MODELING AND ANALYSIS OF CONNECTING ROD BY USING FEA

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ABSTRACT

Connecting rod is the intermediate link between the piston and the crank and is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rods are manufactured using Steel and Aluminum alloy. In recent days Glass Epoxy materials are finding its application in connecting rod to reduce the weight of the same, which helps in reducing the overall weight of the vehicle. Design of connecting rod is complex because the connecting rod works in complicated condition (High Stresses and Loads). To obtain a best & suitable design of connecting rod to sustain various stress & forces, finite element analysis suggest the minimum design specification with the help of ANSYS. A parametric model of the Connecting rod is modeled using CATIA V5 software and to that model, analysis is carried out by using ANSYS 15.0 Software with both kinematic and static boundary conditions. Finite element analysis (FEA) of connecting rod is done by using the materials, viz... Steel & Glass Epoxy. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for four stroke petrol engine were done using ANSYS software. Linear static analysis was carried out for both isotropic materials using Solid 187 (Designated as a Solid Element in the literature of ANSYS) as element type to obtain the stress results. Comparison of both the materials shall be compiled and the post processed results were extensively presented with suitable illustrations and graphs.

Introduction

The Internal Combustion Engine (I.C Engine) is a heat engine that converts chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft. Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine, and the high-pressure gas then expands against the mechanical mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine. The crankshaft, in turn, is connected to a transmission and/or power train to transmit the rotating mechanical energy to the desired final use. For engines this will often be the propulsion of a vehicle (i.e., automobile, truck, locomotive, marine vessel, or airplane). Other applications include stationary engines to drive generators or pumps, and portable engines for things like chain saws and lawn mowers.

Most Internal Combustion Engines are Reciprocating engines having pistons that reciprocate back and forth in cylinders internally within the engine. Reciprocating engines can have one cylinder or many, up to 20 or more. The cylinders can be arranged in many different geometric configurations. Sizes range from small model airplane engines with power output on the order of 100 watts to large multi cylinder stationary

engines that produce thousands of kilowatts per cylinder.

In the Internal Combustion Engine the connecting rod plays a key role in transmitting one form energy into other in order to run the Engine. Connecting rods are used in numerous situations, most commonly in the engines of automobiles. Connecting rods connect the crankshaft to the pistons and are necessary for the proper functioning of an internal combustion engine. The purpose of a connection rod is to provide fluid movement between pistons and a crankshaft.

History of Connecting Rod

Connecting rod is an integral component of an internal combustion engine and it is classified under functional component. It acts as a linkage between piston and crank shaft.

The connecting rod as we know it today, operating inside the cylinder of an internal combustion engine, was first used in 1860, when the French inventor, Etienne Lenoir, built a small, single-cylinder, internal combustion engine. The first internal combustion engine containing connecting rod was incorporated into a vehicle in 1885 by karl benz. Optimization of connecting rod is started as early as 1983 by Webster and his team. Optimization of connecting rod is to make the less time to produce the product that is stronger, lighter and less cost.

Functions of Connecting Rod:

The main function of connecting rod is to transmit the translation motion of piston to rotational motion of crank shaft. The function of the connecting rod also involves transmitting the thrust of piston to the connecting rod. To convey cooling oil to the piston which demand for a quite a larger diameter. Connecting rod undergoes high cyclic load of order 108 to109, that why it undergoes high amount of compressive loading due to combustion as well as tensile loading due to inertia. Therefore, durability of the component is of critical importance. Since compressive forces are much higher than tensile forces, therefore the cross- section of connecting rod is designed as a pin jointed strut in which more weighted is concentrated towards the big end or crank end.

**Parts of Connecting Rod:**

Connecting rod consists of

- Piston pin end
- Shank end
- Crank end

I.   Piston Pin End: Piston pin end is a small end which connects the connecting rod to the piston through the piston pin. Piston pin end of connecting rod is connected to the piston by means of gudgeon pin.

