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DESIGN & ANALYSIS OF “CONNECTING ROD BY FINITE ELEMENT ANALYSIS USING COMPOSITE MATERIALS”

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ABSTRACT:

Connecting rod is one of the important components of whole engine assembly as it acts as a mediator between piston assembly and crankshaft. It’s converting the reciprocating motion of the piston to rotary of the crank. Also, it faces a lot of tensile and compressive loads during its working condition. Generally connecting rods are manufactured using carbon steel and in recent days aluminum alloy are finding its applications in connecting rod.

Here connecting rod material is been checked with different materials like aluminum based composite material reinforced with boron carbide by designing and modeling also describes the analysis. for designing of connecting rod solid works 2020 version is used and for analysis is based on Solid works 2020. the main theme of the work is to analyze the stress, strain deformation of connecting rod by varying the material with same geometry.

KEYWORD’S: Connecting rod, Analysis of connecting rod, four stroke engine, Aluminum alloy reinforced with boron carbide, solid works.

1.INTRODUCTION :

In a reciprocating piston engine, the connecting rod or conrod connects the piston to the crank or crankshaft. Together with the crank, they form a simple mechanism that converts linear motion into rotating motion. Connecting rods may also convert rotating motion into linear motion. Historically, before the development of engines, they were first used in this way driving machinery from water wheels. As a connecting rod is rigid, it may transmit either a push or a pull and so the rod may rotate the crank through both halves of a revolution, i.e., piston pushing and piston pulling. Earlier mechanisms, such as chains, could only pull. In a few two-stroke engines, the connecting rod is only required to push. Today, connecting rods are best known through their use in internal combustion piston engines, such as car engines. These are of a distinctly different design from earlier forms of connecting rods, used in steam engines and steam locomotives.

1.HISTORY

The earliest evidence for a connecting rod appears in the late 3rd century AD Roman Hierapolis sawmills. It also appears in two 6th century Eastern Roman saw mills excavated at Ephesus respectively Gerasa. The crank and connecting rod mechanism of these Roman watermills converted the rotary motion of the waterwheel into the linear movement of the saw blades.

The first steam engines, Newcomen’s atmospheric engine, were single-acting: its piston only did work in one direction, and so these used a chain rather than a connecting rod. Their output rocked back and forth, rather than rotating continuously.

1.2 INTERNAL COMBUSTION ENGINE

Fig 1.1 Failure of a connecting rod is one of the most common causes of catastrophic engine failure.

In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of T6-2024 and T651-7075 aluminum alloys (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of lightness with strength, at higher cost) for high performance engines, or of cast iron for applications such as motor scooters. They are not rigidly fixed at either end, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around the crankshaft. Connecting rods, especially in racing engines, may be called "billet" rods, if they are machined out of a solid billet of metal (this being forge into the rough shape), rather than being cast, the forged steel having a better internal grain structure for strength.

The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most often press fit into the connecting rod but can swivel in the piston, a "floating wrist pin" design. The big end connects to the bearing journal on the crank throw, in most engines running on replaceable bearing shells accessible via the connecting rod bolts which hold the bearing "cap" onto the big end. Typically, there is a pinhole bored through the bearing and the big end of the connecting rod so that pressurized lubricating motor oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons and piston rings.

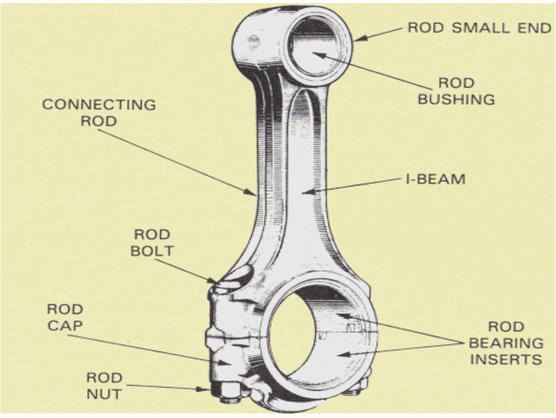


Fig 1.2 Connecting rod parts

Fig 1.3 Master connecting rod

Radial engines typically have a master rod for one cylinder and multiple slave rods for all the other cylinders in the same bank.

