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Fatigue Analysis of I-Section and H- Section Connecting Rod using ANSYS Workbench

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Abstract:- The connecting rod must be able to carry axial pressure/tension and bending stress brought on by the thrust and pull on the piston as well as by centrifugal force. Bending stresses are induced by eccentricity, the crankshaft, case wall deformation, and rotating mass force. connecting rod fatigue is investigated in this work. ANSYS is used to conduct the investigation. The goal of this study is to identify and analyze the connecting rod technical fault that is impacted by reversal loading during its operation life.

The results indicate that a longer connecting rod life can be expected under fully reversed loading and also identify any potential weak areas. Additionally, 10^8 load cycles were added to the permitted number when fully reversal loading was used. The findings could potentially lead to changes in the connecting rod's design, some believe.

Keywords:- *Connecting Rod, I-Section and H-Section, Connecting rod, ANSYS Workbench.*

I. INTRODUCTION

The connecting rods are commonly employed in a variety of engines to transport piston's push to crankshaft, resulting in the conversion of piston's reciprocating motion to crankshaft's rotating motion. It is made up of three parts: the crank end, the shank portion, and the pin end. To allow proper bearing installation, crank-end and pin-end pin holes are drilled. With the aid of a piston pin, one end of the connecting rod is attached to the piston. The other end, which rotates with the crankshaft, is split to fit around it. The two halves are held together by two or four bolts, depending on the size of the large end. The forces created by mass and fuel combustion act on connecting rods. Axial and bending stresses are produced by these two forces [1].

The tractor's connecting rods are generally composed of cast iron by powder metallurgy or forging. The fundamental motivation for using these technologies is to build the components as a whole and achieve great productivity at a low cost [2] while also optimizing the geometry of the connecting rod. Because the engine is designed to perform in a variety of challenging settings, the connecting rod design is intricate. The inertia force due to acceleration/retardation in a cycle, subject the connecting rod to changing pressure [4]. The fatigue analysis offered a connecting rod design [5]. The rupture caused by fatigue and a way for adjusting the connecting rod design specifications [6][7] [8]. Because fatigue is the most common cause of connecting rod failure, the used ANSYS software to perform FE analysis on the U650 Tractor connecting rod and found that the critical point under reverse loading (compressive and tensile) is 46. This value can be enhanced by lowering the stress concentration coefficient in order to improve the connecting rod's fatigue life [9].

The FE analysis was performed on the ANSYS workbench in this study, and the impacts of connecting rod design parameters were explored to increase performance under cyclic loadings. It has been discovered that lowering the stress concentration coefficient and changing certain of the connecting rod design parameters will enhance fatigue life.

II. MANUFACTURING ASPECTS OF CONNECTING ROD

Fig. 1 depicts the connecting rod production methods for conventional fracture crack able steel forging. The charts may be used to make a comparison between the procedures. Heat treatment, machining of the crank end's mating faces, and sleeve drilling are all phases in the current forged steel connecting rod production process that may be removed by using C-70 crack-able steel. After fracture splitting of C-70, an entire block of machining processes is removed. The fracture splitting process eliminates the need to saw or machine a single-piece forged connecting rod into two parts, as well as the necessity to separately forge the connecting rod's cap and body [3]. This creates a hard touch and raises the stiffness of the area [26].

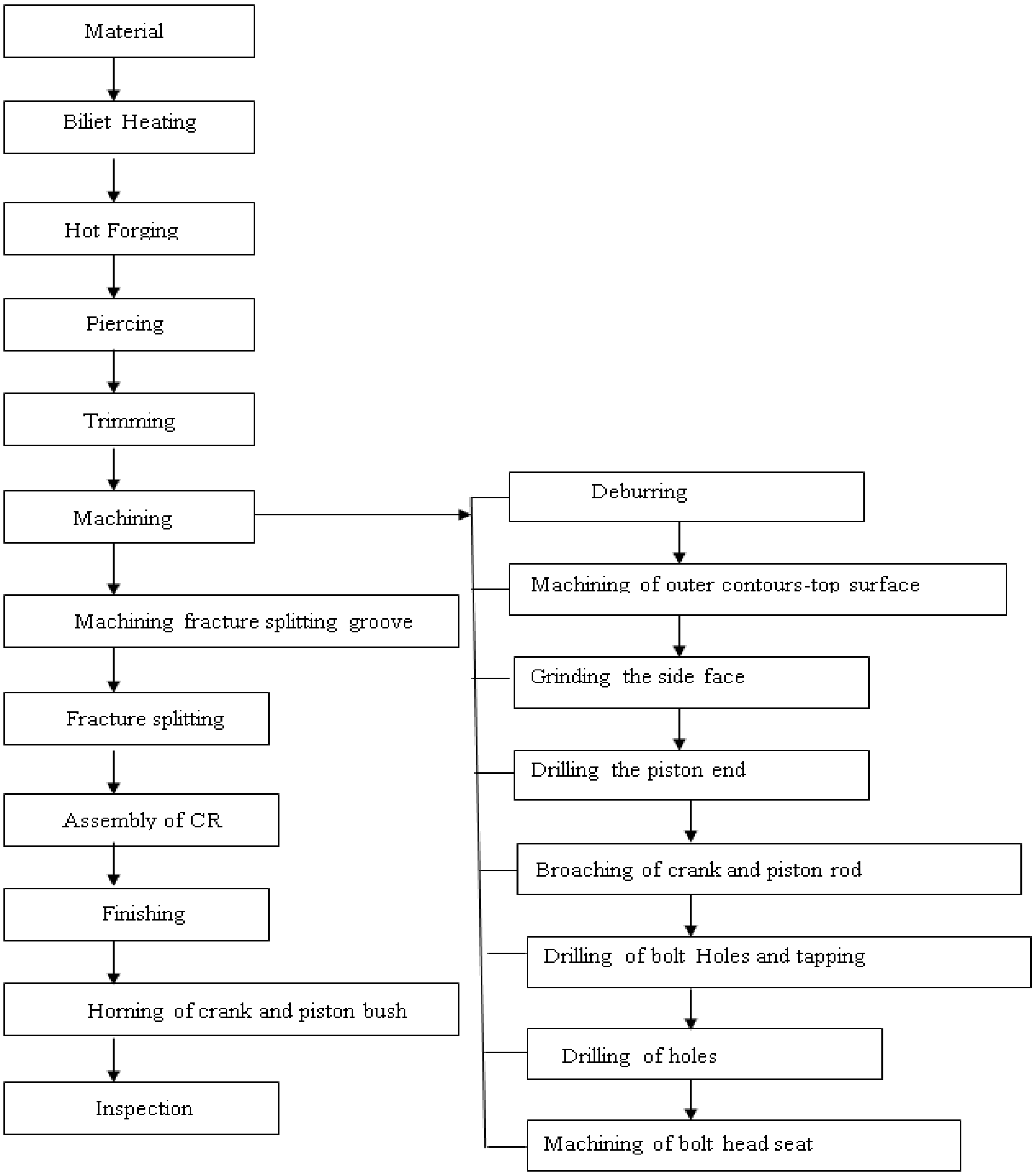

Fig. 1: Process flow diagram for producing C-70 connecting rods

The connecting rod is notched at the point where the rod and cap part ways. Laser notching, broaching, or wire cutting may all be used to create this notch. The connecting rod is broken in half by a hydraulically powered cracking cylinder that goes through the crank end bore. The only manufacturing consideration during the optimization phase was retaining the connecting rod's forgeability.

III. LITRATURE REVIEW

The fatigue life of a component in service is influenced by a variety of elements, including (i) engineering design, and (ii) construction material (iii) service conditions and environment, (iv) manufacture and inspection and (v) complicated stress cycles. Therefore, less conservative designs than those based on conventional criteria can be generated [15].