II.   Centre Shank: It is also called the body and may take up different forms. It has a drilling through its length. The classification of connecting rod is made by the cross sectional point of view i.e..,

- I-section
- H-section
- Channel section
- Tabular section
- Circular section

I-Section   H-Section

Channel section   Circular section
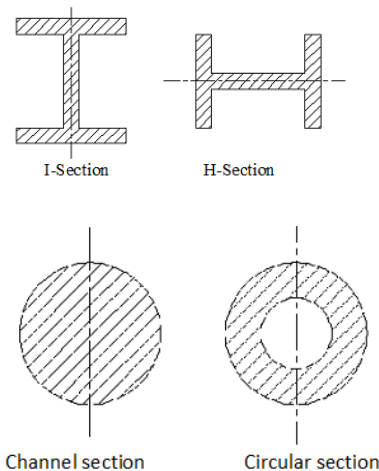
It is usually of   I–section. From view point of functionality, connecting rods must have the highest possible rigidity at the lowest weight.

III.   Crank End: The crank end is a big end which is usually split to surround crank pin end. The location of center of gravity point of connecting rod lies more towards the big end.
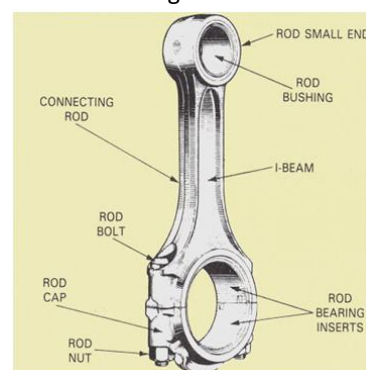
Types of Connecting Rod:-

The different types of connecting rods are:

- Marine type
- Fixed center type
- Fork and blade type
- Articular type

Lubrication of Connecting Rod: It is carried out through the shank bore (drilling) running throughout the shank length. It conducts oil from the big end to the small end for lubrication and to the inside of piston for its cooling.

Forces Acting on Connecting Rod: Connecting rod acted upon by two forces

- Gas loads
- Inertia loads

i.   Gas Forces: The gas force are due to combustion .the magnitude of forces are varying in nature. These forces are due to maximum gas pressure.

ii.   Inertia Force: The inertia forces are due to its own weight .the magnitude of these forces are constant. These forces are due to reciprocating mass.

Stresses and Failure of Connecting Rod: 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 square of the engine speed increase. 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 over-revving of the engine. Re-use of rod bolts is a common practice as long as the bolts meet manufacturer specifications. 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.

Causes for Failure of Connecting Rod

CAUSES	FAILURE
Improper material selection	37%
Fabrication defects	16%
Improper heat treatments	14%
Design errors	12%
Unexpected operating conditions	9%
Fatigue	24%

Manufacturing and Materials of Connecting Rod:

- Manufacturing

The connecting rod is being manufactured by different process such as

- Casting
- Powder metallurgy
- Drop forging

The life of connecting rod is evaluated by the type of process in which it is manufacturing process.

MATERIALS:

The most materials used for connecting rod are as follows:

- Steel
- Aluminium
- Titanium

a.   Steel: Steel rods are the most widely produced and used type of connecting rods. Their application are best used for daily drivers and endurance racing due to their high strength and long fatigue life. The only problem with using steel rods is that the material is extremely heavy, which consume power and stress to the rotating assembly.

b.   Aluminium: Aluminium rods are used widely high horse power, high revolving drag engine. These are 40% lighter than a steel connecting rod. Reducing the weight of rods reduces the mass of the rotating and reciprocating parts and allows the engine to revolve faster and safely. It also reduces vibration and stress on the crankshaft.

c.   Titanium: It has been reported that connecting rods have been forged out of titanium for racing engines. The steel die is sprayed with a MOS2 coating to prevent oxidation of titanium during forging process. Many formula1 race can utilize titanium connecting rod to achieve these 18,000rpm engine speed.

APPLICATIONS OF CONNECTING ROD: The connecting rod are widely used in variety of engines such as,

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- In –line engine
- V-engine
- Opposed cylinder engine.

Literature Review

K. Sudershan kumar [1] et al, described modeling and analysis of Connecting rod. In his project carbon steel connecting rod is replaced by aluminium boron carbide connecting rod. Aluminium boron carbide is found to have working factory of safety is nearer to theoretical factory of safety, to increase the stiffness by 48.55% and to reduce stress by 10.35%.

