Design and Analysis of Connecting Rod for Weight and Cost Reduction

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Abstract – *The project's major goal is to look at ways to reduce weight and cost in the design and manufacture of connecting rods. The study focuses on linking stress analysis, which is followed by optimization by lowering weight and cost. The connecting rod's job is to transfer the piston's thrust to the crankshaft. As a result, the connecting rod must be able to transmit various stresses induced by push and pull on the piston, and it must be extremely strong, stiff, and light. Forged steel, cast iron, wrought steel, powder metal, and other materials are often used in connecting rod manufacture for internal combustion engines. As a result, there is the possibility of using different materials, such as microalloyed carbon steel, to generate less weight alternatives. CREO software is used to create a parametric model of the connecting rod, and ANSYS R18.1 software is used to do structural analysis. After stress, strain, and total deformation have been determined, we must establish which material has unique properties.*

Key Words: *Connecting rod, Forged steel, Microalloyed Carbon steel, CREO, ANSYS, Weight and Cost Reduction*

1.INTRODUCTION

The connecting rod of an automotive engine is a vital component that is mass-produced in large quantities. It links a reciprocating piston to a revolving crankshaft, sending the piston's thrust to the crankshaft owing to gas pressure. Every cylinder in a vehicle with an internal combustion engine requires at least one connecting rod. The connecting rod serves as a connection between the piston and the crankshaft in an internal combustion engine. The connecting rod is divided into three zones. The piston pin end, the middle shank, and the crank end are all parts of the piston. The little end is the piston pin, the centre shank has an I-cross section, and the big end is the crank. The connecting rod is a pin-jointed strut with more weight concentrated at the large end. As a result, the connecting rod's CG point is closer to the large end. The goal of this research was to improve a forged steel connecting rod for weight and manufacturing cost while taking into consideration current advancements. An optimal solution is often the least or highest value that an objective function may obtain given a set of restrictions. However, the optimization performed here is not purely mathematical in nature, because mass reduction, production feasibility, and cost reduction are all part of the optimization. Furthermore, the software employed in this study put limitations on optimization when fatigue life was a factor.

Rather of utilising numerical optimization approaches to reduce weight, quantitative data were analysed subjectively and the structure was changed.

OBJECTIVES

The aim of this work is the design and analysis of the forged steel connecting rod. Steel materials are used for the design of the connecting rod. In this project, the material (forged steel) of the connecting rod was replaced with microalloyed carbon steel. The connecting rod was created in CREO. The model is imported into ANSYS R18.1 for analysis.

2. OPTIMIZATION TECHNIQUE

2.1 Shape Optimization Technique

The topic of optimal control theory includes shape optimization. The most common task is to discover the form that is optimal in terms of minimising a particular cost function while fulfilling certain restrictions. In many circumstances, the solution of a partial differential equation specified on the variable domain is required to solve the functional.

The number of linked components/boundaries in the domain is also taken into account while optimising topology. Shape optimization techniques often function in a subset of permissible shapes with given topological qualities, such as having a certain number of holes in them, therefore such approaches are required. The limits of pure shape optimization can therefore be overcome using topological optimization approaches.

2.2OPTIMIZATION OF CONNECTING ROD

The connecting rod was optimised with the use of a shape optimization approach. The optimization concentrated on the non-essential areas that needed to be cut. The form optimization suggests that the connecting rod's shape and design are unneeded. The major goal is to reduce the connecting rod's weight as well as the overall production cost. The optimised model, as can be observed, reduces the weight from the initial design until the value converges. These optimizations are being implemented in order to determine the ideal design and shape of the connecting rod in order to optimise performance and

strength, particularly at the vital area. Because of the lowest stress and bulk, the optimal connecting rod was chosen as the best optimise design.

3. MATERIAL SELECTION

The material for the connecting rod was chosen based on the following characteristics:
1. Excellent tensile strength
2. Compression strength is high
3. Resistance to wear and tear
4. Excellent elasticity
5. The ability to tolerate heat

$m = AL\rho$
$F/A \leq \sigma$
$m \geq FL\rho/\sigma$
$M = \sigma/\rho$

Where, m = mass
A= area of the cross-section
L = Length
ρ = density
σ = fatigue constraint
F = applied force
M = material index

3.1 Material Used

FORGED STEEL
MICROALLOYED CARBON STEEL

3.2 Chemical Composition of Material

Table -1: Forged steel

MATERIALS	PERCENTAGE
Carbon	0.61
Aluminum	0.095
Manganese	0.82
Bromium	0.00097
Cobalt	7.8
Iron	75.56
Molybdenum	3.25

Table -2: Microalloyed Carbon steel

MATERIALS	PERCENTAGE
Carbon	0.06-0.12
Manganese	1.4-1.8
Niobium	0.02-0.05
Vanadium	0-0.06
Molybdenum	0.2-0.35
Iron	86.65