1.3 SPECIFICATION OF THE PROBLEM:

- **Problem Definition:** As Connecting rod undergoes repetitive loads during it service life, fatigue performance and durability of this component has to be considered in the Design Process. The stresses and weight for carbon steel(c45) are more and life can be improved, hence it necessitates to find the alternative material at given loading conditions. In this project the material (carbon steel) of connecting rod replaced with developed Aluminum alloy. The model of connecting rod was created in solid works 2020 and added to simulation tool bar in same for static and fatigue analysis. After analysis a comparison is made between existing steel connecting rod for the given dimensions for Von misses stress, equivalent strain and total deformation.
- **Objectives of the work**: The objective of the present work is the static and fatigue analyses of a connecting rod made of Aluminum Alloy reinforced with Boron carbide (B4C) to compare the stress distribution ,deformation and fatigue life with carbon steel and aluminum to check whether a steel connecting rod can be replaced with a developed composite connecting rod.

1.4 THEORETICAL CALCULATIONS OF CONNECTING ROD:

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the Rankin formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, {or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

Let A = cross sectional area of the connecting rod.
L = length of the connecting rod.
σ_c = compressive yield stress.
W_{cr} = crippling or buckling load.
I_{xx} and I_{yy} = moment of inertia of the section about x-axis and y-axis respectively.
K_{xx} and K_{yy} = radius of gyration of the section about x-axis and y- axis respectively.

Rankin formula = $(I_{xx}=4I_{yy})$

PRESSURE CALCULATION FOR 150CC ENGINE:

Suzuki GS 150 R Specifications Engine type air cooled 4-stroke

Bore × Stroke (mm)	= 57×58.6
Displacement	= 149.5CC
Maximum Power	= 13.8bhp@8500rpm
Maximum Torque	= 13.4Nm@6000rpm
Compression Ratio	= 9.35/1
Density of Petrol C8H18	= 737.22kg/m3 = 737.22E-9kg/mm3
Temperature = 60F	= 288.855K
Mass = Density × Volume	= 737.22E-9×149.5E3 = 0.11Kg

Molecular Weight of Petrol =114.228 g/mole
From Gas Equation,
PV=MRT, R = R*/Mw = 8.3143/.114228 = 72.76 P = (0.11x72.786x288.85) / 149.5E3
P = 15.469 MPa. ~=16MPa

Design calculations of connecting rod

1. Thickness of flange and web of the section = t = 2
2. Width of the section B = 4t= 4×2 = 8
3. Height of the section H = 5t = 5×2 = 10
4. Area of the section A = 11*t2= 11×4 = 44
5. Moment of inertia about x axis Ixx= 34.91*t4 = 34.91×16 = 558.56
6. Moment of inertia about y axis Iyy= 10.91*t4 = 10.91×16= 174.56
7. Therefore Ixx/Iyy = 558.56/174.56 = 3.2

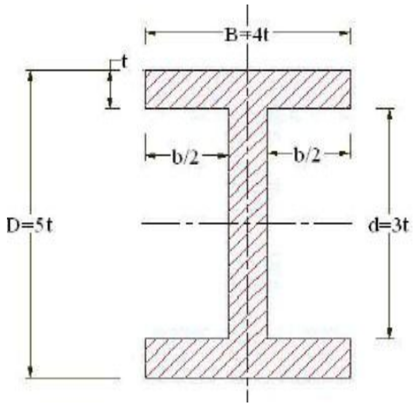
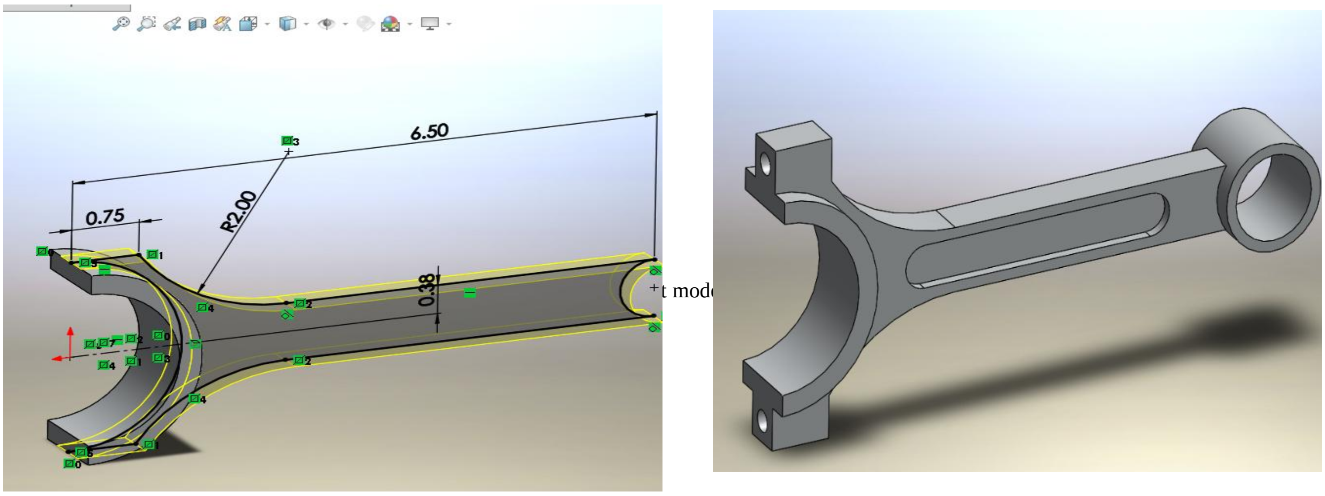