Vivek. C. Pathade [2] et al, he dealt with the stress analysis of connecting rod by finite element method using pro-e wild fire 4.0 and ansys work bench 11.0 software. And concluded that the stress induced in the small end of the connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end.

Pushpendra Kumar Sharma [3] et al, performed the static FEA of the connecting rod using the software and said optimization was performed to reduce weight. Weight can be reduced by changing the material of the current forged steel connecting rod to crackable forged steel (C70). And the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage.

Ram Bansal [4] et al, in his paper a dynamic simulation was conducted on a connecting rod made of aluminum alloy using FEA. In this analysis of connecting rod were performed under dynamic load for stress analysis and optimization. Dynamic load analysis was performed to determine the in service loading of the connecting rod and FEA was conducted to find the stress at critical locations.

Procedure of Creating a Model of Connecting Rod in CATIA: Engine Specifications

Engine Type	In-Line Engine
Engine Description	1.4L 75bhp 4 cyl. In-line
Engine Displacement(cc)	1390
No. of Cylinders	4
Maximum Power	75@5,500 (PS@rpm)
Maximum Torque	110@3,000 (kgm@rpm)
Valves Per Cylinder	4

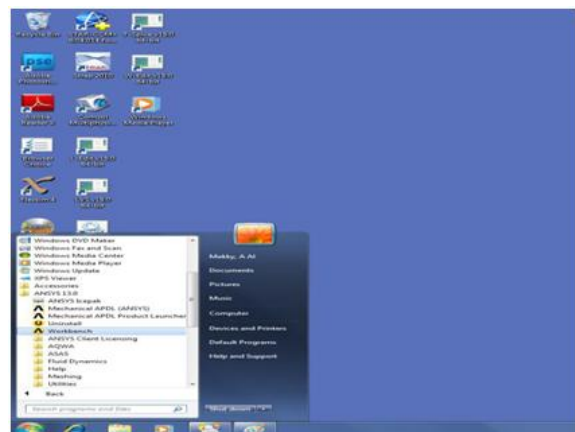| Valve Configuration	SOHC
Fuel Supply System	MPFI
Bore x Stroke	76 x 80.5 mm
Compression Ratio	9.5:1

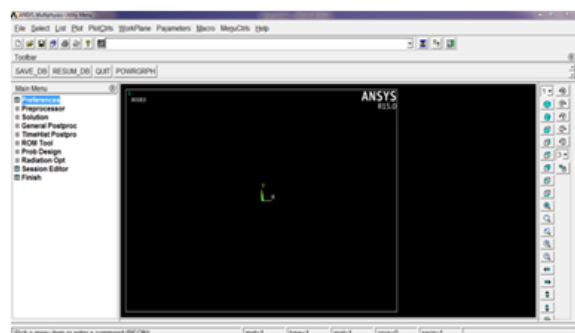## Dimensions of Connecting Rod
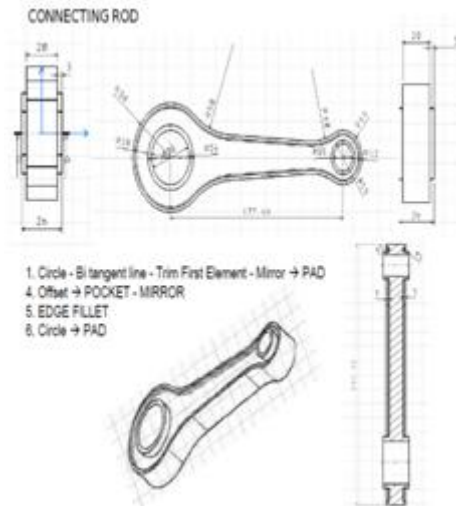
Procedure

The Procedure for Formulation of Analysis of Connecting Rod is Discussed Below:

Step1: Launch ANSYS ,by going to the start-up menu and double clicking on mechanical APDL file in the ANSYS 15.0 folder.

Step 2:-Once the program is launched it should look like as shown below.