Calculating stress and strain using the Finite Element Method (FEM) is a well-established approach in fatigue analysis and estimating lifetime. Del Llano-Vizcaya et al. [16] conducted a multi-axial fatigue investigation of helical compression springs after performing stress analysis in the FE code ANSYS. Based on fatigue study, the constructed a connecting rod[17-19]. Due to reverse torque, the most common mechanism of failure was fatigue [20].

Minimum and Maximum values of octahedral shear stress were used to compute the mean and alternate components of the stress. Their activity lowered the weight of the connecting rod by about 27%. Fig.2 depicts the early and final wrist pin end designs for connecting rods [21].

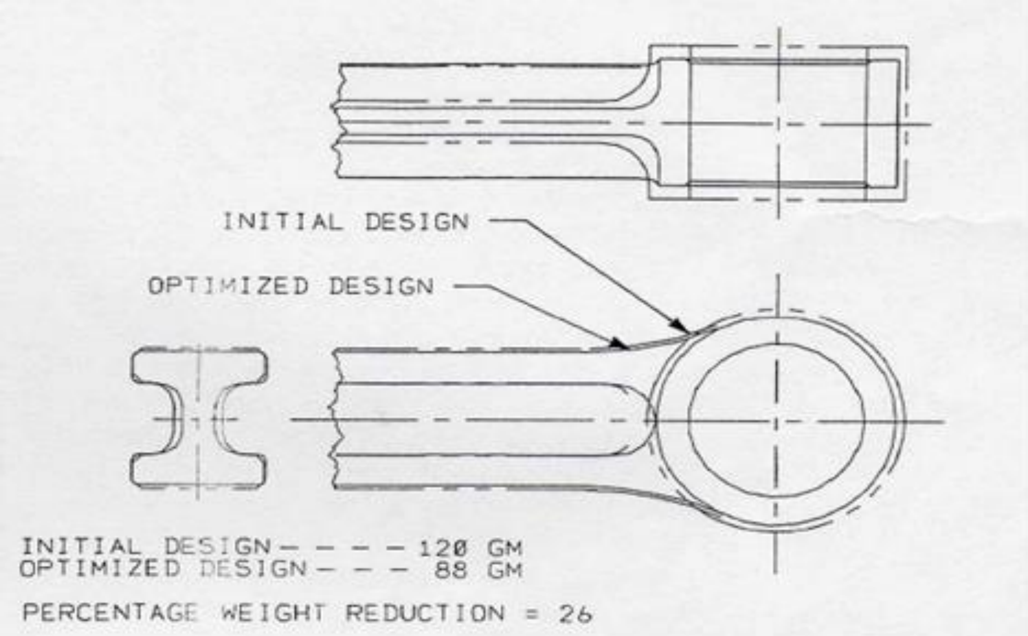

Fig. 2: Final and initial designs for the wrist pin end of a connecting rod [21]

A comprehensive FEA of the connecting rod while examining a connecting rod failure that resulted in a catastrophic engine failure. He computed the connecting rod screw threads, connecting rod threads, as well as the screw prestress. A comprehensive FEA was done that included all of the parameters stated above. The appropriateness of a new design was determined by comparing stress amplitude and the mean stress at the threads acquired from this study. Inelastic FEA was also utilised to generate a steady state scenario via load cycling [6].

Fig..3 depicts the ideal design.

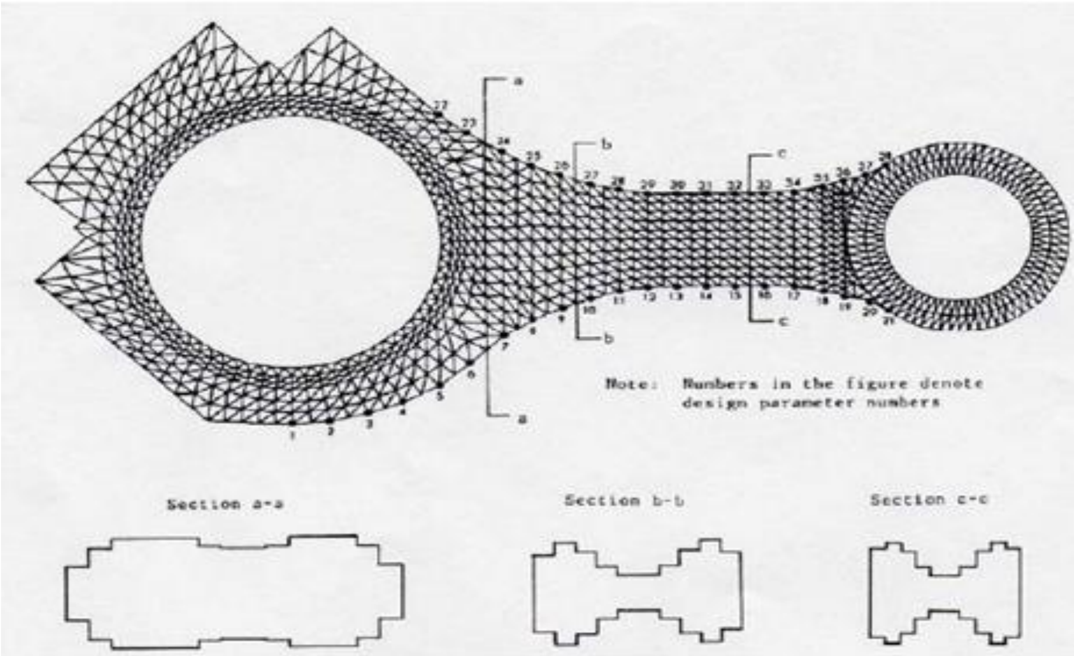

Fig. 3: The optimum design obtained [22]

This prototype, fatigue testing and experimental stress analysis were undertaken, and based on the findings, they recommended the final shape shown in Fig. 4. They estimated the permitted stress amplitude at crucial sites, taking into consideration the R-ratio.

Fig. 4: Design of a PM connecting Rod [23]

Single-cylinder diesel engines are widely employed in agricultural regions for a variety of applications, including water pumping and the operation of auxiliary farm equipment. The failure of two distinct crankshafts in these engines was investigated. To determine the cause of failure, certain characterisation investigations and fracto-graphic analyses were performed. The cranks, on the other hand, have some minor design variations, and both breakdowns occur as a result of a fatigue process [24].

The bending stress at the column centre as well as the variation of the connecting rod's stress at the bottom of the column. The data in Fig.s 5 and 6 demonstrate that the top dead centre at higher engine rpms and 360^0 crank angle are not where the highest tensile stress occurs. Additionally, it was found that the R ratio varies with engine speed and that it varies with location.

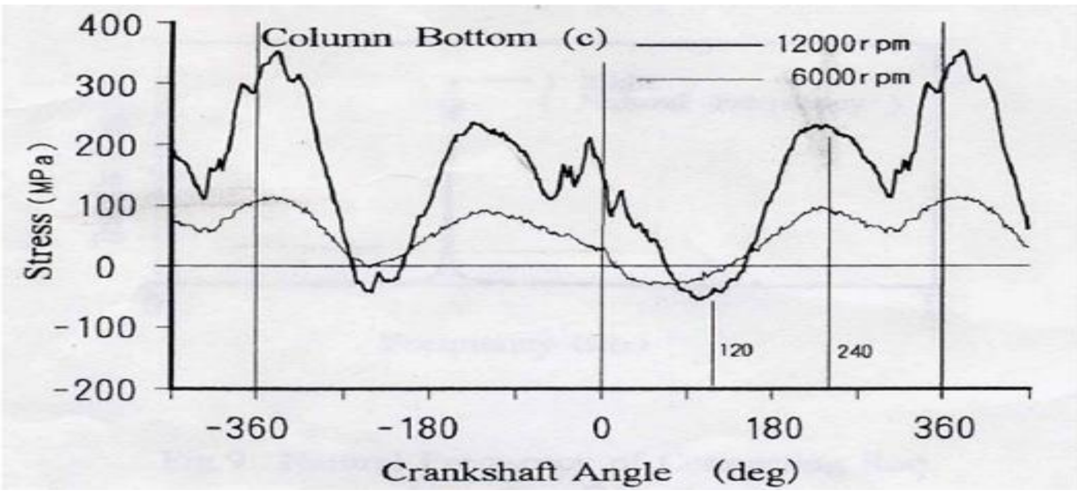

Fig. 5: Stress at the lowest of connecting rod column [27]