Fig 1.4 standard dimensions of I-section

2.0 Design Modeling of Connecting Rod

Designing of connecting rod is made in solid works 2020

fig 2.1 modeling of connecting rod in solid works



2.1.1 Static Analysis:

A static analysis is used to determine the displacement, strain, von misses stress and force in structure or compounds caused by load that do not significant inertia and damping effects.

2.2 Forces Acting on the Connecting Rod

1. The combined effect (or joint effect) of,
a) The pressure on the piston, combined with the inertia of the Reciprocating parts.
b) The friction of the piston rings, piston, piston rod and the cross head.
2. The longitudinal component of the inertia of the rod.
3. The transverse component of the inertia of the rod. 4. The friction of the two end bearings.

Axial forces: Axial forces resulting from gas pressure and inertia of piston assembly modified by the side thrust arising in consequence of the connecting rod crank angle.
The maximum axial load is compressive (at TDC).

1.Tensile stresses occur after firing, due to piston inertia.
2.Bending stresses also occur after firing.
3.Transverse forces:
Transverse forces Known as whip are caused by inertia effects of the rod mass. Fortunately, axial & transverse forces do not occur at the same time.

2.3 Material used to Compare the Results

S. No	Parameters	Old Material (Al6061)	New Material (Al6061+B_4C)	Carbon steel
1.	Density (kg/m$^{3)}$	2.7	2.52	7.87
2.	Young's modules (GPa)	70-80	450	200
3.	Poisson's ratio	0.33	0.18	0.29

Table 1.1 Material properties

The Connecting Rod is being Meshed as Curvature type by defining as 2mm Element Size.