Step 3:- Define the Analysis

Main Menu>Preferences

The following window comes up. Select the type of analysis and click on OK.
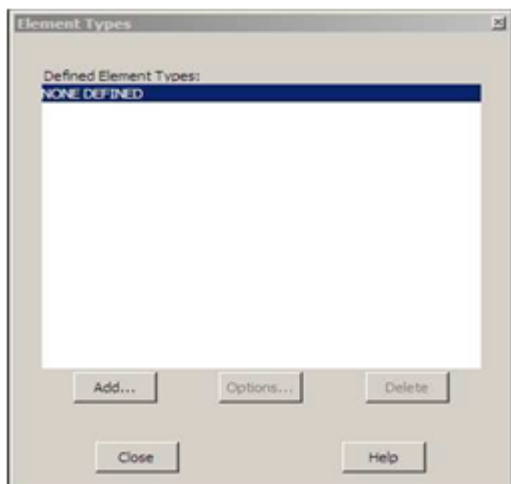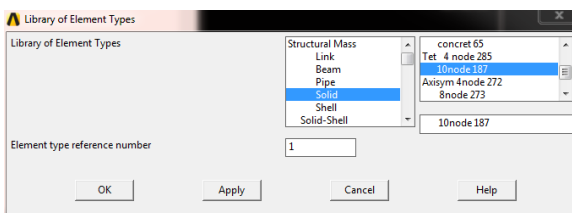

Step 4:-Preprocessor

1.   Define an element type:
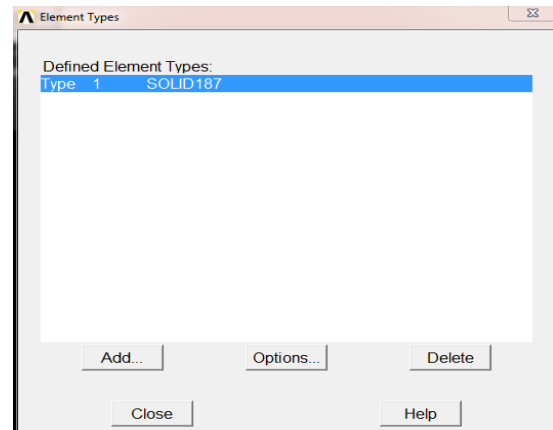
Main Menu>Pre-processor>Element Type>Add/Edit/Delete

•   This brings up the 'Element Types' window. Click on the Add... button.

•   The 'Library of Element Types' window appears. Highlight `Solid', and `10 node 187', as shown. Click on OK.

•   You should see `Type 1 SOLID187 ' in the `Element Types' window as follows:

•   Click on the Options... button in the above window. The below window comes up. Select `Pure Displacement ' for `Element Formulation K6' and click OK.
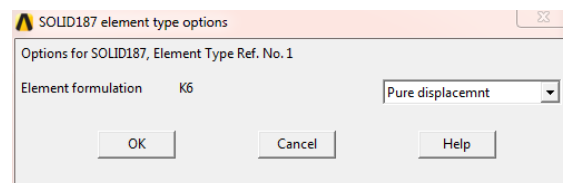
•   Click on the Close button in the `Element Types' window.

Define Material Properties

Main Menu>Preprocessor>Material Props>Material Models

•   In the right side of the `Define Material Model Behavior' window that opens, double

Click on `Structural', then `Linear', then `Elastic', then finally `Isotropic'.
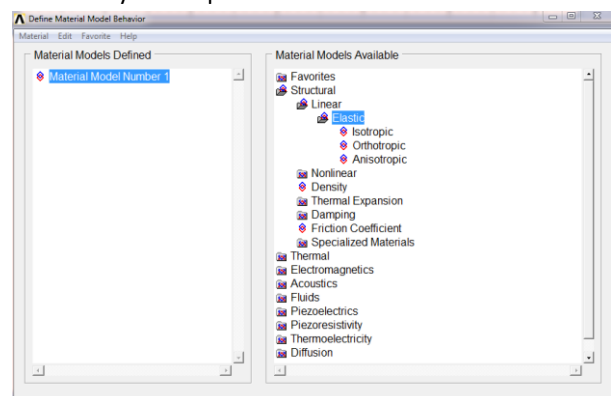
•   The following window comes up. Enter in values for the Young's modulus and Poisson's ratio of the Solid material and enter the values of density also.

