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Structural Analysis of 3D Printed Structure Connecting Rod Using Composite Materials

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ABSTRACT:The piston is hooked up to the crankshaft by a connecting rod. The connecting rod have to switch the motion of the piston to the crank pin, converting the piston's reciprocating movement into the crank's rotating motion. The two most normal motives for connecting rod failure are tensile failure because of high engine speeds and casting disorder due to cyclic load behaviour.

In order to improve common overall performance indicators even as decreasing situation weight, this evaluation explores different cloth options for connecting rods, including metal. An surprisingly huge connecting rod, as well as many styles of steel and composites (which include boron carbide, aluminum-beryllium alloy, aluminum-silicon carbide composite, and titanium alloy) are tested in detail. The final form and substances had been decided via electric and pressure specifications. In order to predict the version's structural power and buckling obstacle, a three-dimensional sturdy model of the connecting rod was evolved the usage of the strong works robust modelling software. This launch treated static structural norms inclusive of Von-Mises stress, deformation, safety component, and modern connecting rod arrangement.

The traditional method of production includes casting connecting rods in a mildew, which is each time-ingesting and luxurious due to the fact to the need for specialized equipment and expertise in mildew layout. Therefore, it is of utmost necessity to enhance the manufacturing technique for connecting rods. The mission's closing goal is to mass-produce connecting rods the use of 3-d printing and other contemporary manufacturing strategies.

KEYWORDS: composite connecting rods, Von-Mises stress, deformation, safety component.

I. INTRODUCTION

1.1 Connecting Rod

The crankshaft rotates in reaction to the rotating movement of the piston, that is transferred to it via the connecting rod. The automobile has a better chance of passing because the pressure is being transferred from the crank to the piston. Masses and stresses in bending, tension, compression, and buckling may be studied through reworking the piston's linear movement into the crankshaft's rotating movement. The bigger quit of the connecting rod is held to the crank shaft via a crank pin and a simple bearing. The smaller prevent is connected to the piston via a connecting pin. Under severe situations, the connecting rod of an inner combustion engine is especially prone to breaking. The ideal connecting rod might be lower priced without dropping resilience beneath huge loads and cyclical strain, light-weight without sacrificing energy, and long-lasting. Connecting rod research has moved faraway from reading substances with a uniform composition toward reading a wide style of metallic alloys and composite materials for you to improve overall performance, strength, stiffness, weight, increase placed on and corrosion resistance, and discount of thermal enlargement. Connecting rods can be made from lightweight materials like Metal Matrix Composites (MMCs), Aluminum-Silicon Carbide Composite, or even just a variety of steel alloys to enhance the engine's average overall performance



Fig -1.1 Connecting rod

II. LITERATURE REVIEW

Here, we talk the relevant guides we took to analyze extra approximately the elements to recall while choosing a connecting rod cloth, and the statistics we got from those classes.

The improved degrees of hardness, electricity, and sturdiness claimed via A.Pandiyan et al. [1] for aluminium alloys and composites were demonstrated by way of testing. A connecting rod made from 6061-T6 may be 7.Ninety eight% lighter than one made from ADC12 whilst preserving the identical electricity-to-weight ratio and ductility. The center of this solution is the topology optimisation method.

Connecting rod shape, manufacturing procedure, and alloys/composites that work well are all investigated through Shubham Tiwari et al. [2]. Powder metallurgy may also support the microstructure of connecting rods, which has been shown to improve their mechanical homes. They decided that switching from steel to titanium alloy all through manufacture would improve the connecting rod's tensile elongation and tensile strength.

Vikas Singh et al. [3] used ANSYS software to evaluate pressure, stress, and strain experiments on an expansion of substances. By applying boundary situations to a connecting rod, finite-element evaluation is utilised to calculate the values of previously unknown sections, including deformation, stress, and pressure. An iterative procedure concerning many materials become used to calculate the equivalence of elastic stress and general deformation.

The first calculations for cloth choice and facts at the most efficient methods of manufacturing numerous distinct chemical substances were completed via SomnathChattopadhyay [4].

It is nicely information that connecting rods are a high-quality area to position Titanium Alloy, in line with the work of Adnan Ali Haider et al. [5]. Its high weight-to-deformation ratio and relatively low degree of distortion. Aluminium Alloy 7075-T6, the subsequent material to be evolved, become lots lighter than Titanium Alloy at the same time as having a decrease Factor of Safety.