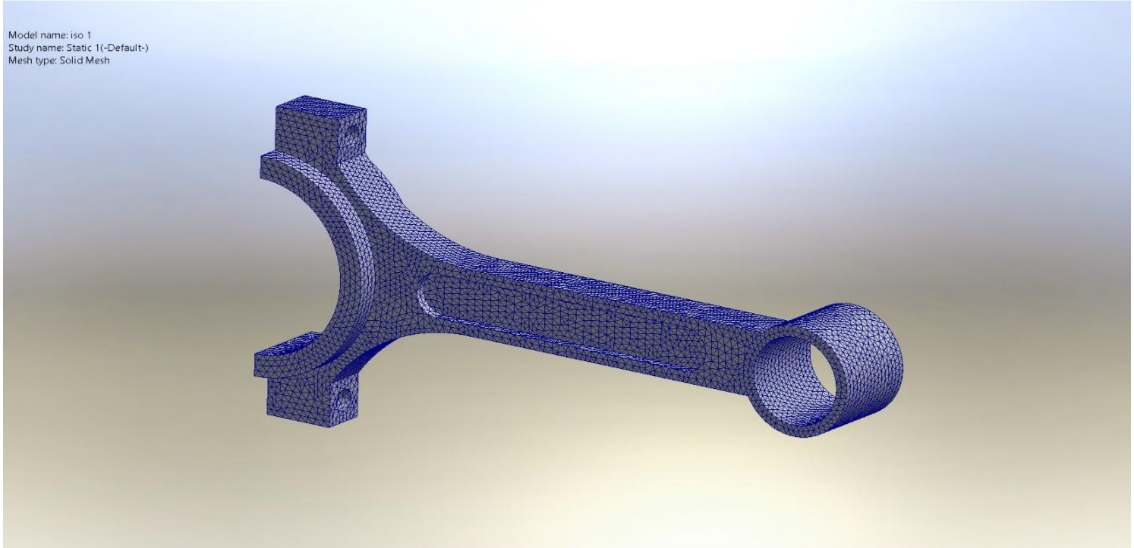


fig 2.2 solid mesh of modeled connecting rod in solid works simulation

3.0 Results:

3.1 Aluminum Alloy 6061: the following are observed

