductile materials. Hence, it is always used for predicting failures of components made using common engineering materials like steel. It is often used in design as it permits any random three-dimensional stress state to be produced as a single positive stress value. Von misses Stress for carbon steel was observed as 49.567. Von misses stress of both aluminium 360 and aluminium boron carbide was observed as 43.925. The percentage stress reduction is same for both aluminium boron carbide and Aluminium but is different for carbon steel [2]. For the material C-70 Steel, when the analytical result is compared with the numerical result, the maximum value of the equivalent (von-misses) stress was found to be 197.41 MPa among all the loading conditions and when the big end of the connecting rod is in tension. This stress was found to be less than the yield strength of the material. [3]. the minimum value of equivalent stress for forged steel is 38.298 MPA and the maximum value of equivalent stress for forged steel is 4.0317e-9. When the equivalent stress test was performed in ANSYS, then the values of stress came to be the same for both the materials [4].

For the finite element analysis 3.15 MPA of pressure and Cast Iron as a material is used. The Maximum Von misses stress was found to be 91.593 MPA. The minimum Von-misses stress was found to be 1.06e-4 MPA. The stress generated during the analysis in ANSYS software is less than the allowable limit of stress of the material. So the model which is presented here is considered to be safe design under the given loading conditions. From the static analysis in ANSYS, the maximum stress in the connecting rod is found at the small/piston end [6].

During the analysis of the connecting rod, the static loading conditions are to be assumed. The Minimum Equivalent (Von-Mises) Stress is found out to be 48331 Pa which is generated at the big end aka piston end and as well as the small end aka crank end. The Maximum value is found out to be 1.504×10^{8} Pa which is generated at the intersection of the small end and the I-section of the connecting rod. At the centre of the I-section it is observed that the minimum stress is generated but as we move away from the centre the stress is increased significantly and reaches the maximum at the inner face of the I-section near the intersection of small end and I-section which is shown in fig 4. Due to the loading conditions, the connecting rod gets deformed at more stressed regions and the corresponding value for maximum deformation generated is 3.8892×10^{-3} m.