III. METHODOLOGY

SOLID WORKS MODELLING

3.1 Introduction to Cad

Modelling a mechanical detail is the first critical step within the analytical system. In the future, we may additionally use this statistics to accurately version the behaviour of the whole connecting rod. The connecting rod have become modelled in Solid Works, a 3D modelling

3.2 Modelling Of I.C Engine Connecting Rod

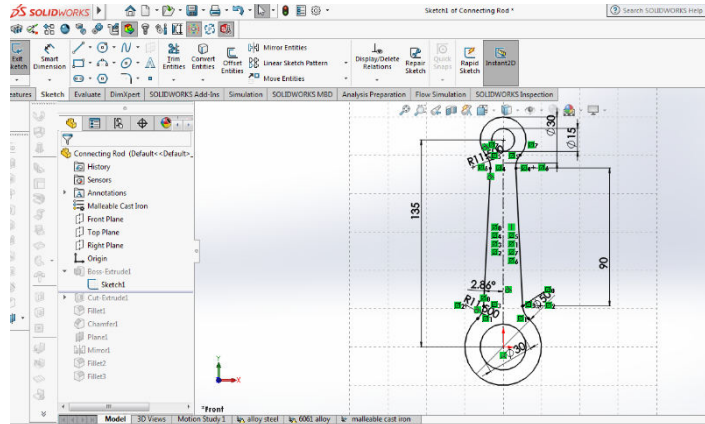


Fig-3.1 2d drawing connecting rod

3.3 Dimensions of Connecting Rod

- Thickness of Connecting Rod = 4.8 mm
- Width of the section = 19.2 mm
- Height of the Section = 24 mm
- Height at the bigger end = 26 mm
- Height at the smaller end = 20 mm
- Inner Diameter at Piston End = 19.4 mm
- Outer Diameter at the Piston End = 35 mm
- Inner Diameter at Crank End = 39 mm
- Outer Diameter at Crank End = 63 mm

3.4 Design calculations

For calculations of force acting on piston, the following parameters have been considered

- Engine Specifications: 150 cc, 4-stroke, air cooled Petrol Engine
- Bore Diameter × Stroke Length = 57 × 58.6
- Stroke Volume = 149 cc
- Maximum Power = 11.9 bhp @ 7500 rpm
- Maximum Torque = 12.8 N-m @ 6000 rpm
- Compression Ratio = 9.5:1
- Molecular Weight, Me = 114.228 g/mole
- Universal Gas Constant, R = 8.314 J/mol-K
- Factor of Safety is assumed to be 2.
- Stroke Length = 58.6 mm.
- Crank Radius = L/2 = 29.3 mm.
- Frictional Forces are neglected.
- Connecting Rod Length to Crank Radius is 4:1 (for IC Engines).

I-section has more shape factor compared to Hsection and also bending strength is more, hence Isection is being considered for analysis.

For I-section calculations, these are the standard parameters:

- Thickness of Connecting Rod = t
- Height, H = 5t
- Width of flange, B = 4t
- I – Section Area = 11t²

Gas Pressure on Piston and Buckling Load Calculations: $PV = m_e \times R_{specific} \times T$



$$P = \frac{m_e \times R_{\text{specific}} \times T}{V}$$

$$m_e = 0.109 \approx 0.11 \text{ kg}$$

$$P = \frac{0.11 \times \left(\frac{8.314}{114228}\right) \times 288.15}{149 \times 10^{-6}}$$

$$P = 15.48 \text{ MPa} \approx 15.5 \text{ MPa}$$

$$F_g = P \times \frac{\pi}{4} (d_b)^2,$$

$$F_g = 16 \times \frac{\pi}{4} (57)^2$$

$$F_g = 39.552 \text{ kN}$$

- Buckling or Crippling Load acting on Connecting Rod:
- $FB = F_g \times \text{F.O.S}$
- $FB = 39.552 \times 2$
- $FB = 79.1 \text{ kN}$