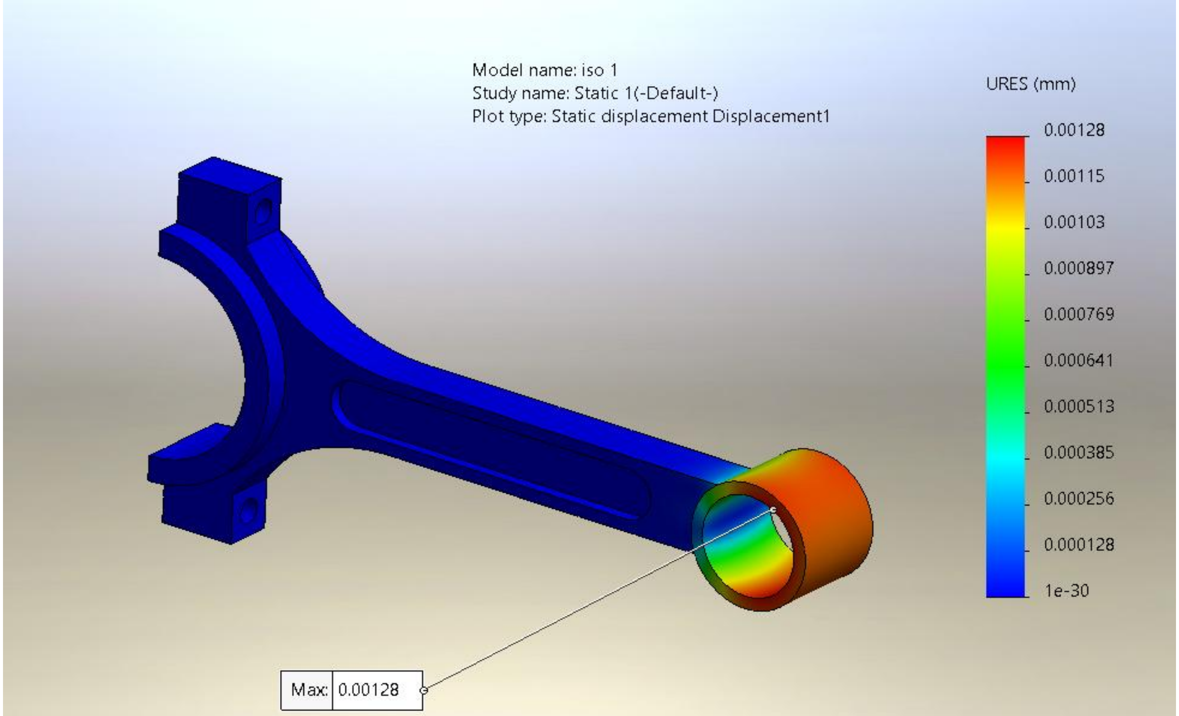


Fig 3.1 Static Displacement in Aluminum Alloy6061

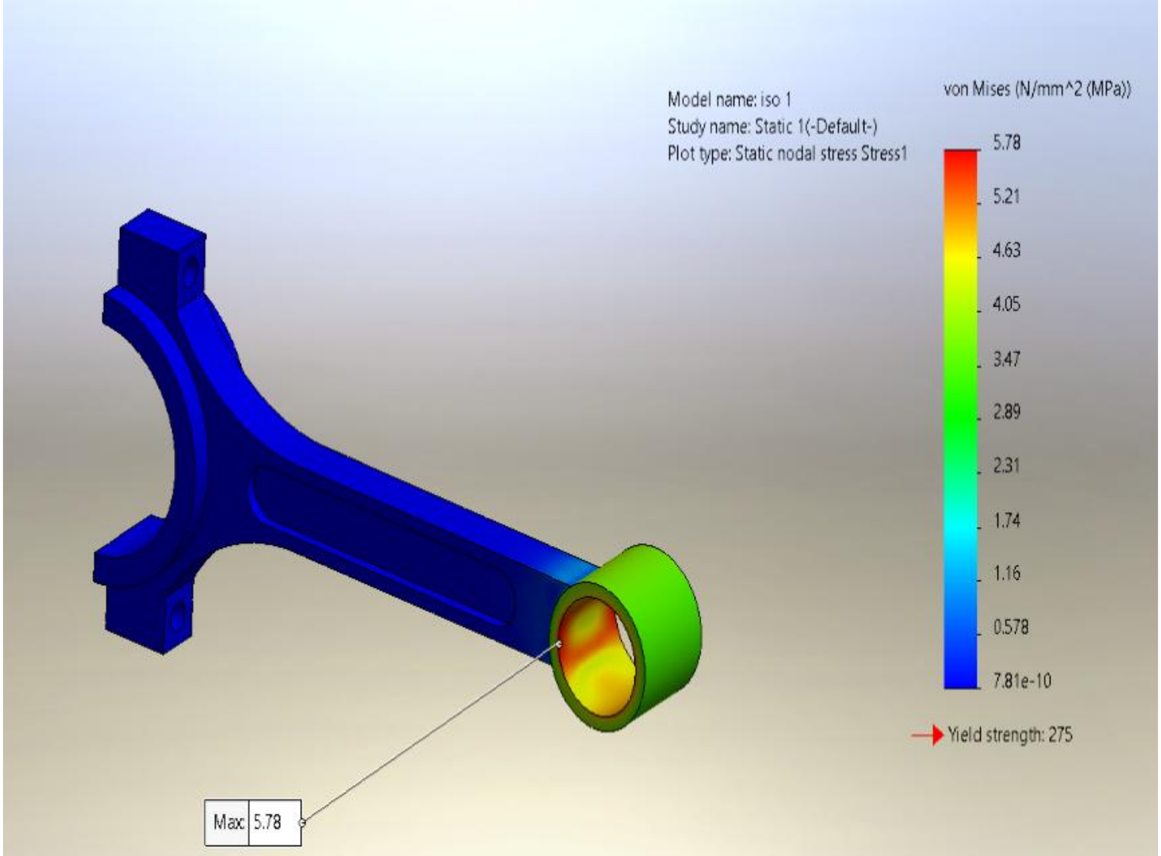


Fig 3.2 Static Stress Analysis in Aluminum Alloy6061

