COMPARATIVE FEA AND EXPERIMENTAL ANALYSIS OF CI-ENGINE CONNECTING ROD WITH VARIOUS AA6082 MMC COMPONENTS

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Abstract - *Performance enhancement of the vapour compression refrigeration systems to gain better refrigerating effect and COP is the current need. This study investigates the effect of adding a liquid-suction heat exchanger on the performance of a vapour compression refrigeration system using R134a. In this application the liquid line is usually placed in contact with the suction line, forming a counter flow heat exchanger. The liquid line is welded to the suction line in the lateral configuration. The temperature of the vapour refrigerant coming out from the evaporator is less than the temperature of the liquid coming out from the condenser. Before the expansion process, heat is transferred from the liquid line to the suction line. As a consequence this in turn reduces the refrigerant quality at the inlet of the evaporator and therefore increases the refrigerating capacity. The LSHE is designed using SOLIDWORKS software for the VCR system and the design is based on the rate of sub-cooling and super-heating. Next to that an analysis is done using ANSYS WORKBENCH on the stream of ANSYS fluent simulation on LSHE to analyze the temperature distribution and velocity of fluid flow. The results revealed that the liquid- suction heat exchanger has a significant effect on the system performance as it influences the sub-cooling and super-heating temperatures. A theoretical analysis has been carried out on the effect of liquid suction heat exchanger on the cooling performance of VCR system. The main objective of this project is to evaluate the performance of modified system with liquid-suction heat exchanger and system without liquid-suction heat exchanger by using R134a and compare their performance improvement with the existing system.*

Key Words: *LSHE, R134a, ANSYS WORKBENCH, SOLIDWORKS, VCR system, performance improvement.*

INTRODUCTION

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. The small end attaches to the piston pin, gudgeon pin (the usual British term) or wrist pin, which is currently most often press fit into the con rod but can swivel in the piston, a "floating wrist pin" design.The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance or from failure of the rod bolts from a defect, improper tightening, or re-use of already used (stressed) bolts where not recommended. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control.

Recent engines such as the Ford 4.6 liter engine and the Chrysler 2.0 liter engine have connecting rods made using powder metallurgy, which allows more precise control of size and weight with less machining and less excess mass to be machined off for balancing. The cap is then separated from the rod by a fracturing process, which results in an uneven mating surface due to the grain of the powdered metal. This ensures that upon reassembly, the cap will be perfectly positioned with respect to the rod, compared to the minor misalignments which can occur if the mating surfaces are both flat.

However, for a given engine block, the sum of the length of the con rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the cylinder block where the cylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

1.1 SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses of connecting rod made of Forged steel. Steel materials are used to design the connecting rod. In this project the material (carbon steel) of connecting rod replaced with Forged steel .Connecting rod was created in CATIAV5 R19. Model is imported in ANSYS 13.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz., Forged steel in terms of weight, factor of safety, stiffens, deformation and stress.

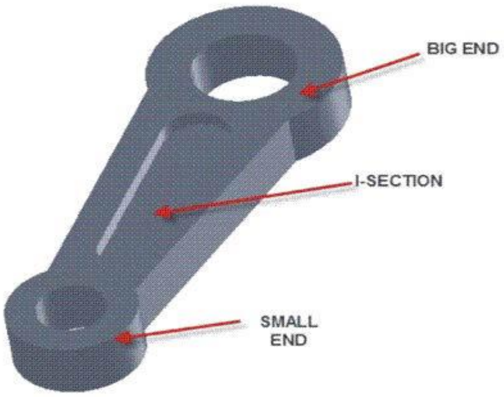


Fig: 1.1 Schematic Diagram of Connecting Rod

Fig: 1.2 Aluminium Connecting Rod

1.2 INTRODUCTION

The connecting rod is the intermediate member between piston and crankshaft. Its primary function is to transmit the push and pull from piston pin to crank pin. Thus it converts the reciprocating motion of a piston into the rotary motion of crank. These are generally manufactured by a drop forging process. The small end is lined with a gun metal bush. The brasses in the big end are of C.I. or Cast Steel and are lined with white metal. Main parts of Connecting rod are Rod, Cap, Nuts (2 Nos.), Bolts (2 Nos.) and small end bush shown in Fig.6.1.