3.5 Material Selection and Properties

The fabric is chosen primarily based on its strength to weight ratio, with the intention of concurrently enhancing energy and reducing weight. The chosen materials are titanium alloy, aluminium beryllium alloy, and aluminium silicon carbide composite, and the results in their analyses are contrasted with the ones of the carbon metal connecting rod fabric, that's the industry trendy. The desk under lists the substances' characteristics:

$$I_{xx} = 1/12 [4t \times (5t^3) - 3t \times (t^3)]$$

$$I_{xx} = 34.91 t^4$$

Moment of Inertia along y – Axis,

$$I_{yy} = 1/12 [2 \times t \times 4 (t) \times 3 + (3t^4)]$$

$$I_{yy} = 10.917 t^4$$

$$\therefore \frac{I_{xx}}{I_{yy}} = 3.2$$

Since the connecting rod to crank radius is 4:1, the length of the connecting rod is:

$$L = 29.3 \times 4 = 117.2 \approx 118 \text{ mm}$$

Thickness of I-section:

From Rankine's formula

$$\frac{FB}{A} = \frac{\sigma_c}{1 + K \left(\frac{L}{k}\right)^2}$$

$$\sigma_c = 320 \text{ MPa (crushing strength)}$$

$K = 4/25000$ for Steel rod, pin connected at both ends so that the rod is freely bends in any plane

$$k = \left(\frac{bh^3 - b_1h_1^3}{12(bh - b_1h_1)}\right)^{\frac{1}{2}} \text{ (Radius of gyration for an I-section)}$$

$$k = 3.174 t^2$$

$$A = 11 t^2$$

Substituting the values in the Rankine's formula:

$$\frac{79.1 \times 10^3}{11 t^2} = \frac{320}{1 + \frac{4}{25000} \left(\frac{586}{3.174 t^2}\right)^2}$$

$$t = 4.74 \approx 4.8 \text{ mm}$$



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Width of I-section:

$$B = 4t$$

$$B = 19.2 \text{ mm}$$

Height of I-section:

$$H = 5t$$

$$H = 24 \text{ mm}$$

$$\text{Height at the bigger end} = 1.1 H$$

$$= 26 \text{ mm}$$

$$\text{Height at the smaller end} = 0.82 H$$

$$= 19.68 \approx 20 \text{ mm}$$

Length of the bearing at smaller end, $l_1 = 0.5 D$, (where D is the diameter of the piston)

$$l_1 = 0.5 \times 57$$

$$l_1 = 28.5 \approx 29 \text{ mm}$$

$$\text{Ratio of length to piston pin diameter at small end,}$$

$$l_1/d = 29/1.5 \text{ (for Petrol Engines)}$$

$$= 19.33 \text{ mm}$$

$$\text{Outer Diameter at Piston End} = 1.8 d$$

$$= 1.8 \times 19.4$$

$$= 34.92 \approx 35 \text{ mm}$$

$$\text{Diameter of Crank Pin} = dp1 = 0.67 D$$

$$= 0.67 \times 57$$

$$= 39 \text{ mm}$$

$$\text{Length of the Crank Pin Bearing, } lp1 = dp1$$

$$lp1 = 39 \text{ mm}$$

$$\text{Outer Diameter at Crank End} = 1.5 \times dp1$$

$$= 1.5 \times 39$$

$$= 62.5 \approx 63 \text{ mm}$$

Forces acting on the Connecting Rod

The connecting rod is challenge to the subsequent forces: Gas stress and the inertia of the revolving additives both exert forces at the piston.

1. Gas strain and the reciprocating components' inertia forces at the piston.
2. Bending forces as a result of inertia of the connecting or inertia forces
4. Forces because of friction within the piston pin bearing and crank pin bearing, 3. Forces due to friction between the piston rings and the piston, and 4.

The first two factors have been taken into consideration on this research.

Forces on the piston due to gas pressure and inertia of the reciprocating parts:

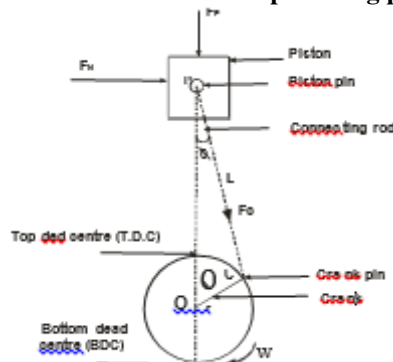


Fig: 1. Forces acting on connecting rod



It is known that the force on the piston due to pressure of gas,

$$F_L = \text{Pressure} \times \text{Area} = p \cdot A = p \times \pi D^2 / 4 \text{-----} (1)$$

And inertia force of reciprocating parts,

$$F_I = \text{Mass} \times \text{acceleration} = m_R \cdot \omega^2 \cdot r \cos \theta \cos 2\theta / n \text{-----} (2)$$

It may be noted that the inertia force of reciprocating parts opposes the force on the piston when it moves during its downward strokes (i.e., when the piston moves from the Top dead centre to Bottom dead centre). On the other hand, the inertia force of the reciprocating parts helps the force on the piston when it moves from the Bottom Dead Centre (BDC) to Top Dead Centre (TDC).