3.2 Boron Carbide: the following are observed

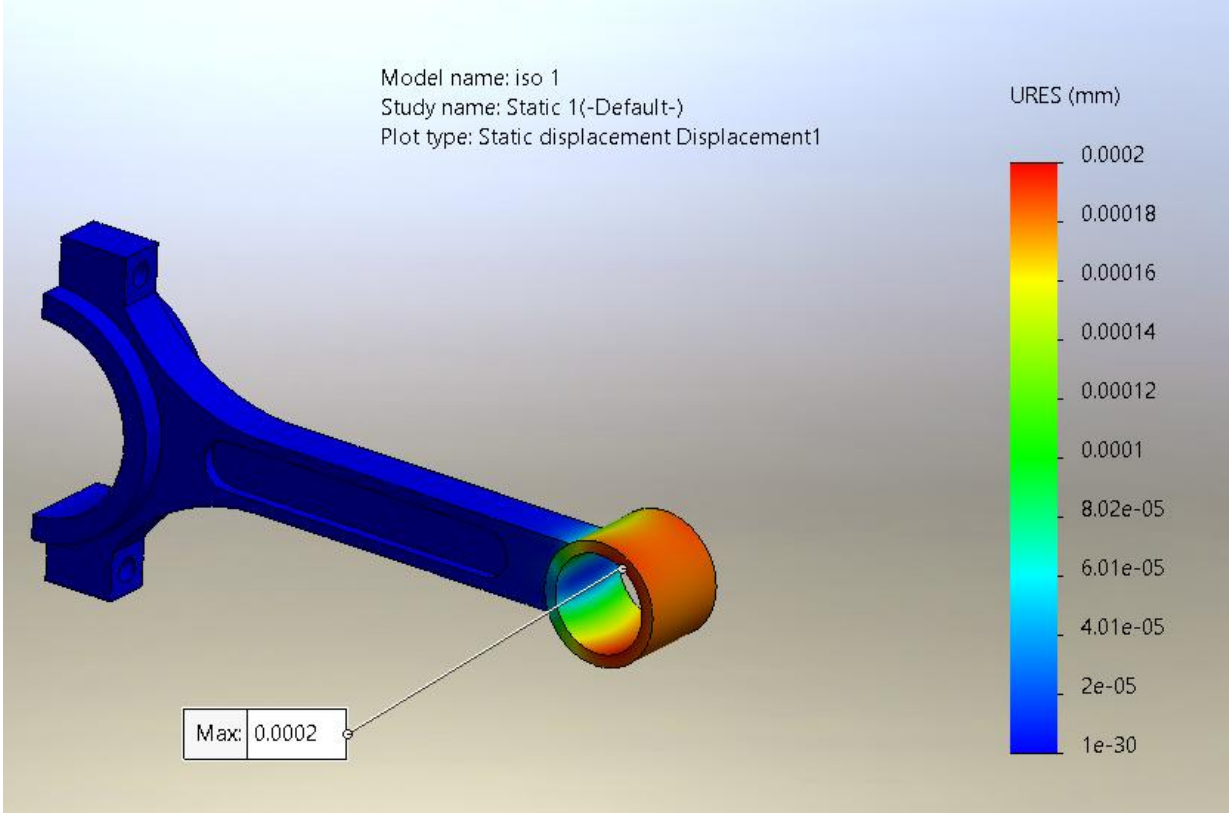


Fig 3.3 Static Displacement in Aluminium Boron Carbide (AL+B_4C)