MATERIAL	ELASTIC MODULUS(N/mm^2)	POISSION'S RATIO	DENSITY (tone/mm^3)
Steel	2.10 x 10^{05}	0.3	7.89 x 10$^-$

			09
Glass	6.00×10^{04}	0.22	2.50×10^{-09}

• Click OK, and then close the `Define Material Model Behavior' window.

Modelling of rod

As connecting rod is a complex structure, it cannot be efficiently drawn in ANSYS (options available to model in ANSYS are limited) so other CAD Packages like CATIA V5 is utilized for creating the three dimensional model of the connecting rod.

A model of the connecting rod using CATIA V5 software is created using step-by-step procedure with the commands and tools is discussed before. Thus the connecting rod model created in CATIA V5 is being imported into Ansys 15.0 for Analysis as shown below.

File>Import>Catia v5

• This brings up the 'ANSYS CATIA V5 Import' window.
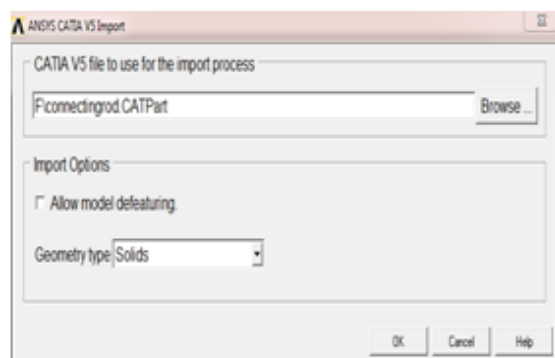
• Click on the Browse button; Select the file located in the system and click OK. This brings up the window.
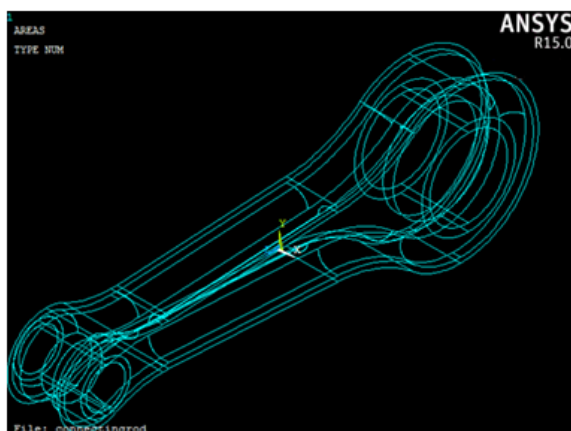
• Turn on the numbering by selecting Utility Menu>Plot Ctrls>Numbering…. The Below window appears. Check the boxes for `Area numbers' as shown, and then click on OK.
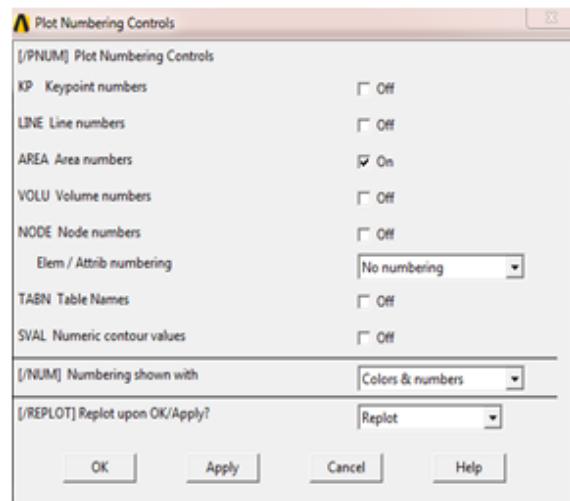
• Select Utility Menu>Plot>Areas. Your graphics window looks like this,

Mesh the connecting rod Model

Main Menu>Preprocessor>Meshing>Mesh>Areas>Free

• Pick the area. Click OK in the picking window.

• Close the `Warning' window. In your ANSYS window, a meshed connecting rod appears as shown below.