:: Net force acting on the piston or piston pin (or gudgeon pin or wrist pin)

$$F_p = \text{Force due to gas pressure} \pm \text{inertia force} = F_L \pm F_I$$

The negative sign is used when piston moves from Top Dead Centre to Bottom Dead Centre and positive sign used when piston moves from Bottom Dead Centre to Top Dead Centre.

When weight of the reciprocating parts ($W_R = m_R \cdot g$) is to be taken in to consideration, then $F_p = F_L \pm F_I \pm W_R$

The force F_p gives rise to a force F_C in the connecting rod and a thrust F_N on the sides of the cylinder walls from fig.1 we see that force in the connecting rod at any instant,

$$F_C = F_p / \cos \Phi = F_p / \sqrt{1 - \sin^2 \theta / n^2} \text{-----} (3)$$

The force in the connecting rod will be maximum when the crank and the connecting rod are perpendicular to each other (i.e. when $\theta = 90^\circ$). But at this position, the gas pressure would be decreased considerably. Thus, for all practical purposes, the force in the connecting rod F_C is taken equal to the maximum force on the piston

IV. EXPERIMENTAL RESULTS

CONNECTING ROD ANALYSES

4.1 Finite Element Method (FEA)

Analysing a connecting rod with the ansys programme A. Finite Element Method (FEA): The FEA is a numerical method for resolving problems which are characterized by partial differential equations or that could additionally be expressed as useful minimization. To depict as an assemblage of finite components is an interesting representational concept. The approximating feature in the finite elements is mounted in phrases of the preferred bodily discipline's nodal values. A problem or entity is damaged down into a number of smaller, simpler additives called finite factors with the aid of the FEM sub, which then solves these components.