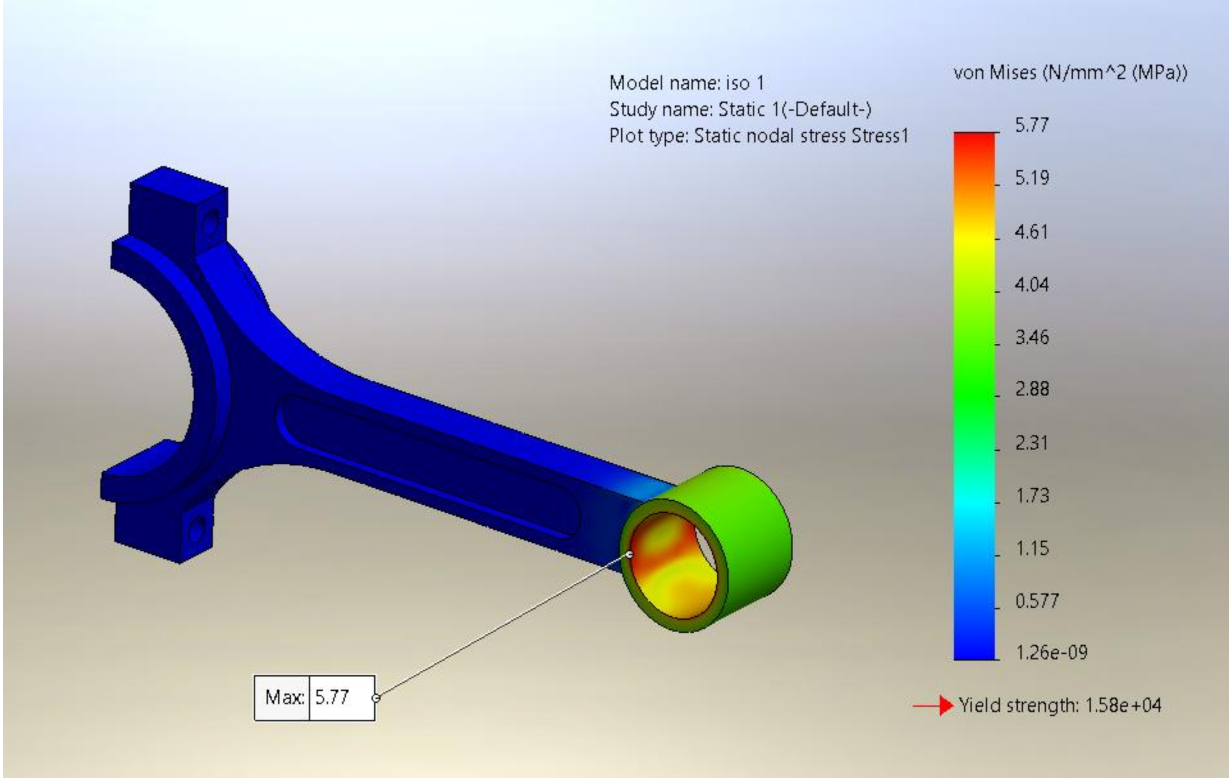


Fig 3.4 Static Stress Analysis in Aluminium Boron Carbide (AL+B_4C)