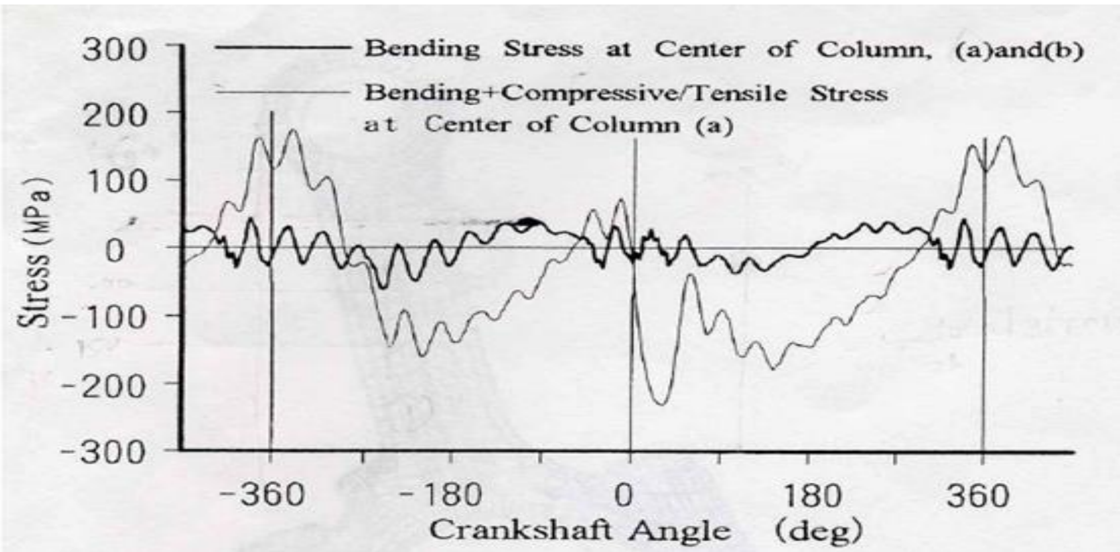

Fig. 6: Stress at the centre of the connecting rod column [27]

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IV. SCOPE AND OBJECTIVE OF THE WORK

The goal of this research was to investigate the fatigue behaviour of connecting rods by modifying a crucial dimension. The first step is to determine the proper load conditions and magnitudes. Increasing the safety factors by overestimating the loads is a no-brainer. The goal of this method is to keep as much strength as is required. Connecting rod fatigue life may be estimated using commercial software such as ANYSIS Workbench and Pro-E. According to the literature study, the connecting rod behaviour is altered by fatigue owing to cyclic loadings, and the results should be considered for additional time and cost savings, which are two very important aspects in production.

V. FATIGUE FAILURE OF CONNECTING RODINTRODUCTION OF FATIGUE FAILURE

Fatigue is a phenomenon that occurs when a material is subjected to fluctuating loading, or more accurately, cyclic stressing or straining. Similar to how humans become fatigued after doing a task repeatedly, metallic components subjected to changing loads become fatigued, resulting in early failure under certain situations.

➢ *Forms of cyclic loading*

- Steady amplitude with Proportionate loading
- Steady amplitude with Non- Proportionate loading
- Unsteady amplitude with Proportionate loading
- Unsteady amplitude with Non- Proportionate loading

➢ *Fatigue failure- mechanism*

A fatigue failure starts with a little fracture; the initial break may be so small that it is undetectable.

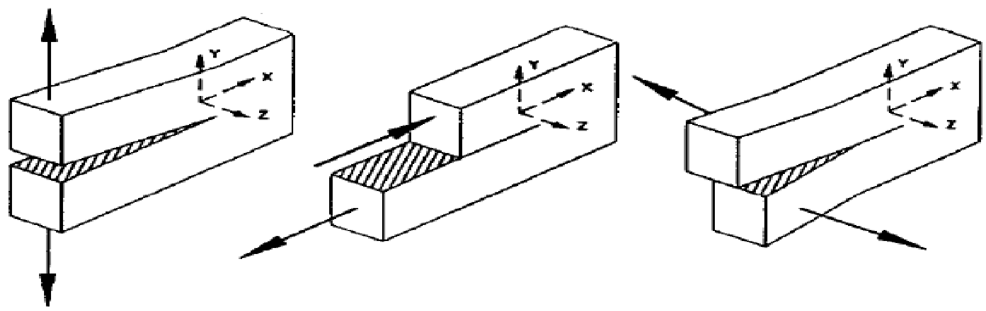

Fig. 7: The three cracking modes that fracture mechanics uses. [29]

- ***Crack Initiation:*** notches, Fillets, bolt holes, keyways, and tool marks or even scratches, which have localised stress concentrations, are probable fracture initiation zones.

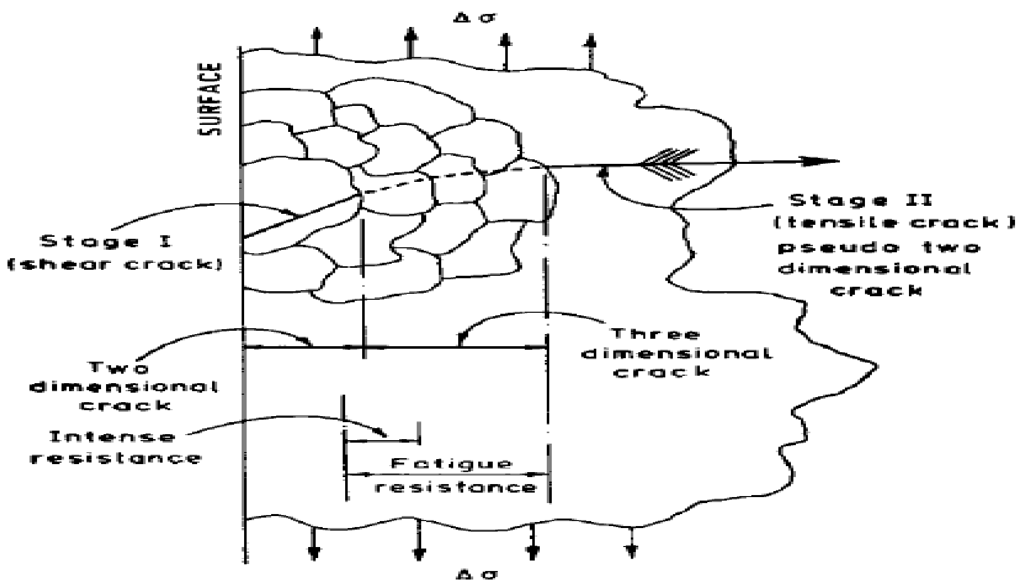

Fig. 8: The transition form of crack growth. [29]

- ***Crack propagation:*** In a fatigue test, Static Linear Elastic Fracture Mechanics gives a numerical criteria for the start of catastrophic failure. If a fracture propagates under repeated loading, the value of a will slowly grow, as will the value of K when the dynamic load is at its maximum.

Fig. 9 displays typical test findings for experiments performed at constant ΔK. Three regions are present.