4.2 CONNECTING ROD ANALYSIS:

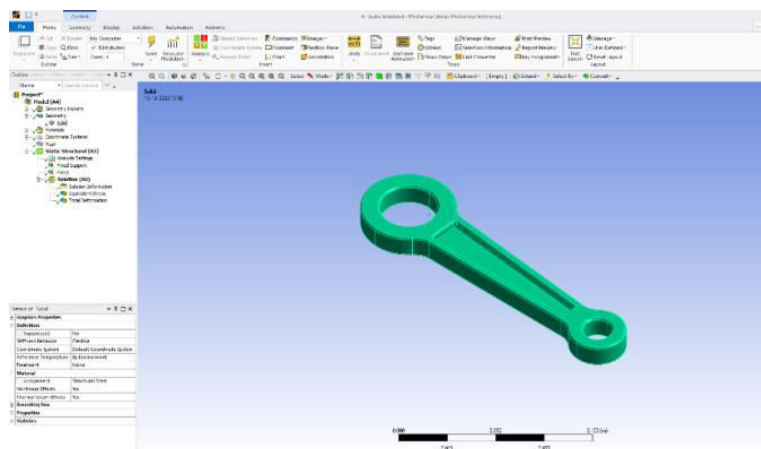


Fig-4.2 geometry file connecting rod

4.3 Material:
4.4 MESH

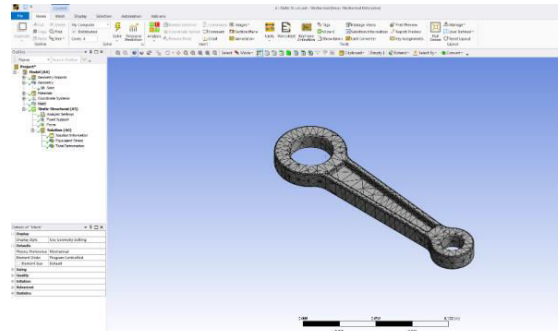


Fig-4.4-mesh file connecting rod

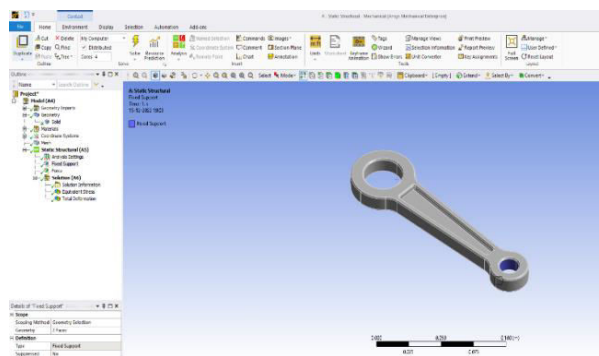


Fig-4.5 deflection fixed support file connecting rod

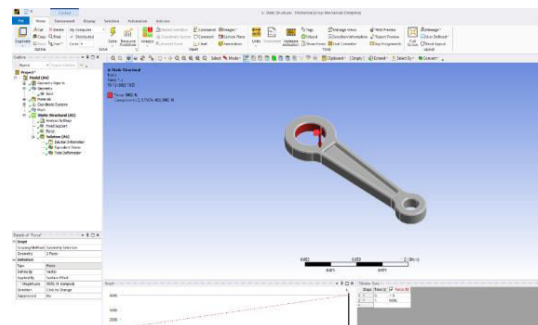


Fig-4.6 deflection file connecting rod

4.5 RESULTS:

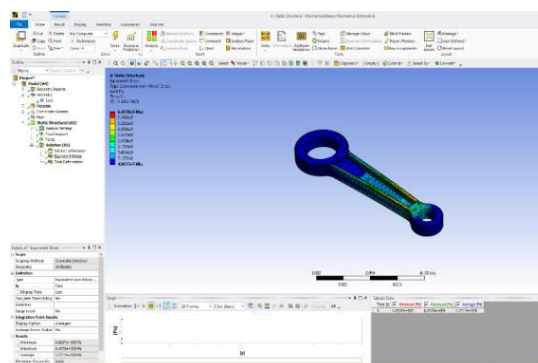


Fig-4.7 equivalent stress connecting rod

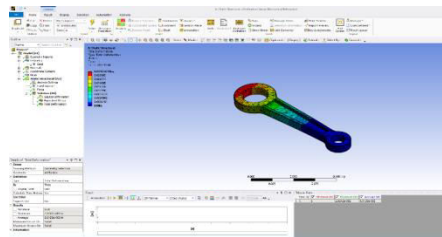


Fig-4.8 total deformation connecting rod

4.6 TITANIUM ALLOY RESULTS:

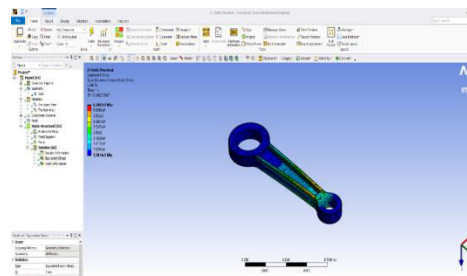


Fig-4.10 Titanium Alloy equivalent stress connecting rod

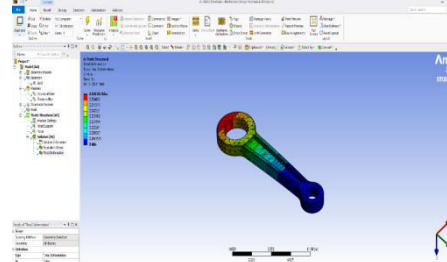


Fig-4.11 Titanium Alloy total deformation connecting rod

4.7 ALUMINUM SILICON:

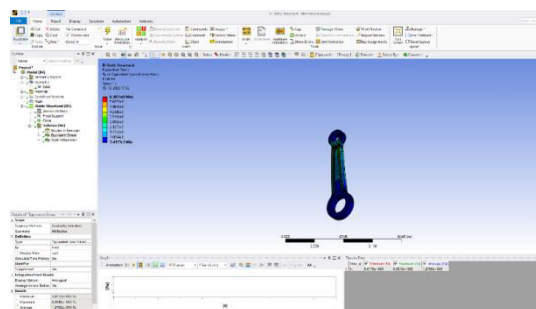


Fig-4.13 Aluminum Silicon equivalent stress connecting rod

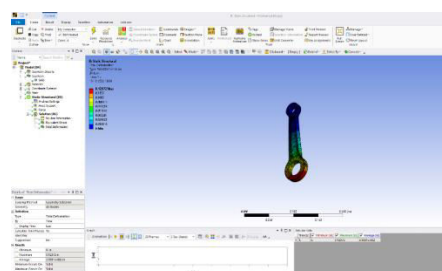


Fig-4.15 Aluminum Silicon total deformation connecting rod

4.8 ALUMINUM BERYLLIUM:

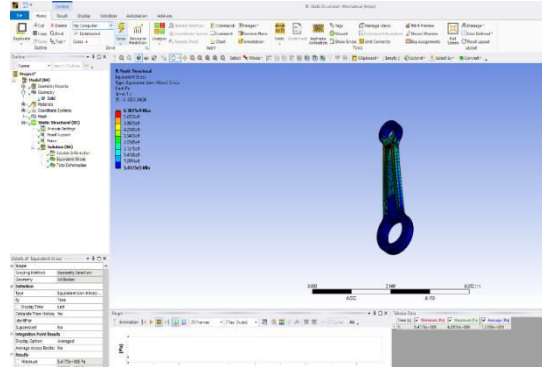


Fig-4.17 aluminum beryllium equivalent stress connecting rod

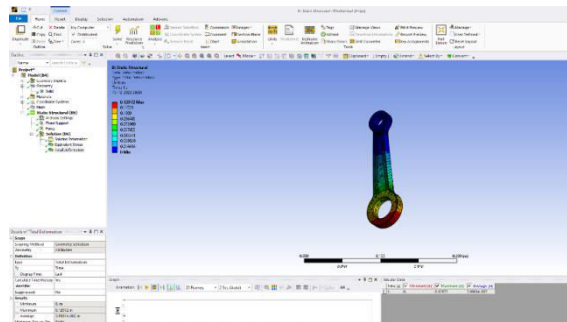


Fig-4.18 aluminum beryllium total deformation connecting rod

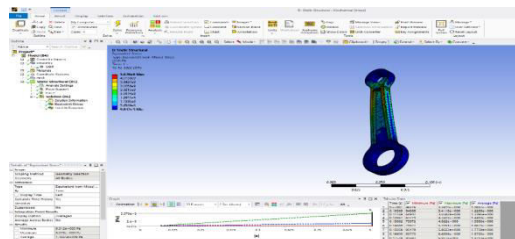


Fig-4.20 Boron Carbide equivalent stress connecting rod