1.3 THEORETICAL BACKGROUND

Forces acting on the connecting rod

1. Force on piston due to gas pressure and inertia of the reciprocating parts.
2. The force due to the inertia of connecting rod (Inertia bending force).
3. The force due to the friction of the piston rings and of the piston.
4. The force due to the friction of the piston pin bearings and crank pin bearing.

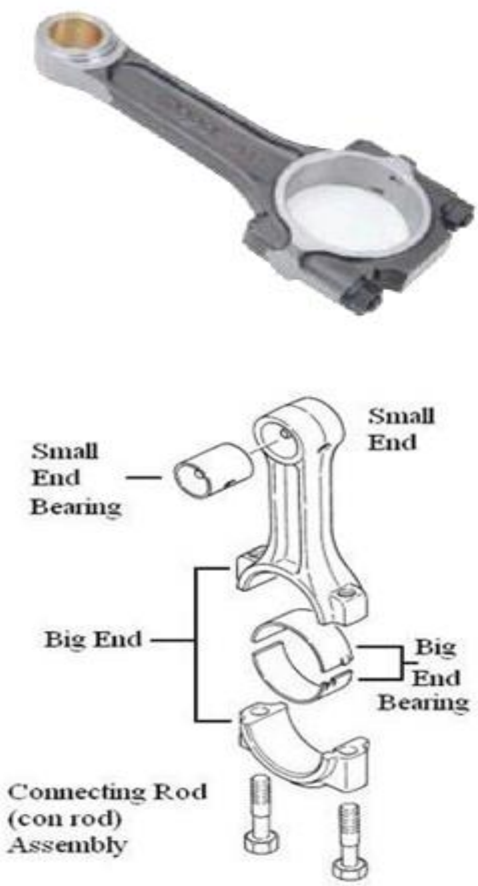


Fig: 1.3 Connecting Rod assembly with press fitted brass bush, Cap, Nuts and Bolts

The connecting rod is considered as column pillar as it is subjected to cyclic compressive and tensile load which is acting in an axial direction. During the suction stroke, the rod is subjected to the partial tensile load. During the compression stroke, the rod is subjected to the partial compressive load.

When power stroke occurs, again the rod is subjected to high compressive load and during exhaust stroke; a small amount of compressive load is there. So cyclic loading occurs with the connecting rod. For the design consideration, compressive failure should be considered which occurs during power stroke as it is higher as compared to other three strokes.

1. The connecting rod is subjected to alternating direct compressive and tensile forces.
2. Compressive forces are much higher than tensile forces; so cross section of connecting rod is designed as strut and Rankin's formula is used.
3. Due to axial load, the rod may buckle as shown in Fig. 6.2 and Fig. 6.3. Consider, the connecting rod as both the ends hinged about X axis for buckling and both ends are fixed about Y axis for buckling.

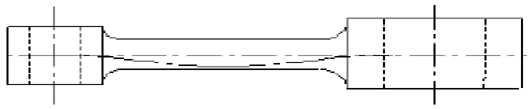


Fig: 1.4 Buckling of Connecting Rod about Y-axis (Both ends fixed Leq = *l*/2)

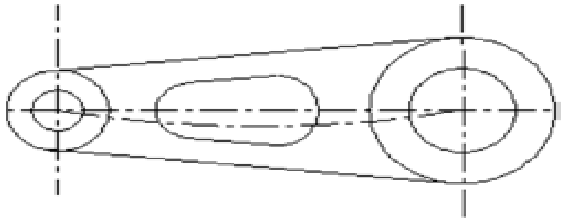


Fig: 1.5 Buckling of Connecting Rod about X-axis (Both ends hinged Leq = *l*)

According to Rankin's formula,

WB about X axis =[σc x A] / [1 + a { Lequ / Kxx }2] , for Leq = *l* ; both ends hinged. (1)

WB about Y axis = [σc x A] / [1 + a { Lequ / Kyy }2], for Leq = *l/2* ; both ends fixed. (2)

Where, Leq = Equivalent length of connecting rod.

a= Rankine's constant = 1/1600for C.I.

= 1/7500 for M.S.

= 1/9000for Wrought Iron

To have an equal strength of connecting rod in buckling about both axis, the buckling load must be equal.