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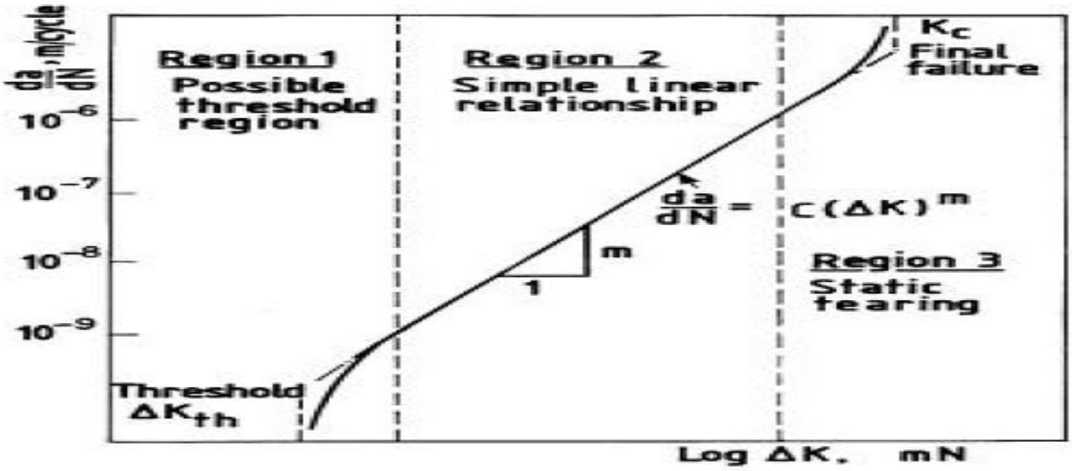

Fig. 9: Crack Propagation Rate at constant ΔK. [29]

- ***Final fracture:*** An abrupt fracture of the component occurs as the region becomes too small to continue withstanding the produced stresses.
- **Stress-Life Based Approach:** There are various available approaches for the fatigue design and components. All call for the same kinds of data. Identification of potential failure sites, load spectrum for the component or structure, strains or stresses brought on by the loads at the potential failure sites, temperature,a methodology, material behaviour, and corrosive environment [25].

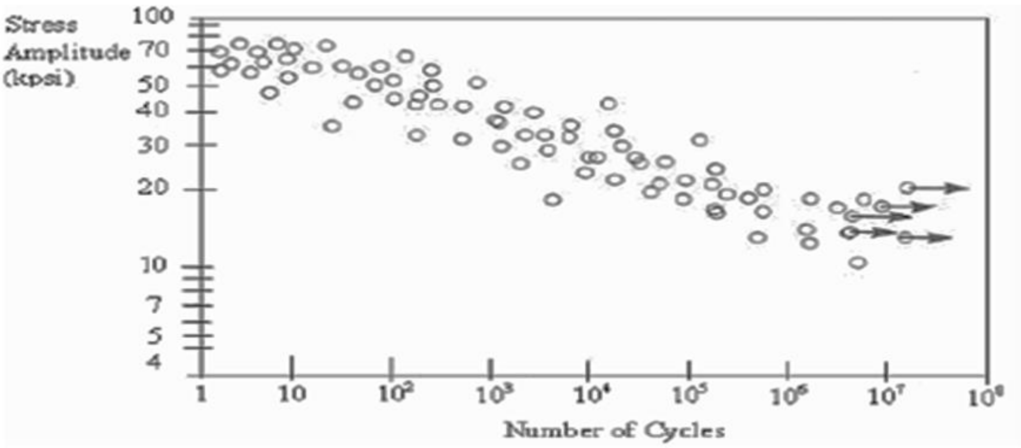

Fig. 10: A typical S-N material data [25]

- **Fatigue Design Process:** One of the observed modes of mechanical failure in real-world situations is fatigue design. for numerous constructions, such as vehicle frames, bridges, aero planes, automobile suspensions, train cars, and fatigue becomes an obvious design factor as a result.

VI. FINITE ELEMENT BASED FATIGUE DESIGN

In order to experience fatigue, a crack must first begin and expand until it reaches a crucial size, occasionally leading to separation into two or more halves. Although there are other criteria for deterioration that may apply in some cases, this applies to parts made of aluminium, steel, and iron, which are by far the most prevalent materials.3.2.1 The elements of a life estimation system in Finite Element Analysis.

For a long time, it was believed that the fatigue analysis procedure followed the logic shown in Fig.10.

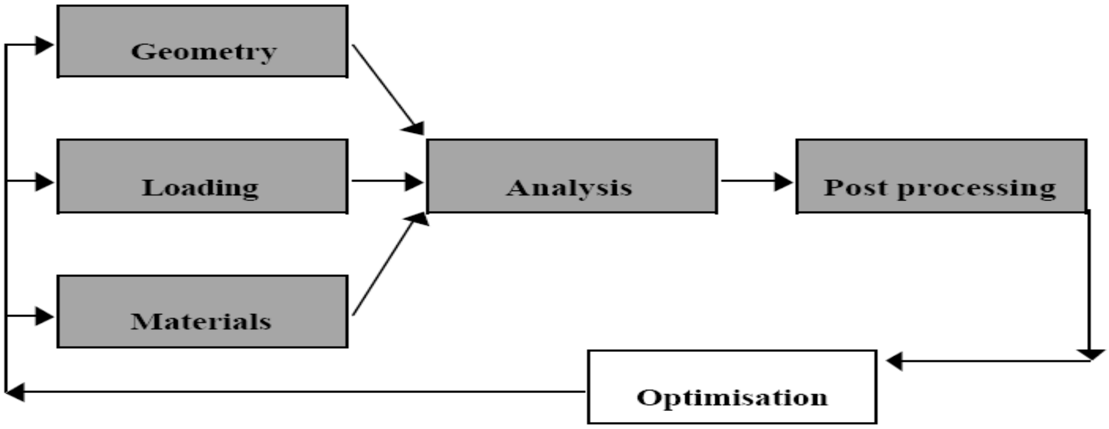

Fig. 11: A Conventional View of Fatigue Analysis Process [29]

A. An overview of the Finite Element Analysis based fatigue environment

An overview of the finite element analysis -based fatigue environment is shown in fig. 11.

B. Problem formulation

The phenomenon of fatigue failure is complicated. the best hypothesis for explaining the fatigue phenomena [10].

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_F}{E}(2N)^a + \varepsilon_F(2N)^b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, N is the fatigue longevity, and ε_F and σ_F are the coefficients of elasticity and fatigue strength, respectively, and $\Delta\varepsilon$ is the total stress.

VII. FE MODELING OF THE CONNECTING ROD

This chapter addresses the creation, simplifications, and correctness of the connecting rod models utilized in Finite Element Analysis.

A. Finite element modelling of I section connecting rod

This section discusses the production, simplifications, and correctness of the I section connecting rod modelling used for Finite Element Analysis.

B. Modeling of I section connecting rod

A collection of uniform guidelines for computer and the mathematical modelling of three-dimensional bodies are known as modelling or solid modelling. Emphasis on physical authenticity in solid modelling sets it apart from comparable fields like computer and geometric modelling graphics.

Fig. 12 displays the connecting rod's geometrical specifications. The Finite Element the analysis of the connecting rod for both I and H cross-sections used the material parameters of the connecting rod listed in Table 1.