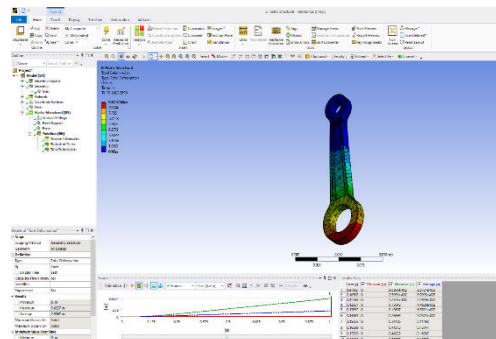


Fig-4.21 Boron Carbide total deformation connecting rod



TENSILE STRENGTH VALUES

Ratio	Dia mm	CSA mm ²	YL KN	YS N/mm ²	TL KN	TS N/mm ²	IGL mm	FGL mm	%E	FD	%RA
Boron	16.34	209.78	10.08	48.05	13.86	66.07	50.00	51.16	2.32	14.93	16.51

COMPRESSIVE STRENGTH VALUES

Identification	Dia mm	CSA mm ²	Compression Load kN	Compression Strength N/mm ²
boron carbide	16.34	209.78	51.02	243.20

HARDNESS TEST

Thickness in mm	Ultimate load Applied in N	Maximum Displacement in mm
16.34	2880	14.34

BENDING TEST

Thickness in mm	Ultimate load Applied in N	Maximum Displacement in mm
16.34	749.33	14.2

ORIGINAL STEEL CONNECTING ROD & COMPOSITE CONNECTING ROD (WAITE COST) COMPARISONS

Materials	WAITE	Cost
Steel	0.8kg /800gm	500 <u>rs</u>
Boron Carbide Composites	0.5kg/500gm	200rs

COMPOSITE CONNECTING ROD (WAITE & COST) COMPARISONS

Our composite connecting rods might also enhance overall performance in evaluation to their steel equivalents whilst lowering weight with the aid of as much as three hundred grammes per rod. Our BORON CARBIDE composite rods were optimised for strain switch via virtue in their form and association, further to possessing all of the blessings of metallic rods. Over 5 years of AWA studies and development thru ATA Engineering and the results of finite detail evaluation studies back them up.