LITURATURE REVIEW

A.Prem kumar [1] et.al investigated in this work connecting rod is replaced by aluminium based composite material reinforced with Boron carbide. And it also describes the modelling and analysis of connecting rod. Proe solid modelling software is used to generate the 3-D solid model of Connecting rod. Ansys software is used to analyse the connecting rod. They have analysed in this project analysis the stress, strain, deformation of connecting rod by varying material with same geometry.

Kuldeep B [2] et.al were analysed aluminium based composite material reinforced with silicon carbide and fly ash. And it also describes the modelling and analysis of connecting rod. FEA analysis was carried out by considering two materials. The parameters like von miss stress, von misses strain and displacements were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 43.48% of weight, with 75% reduction in displacement.

T.R Sydanna [3] et.al were designed the connecting rod by using design analysis procedure. Then we are modelling a connecting rod in solid works 2016 design software and doing static structural analysis in Ansys work bench 14.5 software. Thus the part which is modelled is converted into IGS file to import in Ansys work bench and static structural analysis is carried out pressure load by applying various materials including composite materials, materials used in this project are such as aluminium alloy (which is already existing), 42crmo4, aluminium based composite material reinforced with Boron carbide (Al6061+B4C).

By applying these boundary conditions on connecting rod the unknown variables such as stress, deformation, strain, and maximum shear stress are found using the FEA based software (ANSYS). 42crmo4, Al6061+B4C metals have high strength and low wear tear.

S.Kaliappan [4] et.al were syudied the total frictional power of a diesel engine is typically around 30% of the total shaft power produced by the engine. Among the constituents of the frictional losses are the losses due to piston rubbing force, pumping & blowby losses, power required to drive the auxiliary systems etc. The rubbing force that is caused by the side thrust of the piston in the cylinder, leads to distortion of the piston rings thereby causing more blowby losses. A new connecting rod and drive shaft mechanism is proposed that can substantially reduce the rubbing forces and also offers a lot of other advantages. This paper discusses the benefits that could be derived by adopting the new mechanism and also focuses on the analysis of this new mechanism. It has to be mentioned here that while this new design also impacts the thermodynamic performance of the engine, attention will be focused only on the mechanical design aspects and other modifications that need to be carried out below the zone of piston, This work is concentrate on the load acting on the connecting rod by using the methodology of Finite Element Analysis, for that Static analysis and vibration analysis had been done on the connecting rod using an analysis software.

CONNECTING ROD MATERIALS AND ITS COMPOSITES

3.1 INTRODUCTION

The ever-increasing demand for light weight, fuel efficiency and comfort in automobile industries has lead to the development of advanced materials along with optimized design. The increased demand for light-weight materials with specific strength in the aerospace and automotive industry has spread the development and use of one group of composites: metal-matrix composites (MMCs). MMCs are widely used in industries, as they have excellent mechanical properties and wear resistance. MMCs have slowly replaced some of the conventional light-weight metallic alloys such as the various grades of aluminum alloys in applications where low weight and energy saving are important considerations and yet without sacrificing the strength of the components.

Metal-matrix composites (MMCs) exhibit the ability to withstand high tensile and compressive stresses by the transfer and distribution of the applied load from the ductile matrix to the reinforcement phase. These MMCs are fabricated by the addition of a reinforcement phase to the matrix by the use of several techniques such as powder metallurgy, liquid metallurgy and squeeze-casting. The inclusions in MMC_S can be continuous fibres, discontinuous particulate or whiskers. Particulates make excellent inclusions, because they lead to predictable isotropic behavior in the composite. In addition some particulate metal matrix composites (PMMCs) are attracting attention because of their good mechanical, thermal and tribological properties. Particulate-reinforced composites cost less than fiber-reinforced composites owing to the lower cost of fibers and manufacturing cost.

Besides their increased strength, hardness and thermal conductivity, PMMCs have been found to have better wear resistance than the unreinforced matrix metal.

As a result of their improved wear resistance and excellent thermal conductivity, AlSiC PMMCs have been considered for use in automobile brake rotors. Conventional material for brake rotor is gray cast iron. The volume fraction of reinforced particles or whiskers is generally within the range 10-30%. Aluminum composites are widely employed in the aerospace industry. Hyper-eutectic Al-Si based composites such as A356 (A1, 7Si, 0.3Mg) that contain Al_20_3, ZrO, particles or Sic particles' are used in the fabrication of automotive engine components.