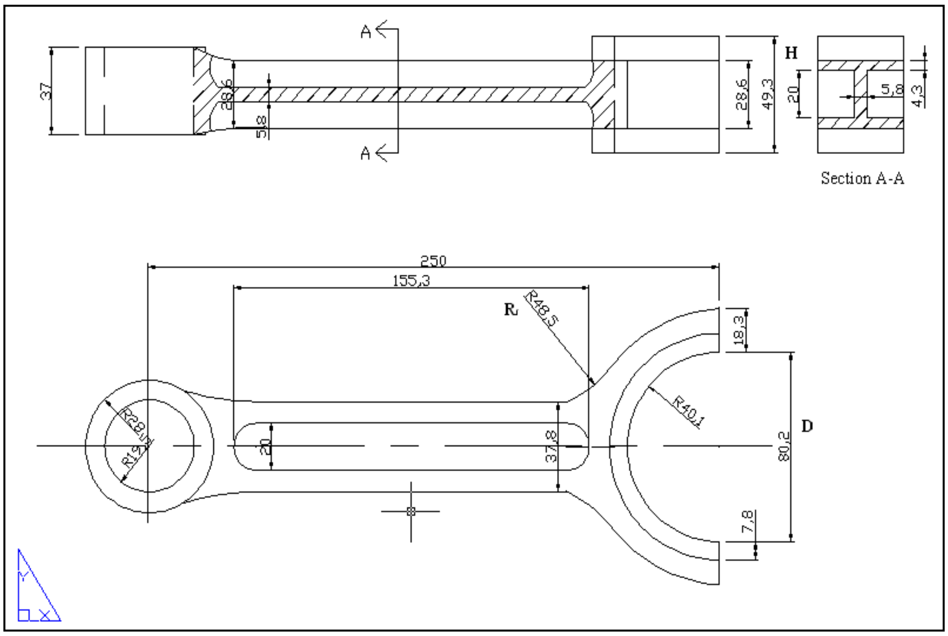

Fig. 12: The I section connecting rod's geometry

Table 1: The connecting rod properties used for Finite Element Analysis

Input Parameters	Values
Yield Strength	483 MPa
Shear Modulus	79 GPa
Brinell Strength	229-269 HB
Tensional strength	621 MPa
Young's Modulus	207 GPa
Correction Coefficient	0.8
Poison Ratio	0.3
Connecting Rod Material	C-70 Alloy steel
Density	7.7 Mg/m^3

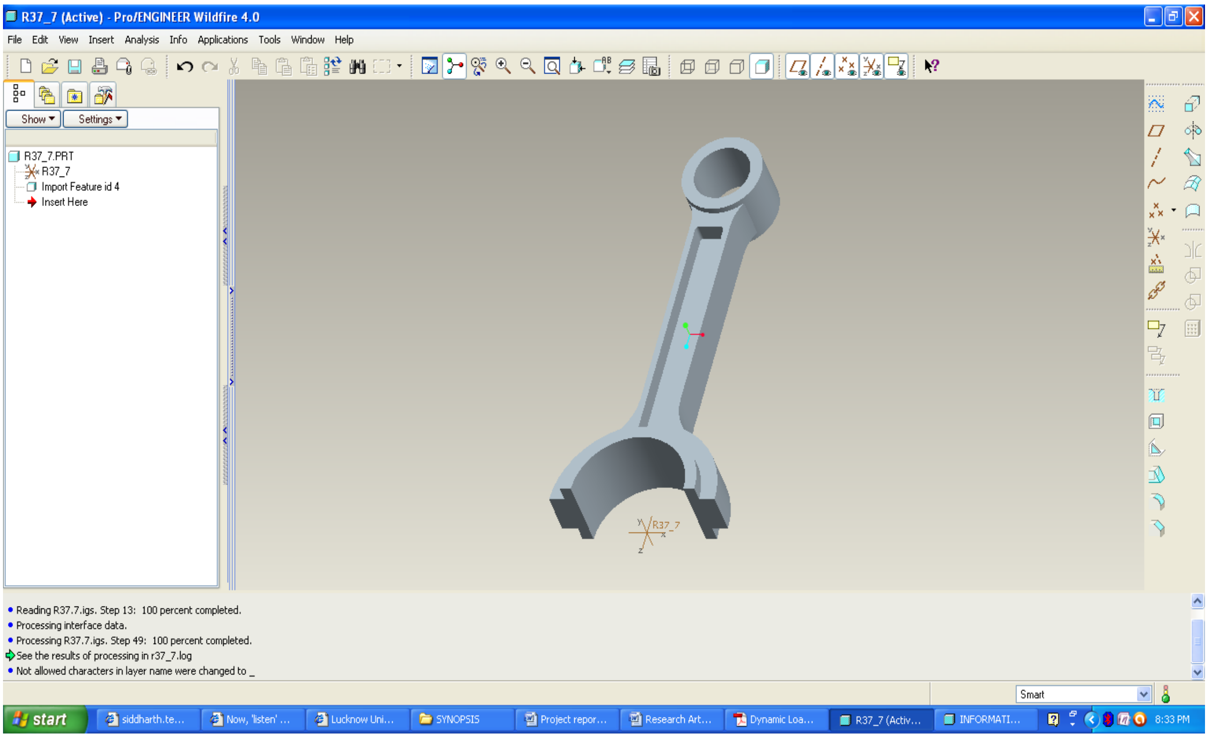

Fig. 13: I section Connecting Rod Geometrical Model

- **Mesh generation of I section:** Mesh generation is the process of producing a polygonal or polyhedral mesh that closely reflects a geometric domain. the phrase "grid generation" is frequently used synonymously.

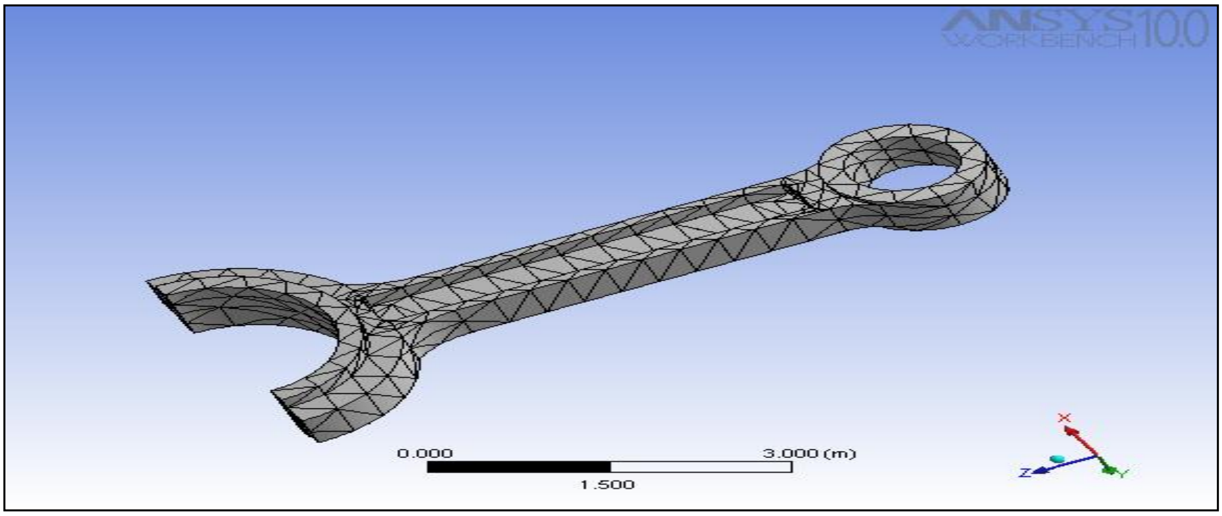

Fig. 14: I section Connecting Rod Meshing Model

C. Boundary conditions for I section

➢ *Loading*

The big ends are considered to be under tensile loading, as shown in Fig. 13, the contact surface area, as shown in Fig. 14. Based on the findings of an experiment, Webster et al. 1983[38]. On the contact surface, the normal force is determined by:

$$F = F_o \cos\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

The total resultant load is given by the relation, when the load is distributed at an angle of 180°.

$$F_t = \int_{-\pi/2}^{\pi/2} F_o(\cos^2\theta) rt d\theta = F_o rt\pi/2 \ldots\ldots\ldots(3.2)$$

Fig. 15 describes θ *and* r, t. The normal Force constant F_o is,

$$F_o = F_t/rt\pi/2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.3)$$

Four finite element models were examined in this study. Both compressive and tensile loads underwent FEA.

D. FE Modeling of H Section Connecting Rod

➢ *Modeling of H section connecting rod*

Fig. 16 displays the H section connecting rod's geometrical dimensions. The Finite Element analysis of the connecting rod for H section used the material parameters of the connecting rod as indicated in Table 1.