During engine cycles, our BORON CARBIDE composite connecting rods bend a ways less than metal connecting rods might due to stretching and warmth growth. BORON CARBIDE composite connecting rods are much less high-priced in the end and remaining longer than rods manufactured from greater current substances.

(FEA) ANALYSIS RESULTS STATIC STRUCTURAL ANALYSIS AND THERMAL ANALYSIS OF CONNECTING ROD

6.1 Table Results

s.no	Material	von misses stresses [Mpa]	Displacement [mm]
1	STEEL	645.78	29.2
2	BORON CARBIDE	507.8	96.23
3	ALUMINUM SILICON	638.1	129.72
4	ALUMINUM BERYLLIUM	643.15	109.78
5	TITANIUM ALLOY	636.67	60.782

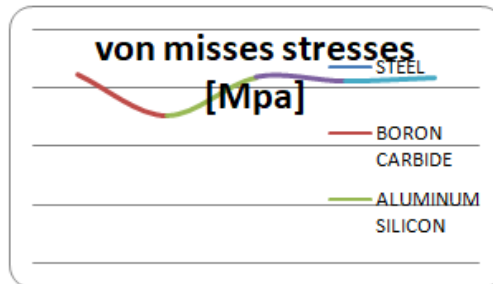


Fig-6.1 vonmisses stresses

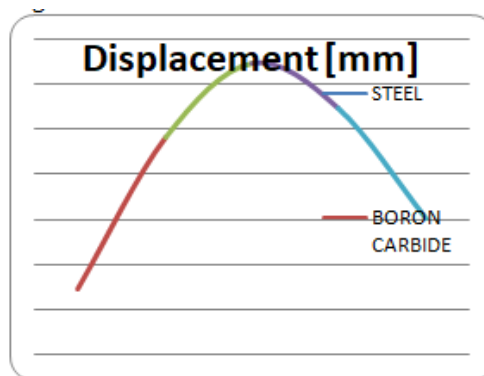


Fig- 6.2 total displacement

From the above results Boron carbide has yielded less stresses compared to other composites and steel material . so the best material among them is Boron carbide

V. CONCLUSION

ANSYS Workbench became used to research the connection's behaviour beneath tensile and compressive masses, and CATIA V5 changed into used to create a very last model of the relationship that satisfies all design necessities. Right now, mechanical checks for hardness, tensile energy, and bending are the standard for characterising advanced composites. The following deductions are possible because of this paintings. According to this examine on matrix mechanical residences, Boron carbide reinforcement increases the tensile and compressive strengths of the material. Powerful momentum upon impact.

Due to its very low pressure age in contrast to other composites and metal material, boron carbide has been proven to be the fine fabric thru finite element analysis. We conclude that Boron Carbide is the advanced cloth due to the fact to its extended resistance to deformation and displacement. Synthetic composites

Each of our composite connecting rods weighs 400 grammes less than its metallic counterpart and is tons extra environmentally pleasant. Our BORON CARBIDE composite rods are designed and organised to disperse strain extra softly without sacrificing any of the benefits of metal rods. Results from over five years of AWA research and development by ATA Engineering and their finite element analytic investigations offer credence to its dependability.

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2. The article "Parameters Influencing Connecting Rod: A Review" by way of Ajay Kumar Kaviti and Shubham Tiwari regarded within the August 2015 difficulty of the International Journal of Scientific and Engineering Research (ISSN: 2229-5518). IJSER 2015, Volume 9, Issue 3, February 2020, International Journal of Engineering and Advanced Technology, ISSN 2249-8958 Using ANSYS Workbench sixteen.2, Vikas Singh, Sumit K. Verma, Harish Chandra Ray, Vishal K. Bharti, and Abhinesh Bhaskar designed and analysed connecting rods made from a huge range of materials.
3. The studies carried out by using Somnath Chattopadhyay offer the groundwork for this (AC 2010-926, "Selection of Material, Shape, and Manufacturing Process for a Connecting Rod").



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