3.2 COMPOSITE

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their constituents (physical property of steel are similar to those of pure iron) . Favourable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

MATRIX PHASE

1. The primary phase, having a continuous character,
2. Usually more ductile and less hard phase,
3. Holds the reinforcing phase and shares a load with it.

3.3 REINFORCING PHASE

1. Second phase (or phases) is imbedded in the matrix in a discontinuous form,
2. Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

Composites as engineering materials normally refer to the material with the following characteristics:

1. These are artificially made (thus, excluding natural material such as wood).
2. These consist of at least two different species with a well defined interface.
3. Their properties are influenced by the volume percentage of ingredients.
4. These have at least one property not possessed by the individual constituents.

Performance of Composite depends on:

1. Properties of matrix and reinforcement,
2. Size and distribution of constituents,

3.3.1 CLASSIFICATION OF COMPOSITES

Composite materials are classified

a. On the basis of matrix material,

b. On the basis of filler material.

(a) On the basis of Matrix:

A. Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

B. Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibers of other ceramic material (dispersed phase).

C. Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated polyester (UP), Epoxy) or thermoplastic (PVC, Nylon, Polystyrene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

(b) On the basis of Material Structure:

1. Particulate Composites
2. Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.
3. Composites with random orientation of particles.
4. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.
5. Fibrous Composites
6. Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).
7. Composites with random orientation of fibers.
8. Composites with preferred orientation of fibers.
9. Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
10. Unidirectional orientation of fibers.
11. Bidirectional orientation of fibers (woven).

12. Laminate Composites

3.4 ALUMINUM USE IN THE AUTO INDUSTRY

Automakers lightened average car weights by about 25 percent, to about 3,000 pounds during 1978-80, doubling fuel economy and improving performance. Some industry analysts think that the average automobile will have to be lightened further, by 500 to 700 pounds (16 to 22 percent), to meet upcoming fuel efficiency and emissions requirements

OBJECTIVES

4.1 OBJECTIVES OF PRESENT WORK

Connecting rod is one of the engine's key components which connect the piston to the crankshaft and converts the piston's reciprocating motion into the crankshaft's rotation. Connecting rod must be sufficiently strong to withstand the thrust from the piston during the combustion process. During its lifespan, it faces a lot of tensile and compressive loads. The objective of this analysis is to changing the material of connecting rod for weight reduction possibilities. Model & Analysis of the connecting rod is performed with the help of SOLIDWORKS

MATERIALS AND ITS DETAILS FOR ANALYSIS

5.1ALUMINUM-7075

Al 7075 has a good surface finish; high corrosion resistance is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.

5.1.1CHEMICAL COMPOSITION OF ALUMINUM 7075

Table 5.1- Typical chemical composition for aluminum alloy 7075

ELEMENT	% PRESENT	
	MIN	MAX
Si	-	0.40
Fe	-	0.50
Cu	1.2	2.0
Mn		0.30
Mg	2.1	2.9
Zn	5.1	6.1
Ti	-	0.20
Cr	-	0.28
Al	-	-

5.1.2 AL 7075 ALUMINUMMECHANICAL PROPERTIES

Table: 5.2 AL7075 mechanical properties

Density	2.8
Melting Point	660.2
Modulus of Elasticity	68.3gpa
Thermal conductivity	0.57cal/Cms°C
Crystal Structure	Fcc
Electrical resistivity	2.69

5.1.3 APPLICATIONS OF 7075 ALUMINUM

Typical applications are Aircraft structures, Gears & shafts, Automotive

5.1.3 MACHINE ABILITY

The heat-treated alloy has fairly good machining properties, but tools should preferably be of high-speed steel and must be kept sharp. A moderately high rate of tool wear may be expected. Liberal cutting lubricant should be employed.

5.2 ALUMINUM-5083

Aluminium 5083 is known for exceptional performance in extreme environments. 5083 is highly resistant to attack by both seawater and industrial chemical environments. Alloy 5083 also retains exceptional strength after welding. It has the highest strength of the non-heat treatable alloys but is not recommended for use in temperatures in excess of 65°C.