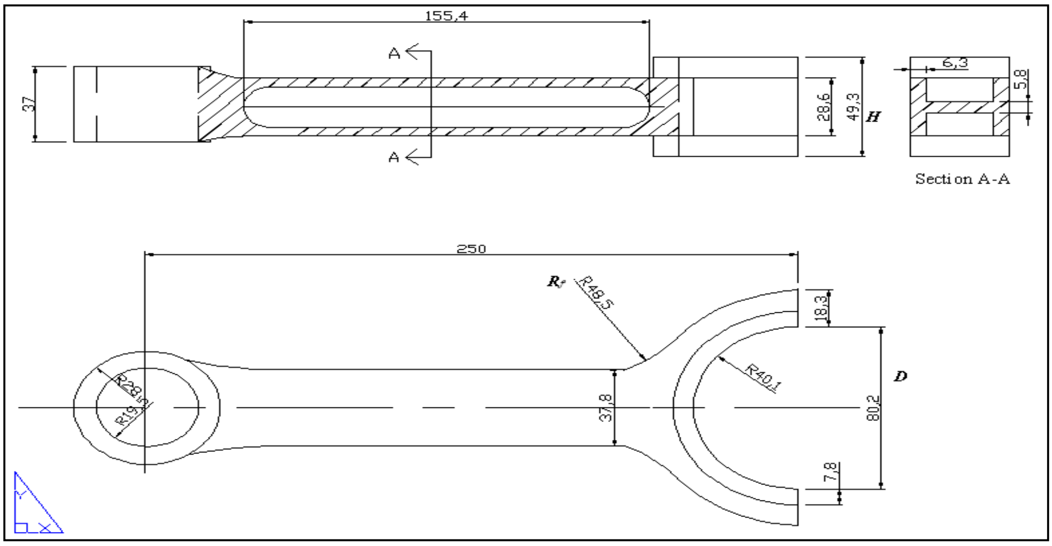

Fig. 15: The H section connecting rod's geometry [9]

➢ *Mesh generation of H section*

The FE analysis is performed using pro/e and ansys workbench software. using pro/e software, a 3d model of the h section connecting rod was created.

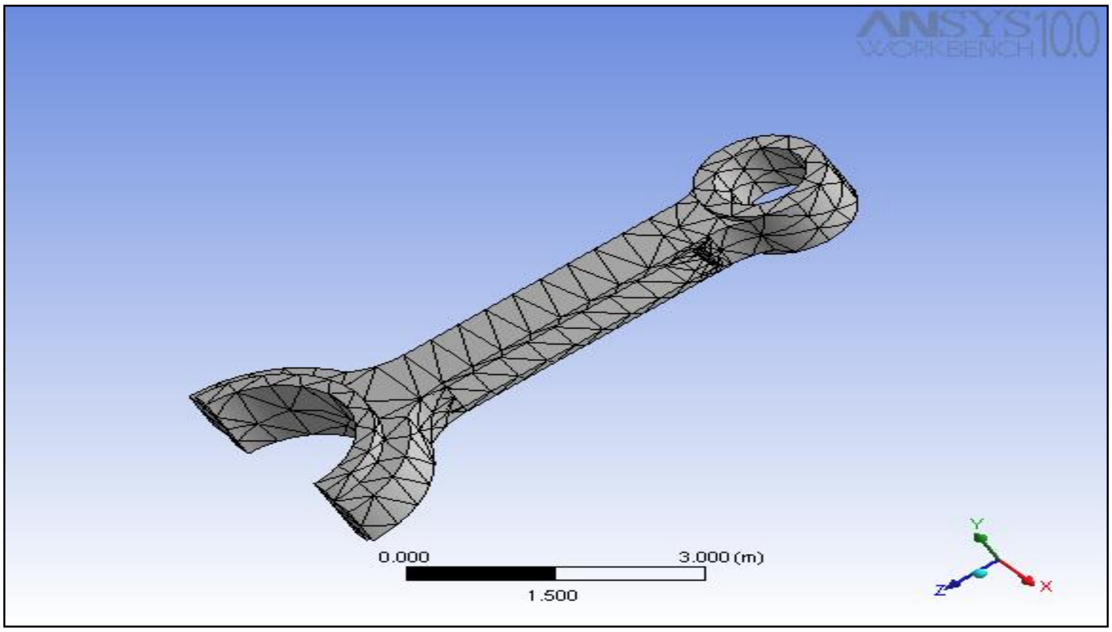

Fig. 16: H section Connecting Rod Geometrical Model

➢ *Boundary conditions of H section*

- Loading

The big ends are considered to be under tensile tension, as shown in Fig. 17, with a sinusoidal distributed loading throughout the contact surface area. Based on the findings of an experiment (Webster et al. 1983) [38]. On the contact surface, the normal force is determined by:

$$F = F_o \cos\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The total resultant load is given by when the load is distributed over an angle of 180°.

$$F_t = \int_{-\pi/2}^{\pi/2} F_o(\cos^2\theta) rtd\theta = F_o rt\pi/2 \ldots\ldots\ldots(2)$$

Fig. 18 describes θ *and* r, t. The normal Force constant F_o is,

$$F_o = F_t/rt\pi/2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

VIII. VALIDATION OF FINITE ELEMENT ANALYSIS

M. Omid et al. [9] determine the characteristics of the substance employed for linear elastic finite element analysis. The stresses in the shank region halfway down the connecting rod's length were checked under two scenarios of compressive load application in order to validate the Finite Element Analysis model. The big end was first subjected to a 9500 N evenly distributed load while being restrained at the tiny end.

In this observation, the connecting rod's FE analysis was done using the ANSYS workbench software and validated against results obtained by Omid et al. [25] and displayed in Table 2.

Table 2: Validation of Finite Element Analysis of the connecting rod

Stresses	ANSYS Workbench	ANSYS 10
Maximum Stress in Compression (MPa)	23.33	24.00
Maximum Stress in Tension (MPa)	29.94	29.40

IX. RESULTS AND DISCUSSION

Near the connecting rod's big end, the I section connecting rod's maximum stress developed is 33.56 MPa. Near the connecting rod's big end, the H section connecting rod's maximum stress is 47.136 MPa. Enhancing the force cycles to 10^6 constantly results in the calculation of the stresses corresponding to the critical points.

X. RESULTS OF I SECTION CONNECTING ROD

Fig. 17 displays the S-N curve for an I section connecting rod based on the results of a fatigue test for the particular alloy, the parameters of which are listed in Table 3. The basic critical dimensions of the connecting rod I section as shown in Fig. 18 are *D=80.20mm, H= 49.30mm and R_f = 485mm.*

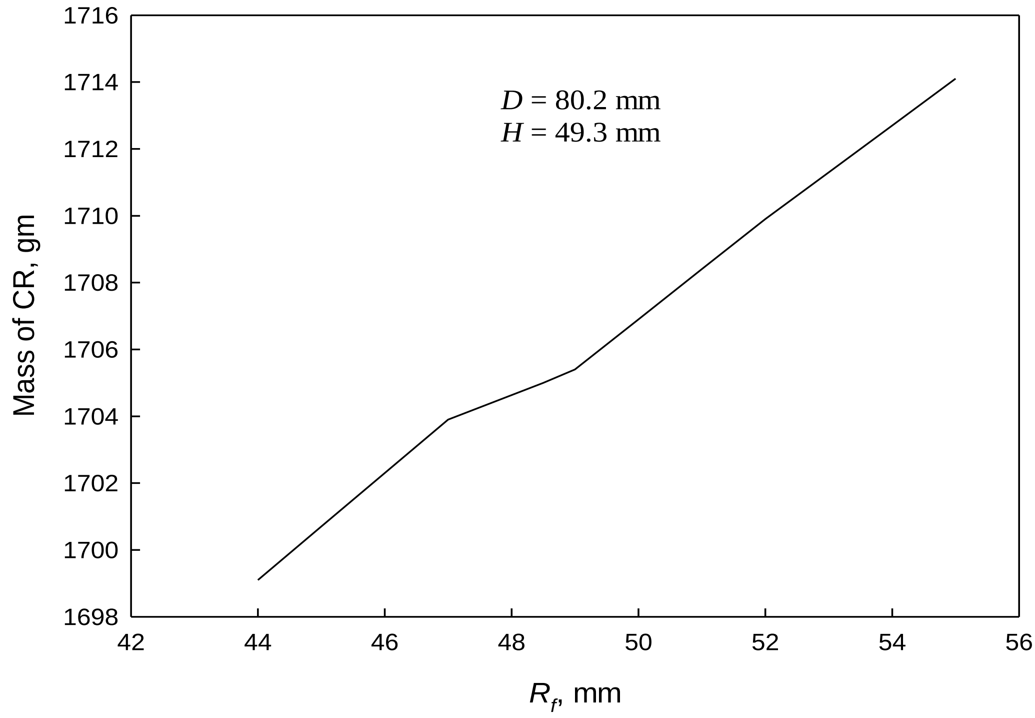

Fig. 17: The influence of the radius of rounding near the connecting rod on the weight of the connecting rod and the cross section