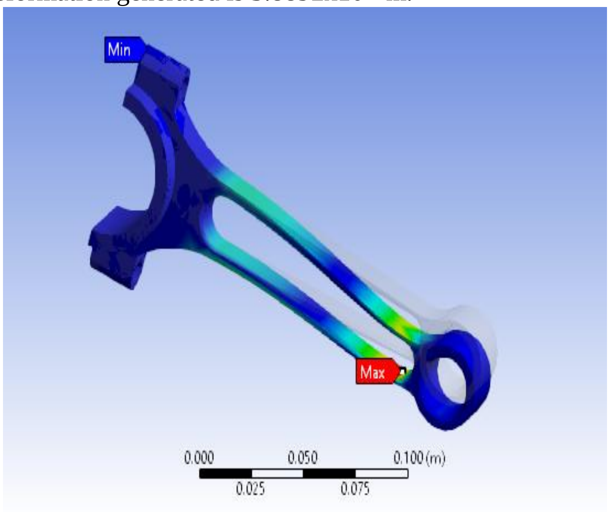

Fig 4. Equivalent (Von-Mises) Stress of the Connecting Rod

Factor of Safety Analysis

Factors of safety (FoS) is the ratio of the failure stress to the allowable stress, and the value of the allowable stress is used in design for determining the dimensions of the component. Safety is an essential aspect of research. The final product must be safe for the people who are involved in the manufacturing of the product and also in any way the final product must not put the user in any danger whichever equipment, processes and materials are used. Models and prototypes testing and evaluating is also important as these will inform us about safety issues and will lead to the modifications of the actual design. That is why the Safety Factor is the most important factor that must be included during designing and higher the factor of safety, safer is the component and higher is the cost. For example, if a component has a factor of safety of 6, it means that the component can carry the load 6 times the actual load for which it was designed. And eventually, its cost will also increase. For forged steel, a load of 4319 N was applied and the Minimum safety factor was observed to be 1.13 and the maximum safety factor was observed as 15 and for the load of 21598 N, the Minimum safety factor was observed to be 0.23 and the maximum safety factor was observed as 15 [1]. The factor of safety of three different materials Carbon Steel, Aluminium 360 and Aluminium boron carbide when calculated theoretically was found to be 6 for each materials. But the working factor of safety of Carbon Steel, Aluminium 360 and Aluminium boron carbide was observed to be 8.47, 4 and 6.95 respectively. The value of factor of safety which is analysed is closer to the factor of safety which is calculated theoretically for aluminium boron carbide [2]. By using C-70 Steel the existing design is considered to be over safe but only for the static loading condition as the factor of safety was found to be 3.2 [3]. When calculated theoretically, the factor of safety was found to be 12.23 for forged steel and factor of safety (from Soderberg's) and the stiffness is increased of forged steel material when it is compared to the existing carbon steel [4]. For the material SAE 4340 Steel, using FE-safe software the fatigue life was calculated which also shows a finite life of 6.94×10^{6} cycles and the factor of safety of 0.975. Without considering the shot peening effect the part will be failing in the design stage as the safety factor which is obtained from FE-safe is less than 1. When calculated analytically the estimated life was found to be 2.53×10^{6} cycles. The shot peening reduces the surface tensile stresses of the material and makes the peak stress values within the allowable limit as the life calculated from FE-safe software was 1.2×10^{7} and showing an infinite life with a factor of safety 1.047 [5]. From the fig 5, we can observe that the maximum factor of safety is 15 for the big end of the connecting rod and as well as for some region of the small end. The minimum factor of safety is found out to be 1.20765 and is for the I-section of the connecting rod. At the centre of the I-section the factor of safety can be observed as 15 but as we move away from the centre the value of factor of safety decreases drastically to 1.20765.

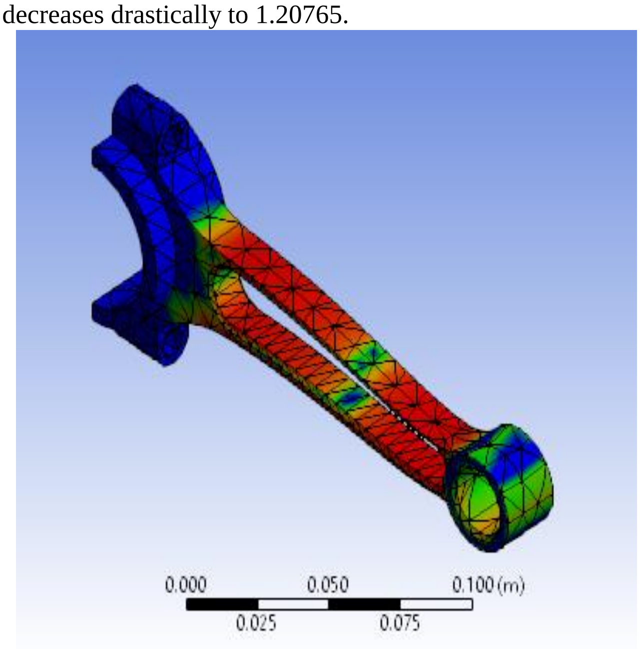

Fig 5. Factor of Safety of the Connecting Rod

III. CONCLUSION

In this manuscript connecting was designed by using solid works with structural steel material and with standard dimensions. Stress and Factor of Safety Analysis was done using Ansys R17.1 while keeping environmental temperature at 22°C. The Minimum Equivalent (Von-Mises) Stress is found out to be 48331 Pa and the Maximum value is found out to be 1.504×10^8 Pa. We can observe that the maximum factor of safety is 15 and the minimum factor of safety is found out to be 1.20765.

In Factor of Safety analysis, it is observed that the more strain is acted at the middle of the connecting rod whereas the pinion and big end is having less strain which indicates that the failure chances will be more in the middle.

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