5.2.1CHEMICAL COMPOSITION OF ALUMINUM 5083

Table 5.3- Typical chemical composition for aluminum alloy 5083

ELEMENT	% PRESENT
Manganese (Mn)	0.40 - 1.00
Iron (Fe)	0.40 max
Copper (Cu)	0.10 max
Magnesium (Mg)	4.00 - 4.90
Silicon (Si)	0.0 - 0.40
Zinc (Zn)	0.0 - 0.10
Chromium (Cr)	0.05 - 0.25
Titanium (Ti)	0.15 max
Other (Each)	0.0 - 0.05
Others (Total)	0.0 - 0.15
Aluminium (Al)	Balance

5.3 I-220-H BERYLLIUM

I-220-H beryllium is an instrument grade beryllium metal used in applications requiring high resistance to plastic deformation at low stress levels. The high resistance to plastic deformation at low stress levels is crucial for applications that require high micro-yield strength.

5.3.1CHEMICAL COMPOSITION OF I-220-H BERYLLIUM

Table 5.5- Typical chemical composition for I-220-H Beryllium

ELEMENT	% PRESENT
Aluminium	0.1 %
Beryllium	98 %
Carbon	0.15 %
Iron	0.15 %
Magnesium	0.08 %
Other	0.04 %
Silicon	0.08 %
Aluminium	0.1 %
Beryllium	98 %
Carbon	0.15 %
Iron	0.15 %

5.2.2 AL 5083ALUMINUMMECHANICAL PROPERTIES

Table: 5.6 I-220-H Beryllium mechanical properties

Density	1.86 g/cm³
Tensile strength	448 MPa
Yield strength	345 MPa

THEORITICAL CALCULATION AND DESIGN ANALYSIS

6.1. 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.

6.2 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).

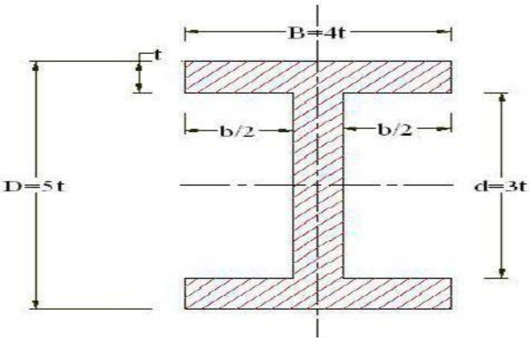
Tensile stresses occur after firing, due to piston inertia.

Bending stresses also occur after firing.

6.3 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.

DESIGN 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 = 11t²= 11×4 = 44
5. Moment of inertia about x axis Ixx= 34.91t4

= 34.91×16 = 558.56

6. Moment of inertia about y axis Iyy= 10.91t4

= 10.91×16= 174.56

7. Therefore Ixx/Iyy = 558.56/174.56 = 3.2

6.5 INTRODUCTION TO SOLIDWORKS

SolidWorks (stylized as SOLIDWORKS) is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by

Dassault Systems. According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Also, according to the company, fiscal year 2011– 12 revenue for SolidWorks totalled $483 million A.

6.6 MODELLING AND SOLIDWORKS ANALYSIS

Fig-6.1 Geometric Modal

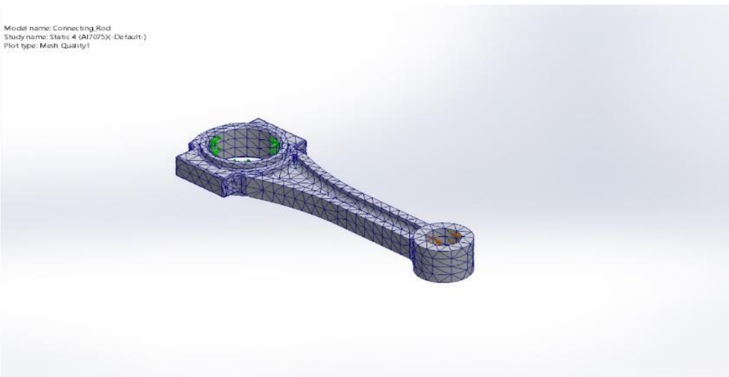


Fig-6.2 Mesh Modal

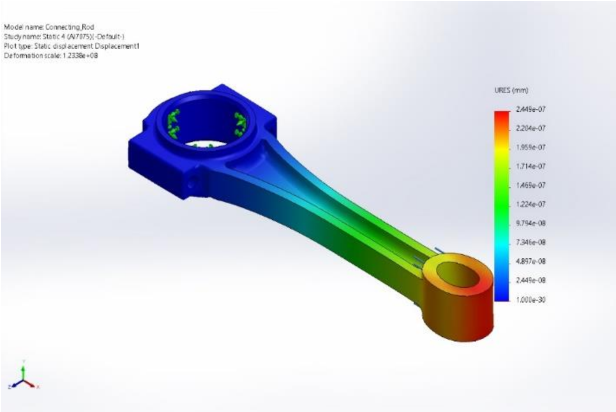


Fig-6.3 Total displacement (AA7075)