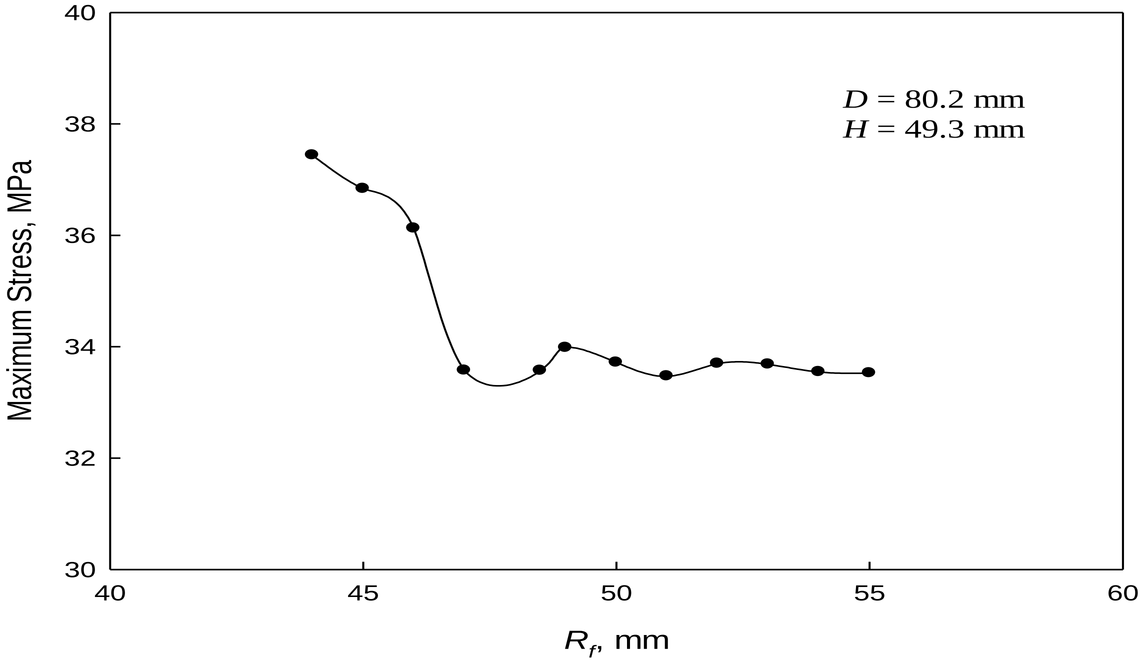

Fig. 18: Largest stresses produced at the crucial point during cyclic load and the impact of large end fillet radius

Keeping all other parameters constant, Fig. 19 illustrates the impact of big end D on connecting rod mass. The connecting rod mass is found to be inversely proportional to the connecting rod inside diameter and decreases with increasing D as expected. The impact of huge end D on the (σ_{max}) arising at the crucial point during cyclic loading is depicted in Fig. 4.4.