3.3 Plain Carbon Steel: the following are observed

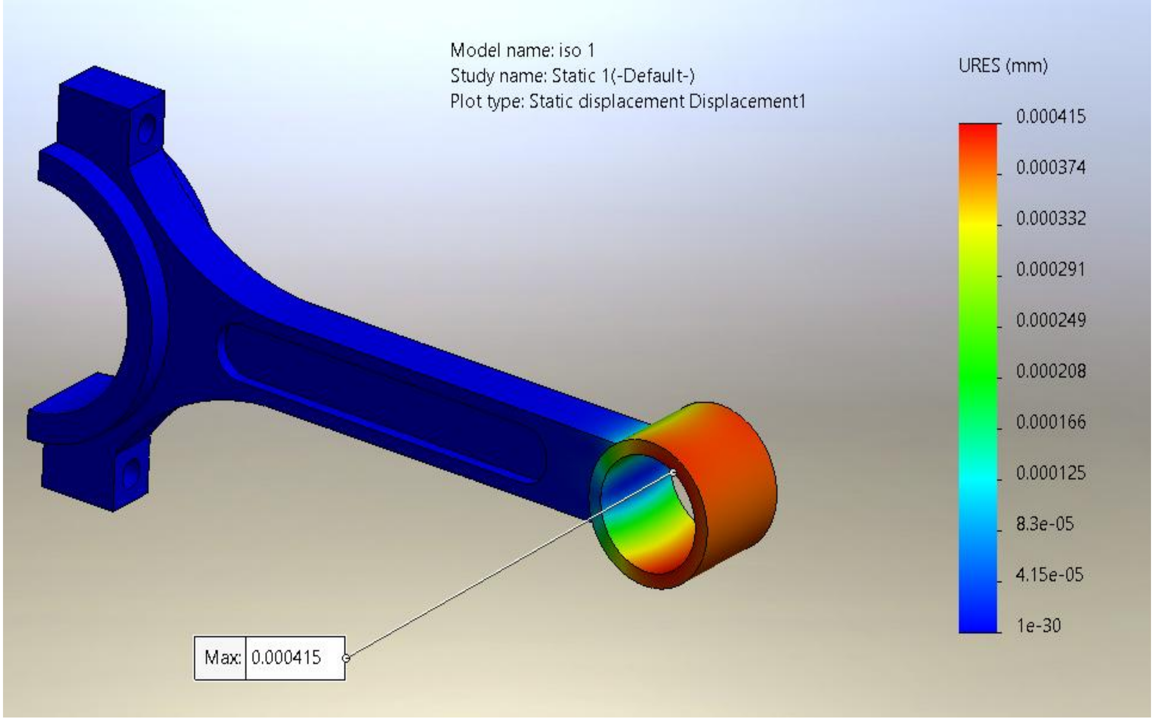


Fig 3.5 Static Displacement in Plain Carbon Steel

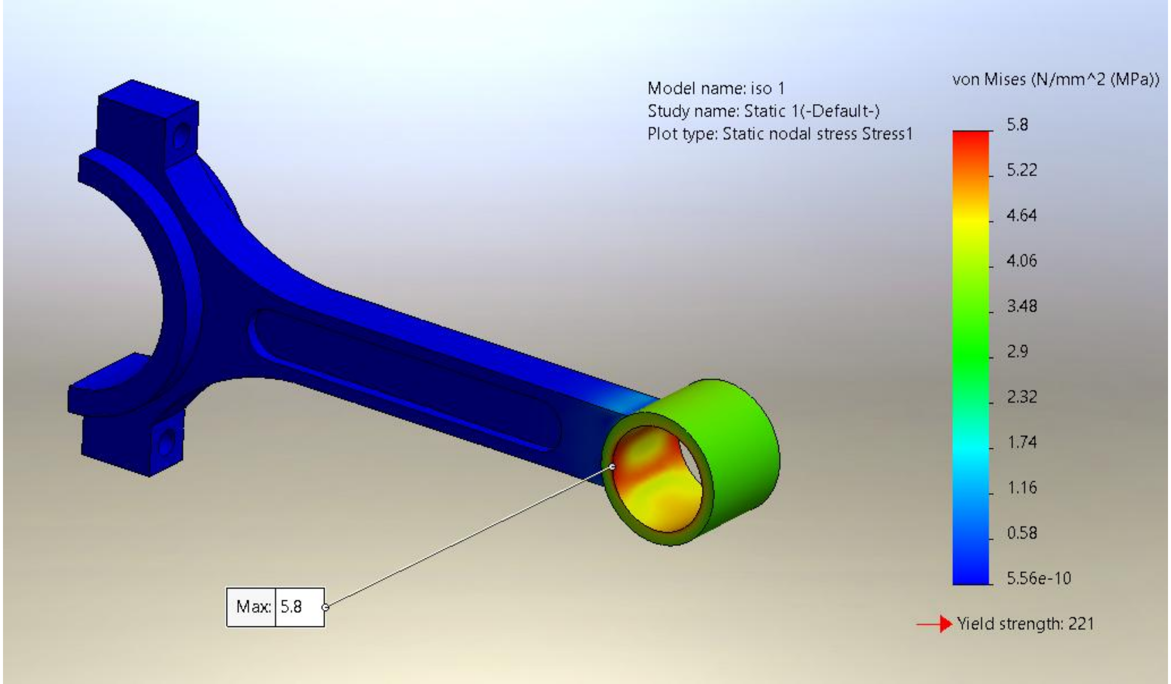


Fig 3.6 Static Stress Analysis in Plain Carbon Steel

COMPARING RESULTS

Material	Max Static Stress (MPa)	Displacement (MM)	Remarks
Aluminium Alloy 6061	5.78	0.0012	
AL+Boron Carbide	**5.77**	**0.0002**	**Has least deformed**

Plain Carbon Steel	5.8	0.000415	

From the above table we can observe that AL+Boron carbide has less deformation as compared with aluminum alloy and plain carbon steel.

Conclusion:

In automotive industries, to achieve reduced fuel consumption as well as greenhouse gas emission is a current issue of utmost importance. To reduce automobile weight and improve fuel efficiency, the auto industry has dramatically increased the use of aluminium in light vehicles in recent years.

Aluminium alloy-based metal matrix composites (MMCs) with ceramic particulate reinforcement have shown great promise for such applications. These materials having a lower density and higher thermal conductivity as compared to the conventionally used. Weight reduction of up to 50 – 60 % in the systems. Moreover, these advanced materials have the potential to perform better under severe service conditions like higher speed, higher load etc. The objective of the present work is to design and analysis of connecting rod made of Aluminium Alloy. Steel materials are used to design the connecting rod. In this project the material (Forged steel) of connecting rod replaced with Aluminium Alloy.

The present work aimed at evaluating alternate material for connecting rod with lesser stresses and lighter weight. This work found alternate material for minimizing stresses in connecting rod.

Future Scope

From analysis it is observed that the minimum stresses among all loading conditions, were found at crank end cap as well as at piston end. So, the material can be reduced from those portions, thereby reducing material cost. For further optimization of material dynamic analysis of connecting rod is needed.

After considering dynamic load conditions once again finite element analysis will have to be performed. It will give more accurate results than existing. Design modifications can be done to minimize the weight of the connecting rod and inertia force.

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Books

1. Design Data Book by Jalaluddin
2. Machine Design Data Book by VB BHANDARI