3.3 Mechanical Properties of Forged Steel and Microalloyed Carbon Steel

Table -3: Mechanical Properties of Forged Steel and Microalloyed Carbon Steel

Mechanical properties	**Forged steel**	**Microalloyed carbon steel**
Ultimate strength (MPa)	625	750
Young's modulus(N/mm^2)	200	211
Percentage of elongation (%)	27	32
Percent reduction in area (%)	42	25
Hardness, HRC	28	23

4. SPECIFICATIONS OF EXISTING CONNECTING ROD

1. Length of the connecting rod = 176mm
2. Speed =4500rpm
3. Mass of the reciprocating parts =2.25kg
4. Factor of safety =6
5. Maximum pressure =3.5 N/mm^2
6. Piston diameter = 90mm
7. Height near the big -end(H_1) = 15 mm
8. Height near the small-end (H_2) = 11 mm
9. Mass of the connecting rod = 0.861 kg

10. Dimensions of crank-pin
    Length = 47.18 mm
    Diameter = 37.75 mm
11. Dimensions of piston-pin
    Length = 48.84mm
    Diameter = 32.56mm

4.1 Design Calculations for Connecting Rod

Calculation of loads

Axial loads

a) Gas load

Gas load (P) = ρA N

$$A = \frac{\pi D^2}{4} \text{ m}^2$$

b) Inertia load

Inertia load (F) = ma N

$$a = \omega^2 R(\cos\theta + {}^{R}/_{L}\cos(2\theta)) \text{ m}^2$$

The axial load (Q) acing on the connecting rod is given by,

$$Q = \frac{P}{R/L[(\frac{L}{R})2 - \sin 2\theta]} \text{ N}$$

Bending load

Total inertia bending force is given by

$$F_b = \frac{\rho A_i L^2 \sin(\theta+\phi)}{2} \text{ N}$$

Furthermore, this force will induce a minor deflection, causing the axial load to be eccentric to the connecting rod's neutral axis.

Calculation of stresses

Stress due to axial loads

These stresses calculated as follows,

$$\sigma = \frac{Q}{A_1} \text{ N/m}^2$$

The acceleration is calculated at the section's centre of gravity, and the inertia forces are calculated as follows:

$$F^i = m^i x a^i \text{ N}$$

The axial stresses are calculated by adding this force to the axial force operating on the connecting rod.

Stress due to inertia bending force

The bending moment at any section 'x' m from the small end is given by

$$M = \frac{\pi}{3}\left[1 - \frac{x^2}{L^2}\right] F_b \text{ Nm}$$

The stress is calculated by using the formula,

$$\sigma_b = M/Z$$
$$Z = I/(2.5\, x\, t)$$
$$I = 419\, x\, t^4$$

The axial and bending stresses estimated above result in a stress fluctuation over the connecting rod's I-section. The stresses at the I-outer section's and inner are computed as follows:

$$\sigma = \sigma_a$$

5.ANALYSIS OF CONNECTING ROD

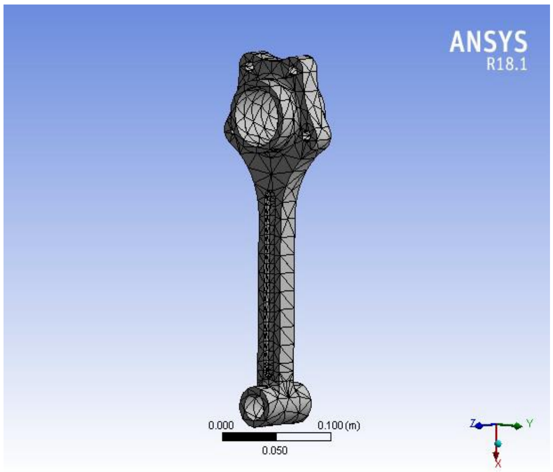

Fig -1: Meshed view of Connecting Rod

5.1 Stress Analysis of Connecting Rod

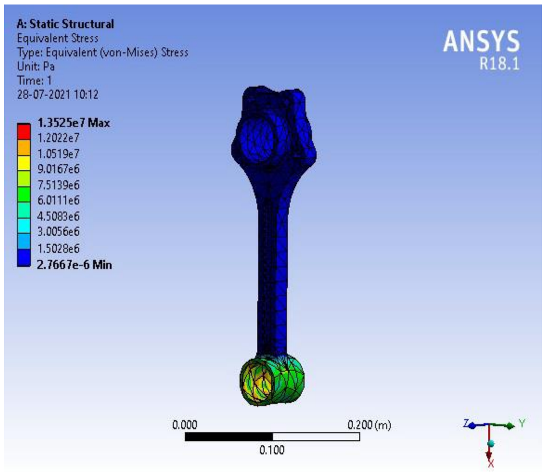

Fig -2: Forged Steel

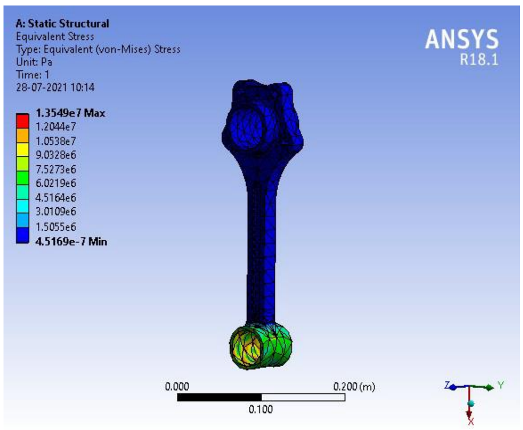

Fig -3: Microalloyed Carbon Steel

5.2 Strain Analysis of Connecting Rod

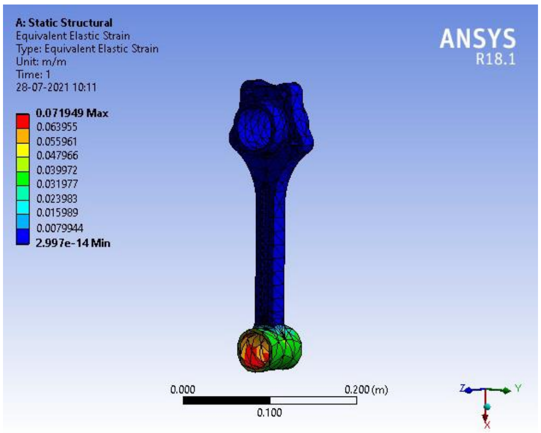

Fig -4: Forged Steel

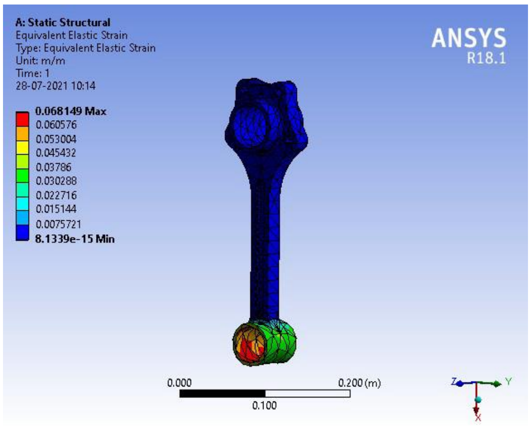

Fig -5: Microalloyed Carbon Steel

5.3 Displacement Analysis of Connecting Rod

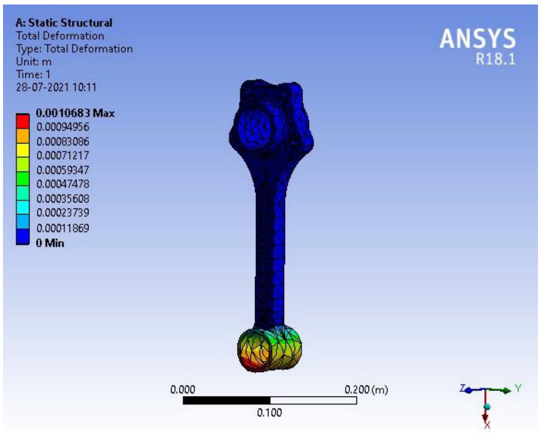

Fig -6: Forged Steel

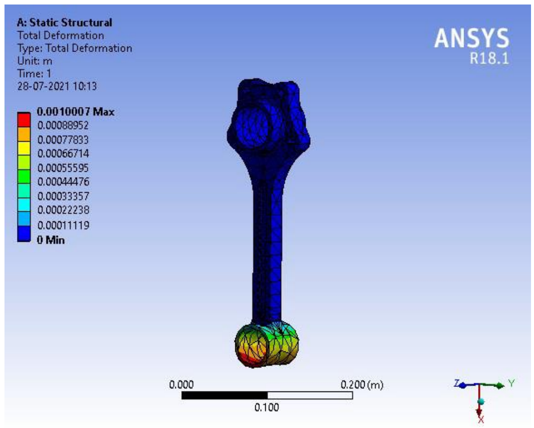

Fig -7: Microalloyed Carbon Steel

6.RESULT AND DISCUSSION

Table -4: Comparison of Forged Steel and Microalloyed Carbon Steel Result

S. NO	RESULT	FORGED STEEL	MICROALLOYED CARBON STEEL
1	Maximum Equivalent stress (pa)	1.3525e7	1.3549e7
2	Maximum equivalent strain	0.071949	0.068149
3	Maximum total deformation (m)	0.0010683	0.0010007

7. CONCLUSIONS

Axial stresses are created when connecting rods are exposed to mass and gas forces. As a result, a connecting rod must be able to transmit axial tension, axial compression, and bending loads generated by the piston's push and pull. Hundreds of millions of cyclic loadings are applied to a connecting rod.

As a result, it's usually built to last an eternity. Because he weight of the piston and connecting rod influences the forces generated during engine operation, it is vital to lower connecting rod weight. After examining the aforementioned literatures, it is clear that, while forged steel connecting rod has received a lot of attention, there is room to experiment with microalloyed carbon steel connecting rod as a lighter alternative.

The connecting rod was optimized through material change and analysis using ANSYS software. We compared the results to find the best alternative to forging steel. As the composition of the material must change, it must also withstand the properties of the material making up the connecting rod. This reduces the weight and cost of the connecting rod.

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