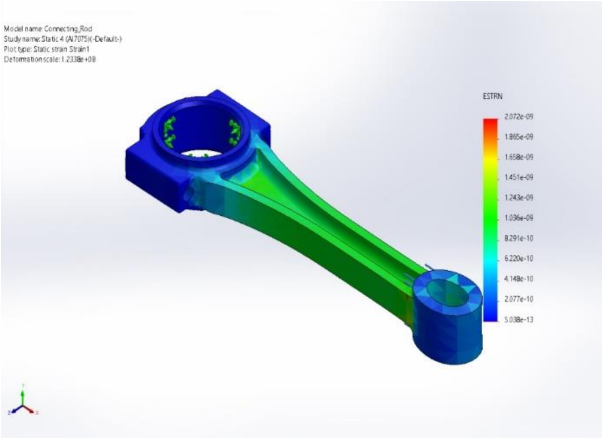


Fig-6.4 Equivalent Elastic Strain (AA7075)

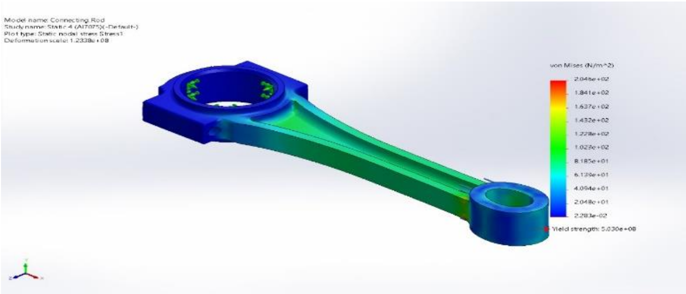


Fig-6.5 Equivalent Stress (AA7075)

Table: 6.1 Result Summery of Total Von-mises Stress, Displacement & Strain

AA7075	TYPE	MIN	MAX
Stress1	VON: von Mises Stress	2.283e-02 N/m^2	2.046e+02 N/m^2
Displacement1	URES: Resultant Displacement	0.000e+00 mm	2.449e-07 mm
Strain1	ESTRN: Equivalent Strain	5.083e-13	2.027e-09

AA5083	TYPE	MIN	MAX
Stress1	VON: von Mises Stress	2.271e-02 N/m^2	2.047e+02 N/m^2
Displacement1	URES: Resultant Displacement	0.000e+00 mm	2.497e-07 mm
Strain1	ESTRN: Equivalent Strain	5.201e-13	2.113e-09

I-220-H BERYLLIUM	TYPE	MIN	MAX
Stress1	VON: von Mises Stress	6.449e-03N/m^2	2.125e+02N/m^2
Displacement1	URES: Resultant Displacement	0.000e+00 mm	5.837e-08mm
Strain1	ESTRN: Equivalent Strain	7.666e-14 Element: 2078	4.541e-10 Element: 8434

6.7 CONCLUSION OF SOLIDWORKS FEA ANALYSIS

According to the FEA analysis we have found minimum Strain and displacement occurs at I-220-H Beryllium material. And von Mises Stress were almost equal to all the material. So we concluded regarding Strain and displacement character better than AA7075 & AA5083.

RESULT CONCLUSION

The present material used for analysis of connecting rod AA7075 & AA5083 is high deformation when compared to I-220-H Beryllium material. So, instead of aluminium alloy we have preferred I-220-H Beryllium have low deformation the result is increasing the lifetime of the connecting rod. According to the FEA analysis we have found minimum Strain and displacement occurs at I-220-H Beryllium material. And von Mises Stress were almost equal to all the material. So we concluded regarding Strain and displacement character better than AA7075 & AA5083.

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