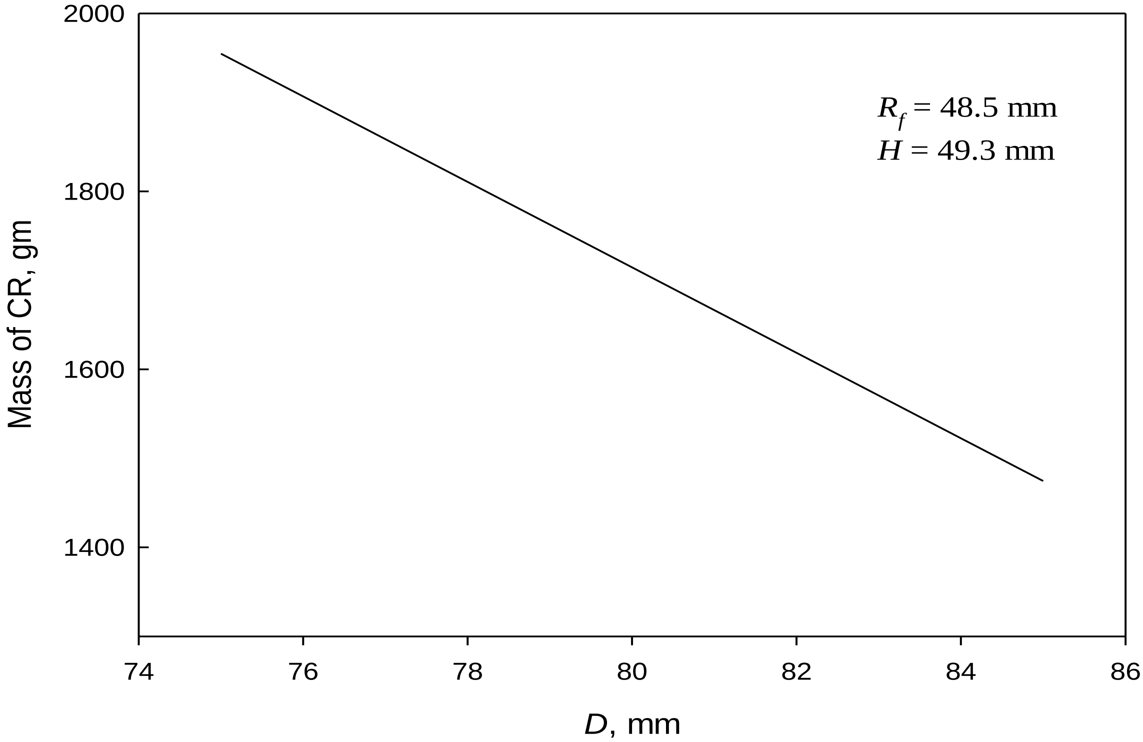

Fig. 19: The effect of big end D on the mass of I section connecting rod

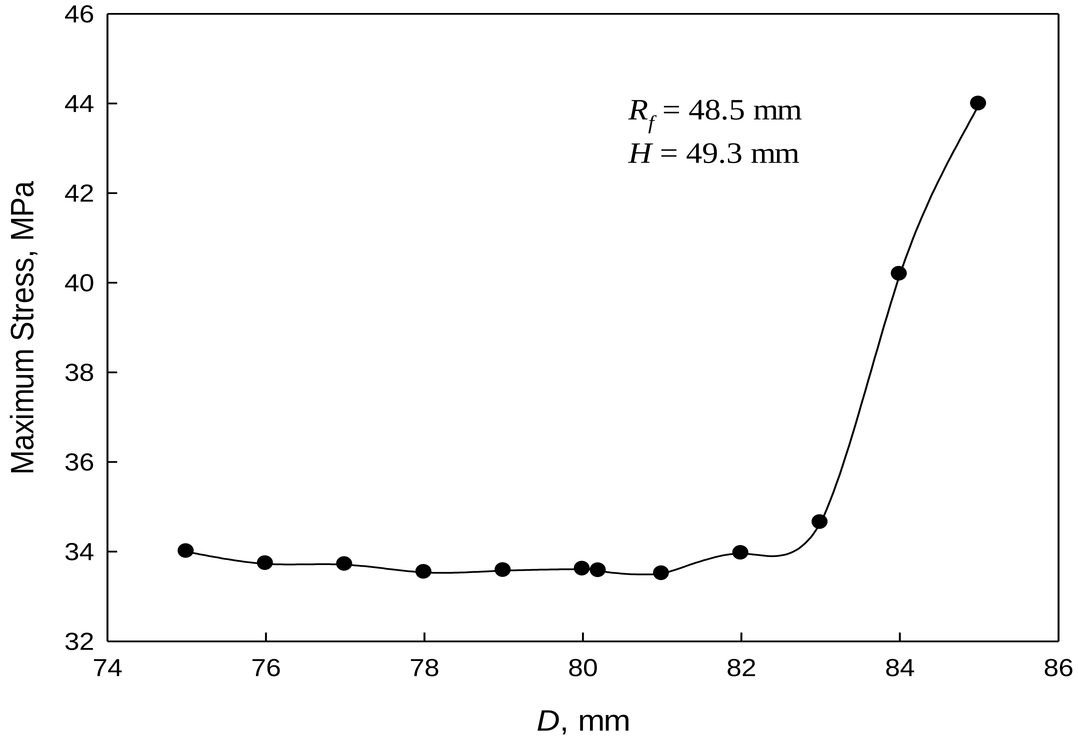

Fig. 20: The effect of big end "D" on the (σ_{max}) generated at the critical point under the cyclic loading

Keeping all other dimensions constant, Fig. 22 illustrates the impact of the large end's height (H) on the mass of the connecting rod. Keeping all other dimensions constant, Fig. 23 illustrates how the height (H) of the big end affects the highest stresses produced at the crucial point.

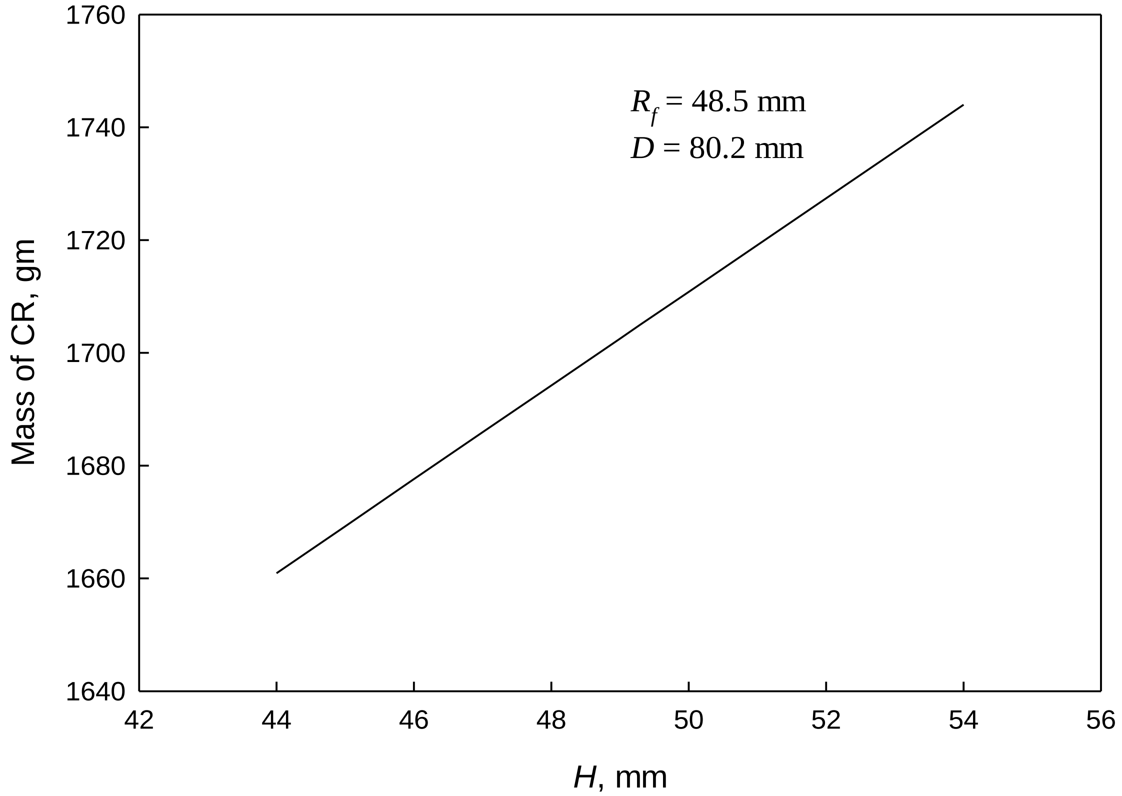

Fig. 21: The effect of ***H*** of the big end on the mass of I section connecting rod, keeping other dimensions' constant

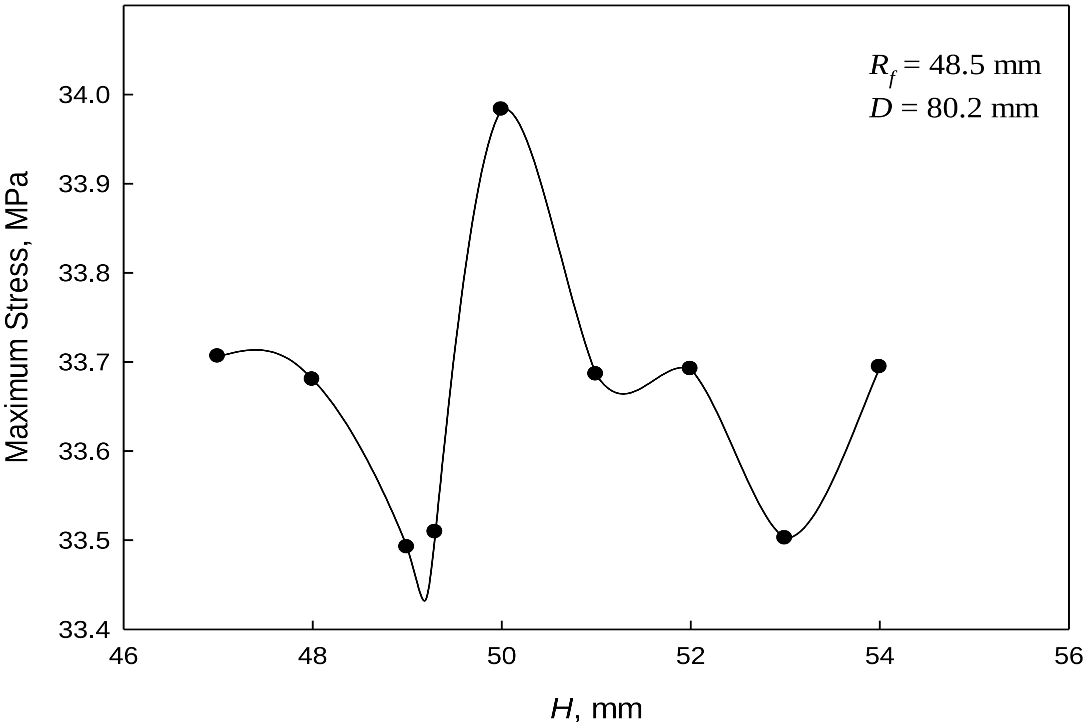

Fig. 22: The effect of height (***H***) of big end on the (σ_{max}) generated at the critical point, keeping other dimensions' constant

XI. CONCLUSION

With the help of ANSIS software and the finite element analysis approach, it is possible to study various components from a variety of angles, including fatigue, which saves time and money. The way loadings were defined had a positive impact on the outcomes. They should therefore closely match the actual circumstances. Because fatigue analysis requires some static analysis, it is necessary to specify boundary conditions that are most realistic. In this study, we get to the conclusion that the critical node close to the big end fillet is optimal for the three critical dimensions. The manufacturing sector is the optimum match for this connecting rod design. In the future, I section connecting rods and H section rotating parts will be compared.

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