Apply Loads

I. Boundary Conditions

Main Menu>Preprocessor>Loads>Define Loads>Apply>Structural>Displacement>Symmetry B.C.>…with Area

• Pick Area #81, 82. Click Apply (in the picking window). Pick the area. Click OK.
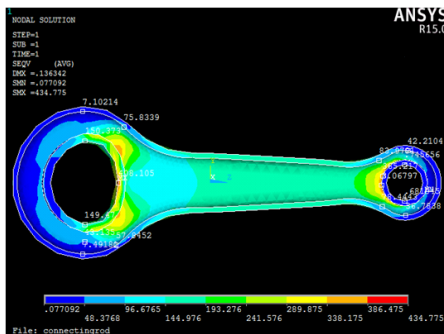
Apply Loads:

Main Menu>Preprocessor>Loads>Define Loads>Apply>Structural>Pressure>On Areas

• Pick Area #79. Click OK in the picking window.

• In the below window that comes up, select `Constant value' for `Apply PRES on Areas as a',

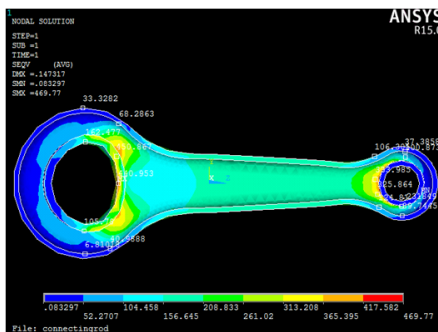• Enter `value ' for `Load PRES value', then click OK.
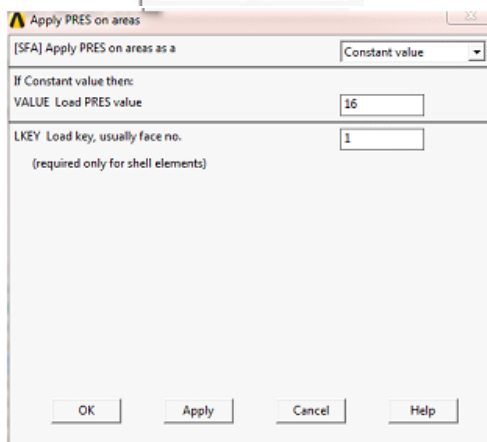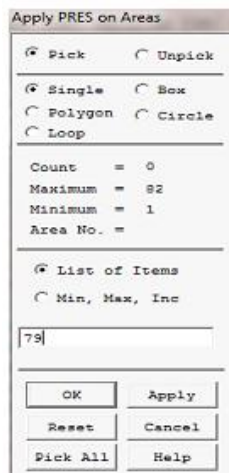
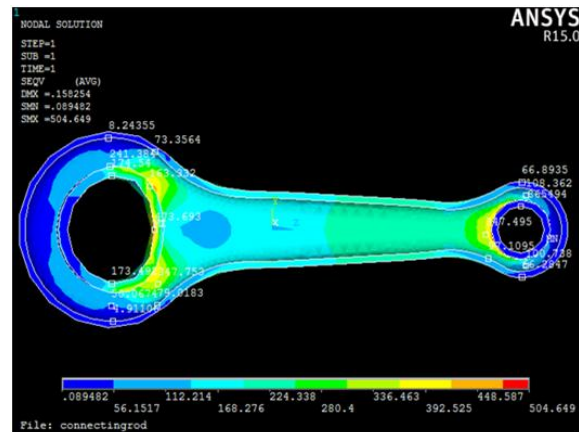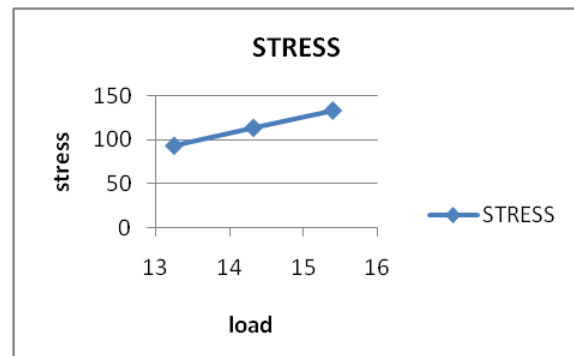Steel
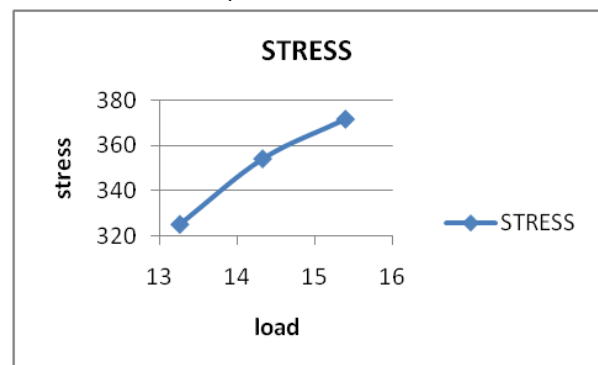At 13.26 KN

AT 14.325 KN

At 15.39 KN

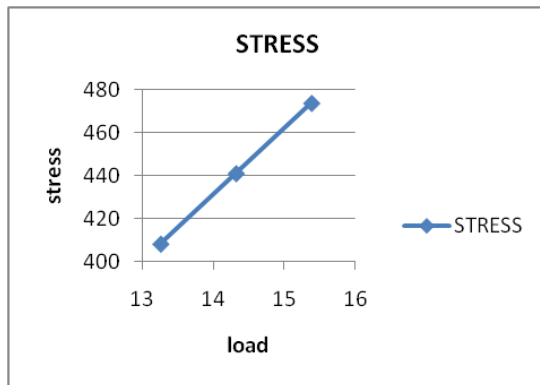Table: -STEEL Stress at Different Sections Corresponding to Load

Loads applied	Max stress on the sections (MPa)			
(KN)	A-A	B-B	C-C	D-D
13.26	150.373	408.105	325.217	93.358
14.325	163.477	440.953	353.985	113.479
15.39	177.385	473.693	371.362	132.82

Graph:-Section A-A

Graph: Section B-B

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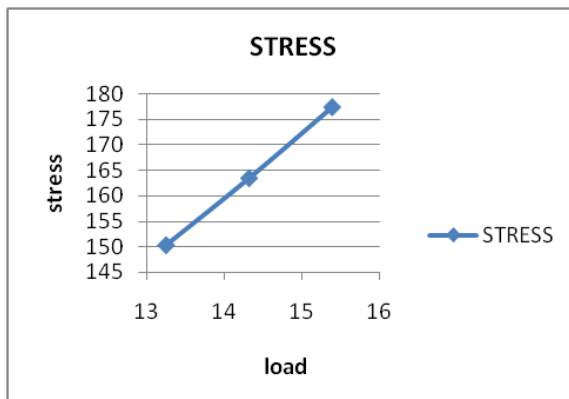
Graph: Section C-C

Graph: Section D-D

Glass Epoxy

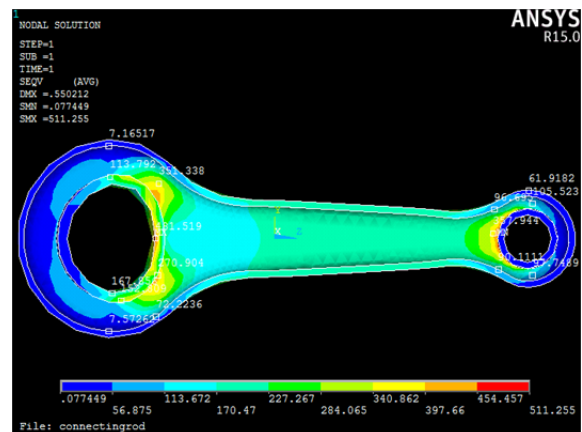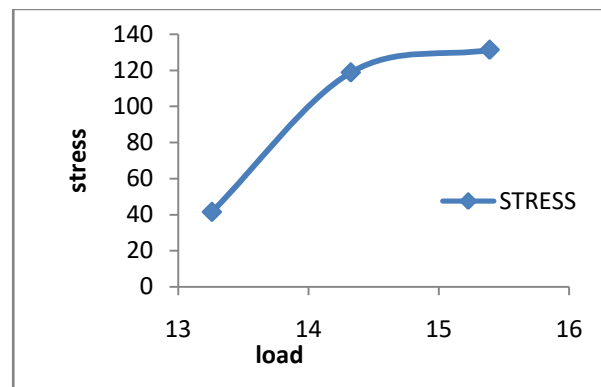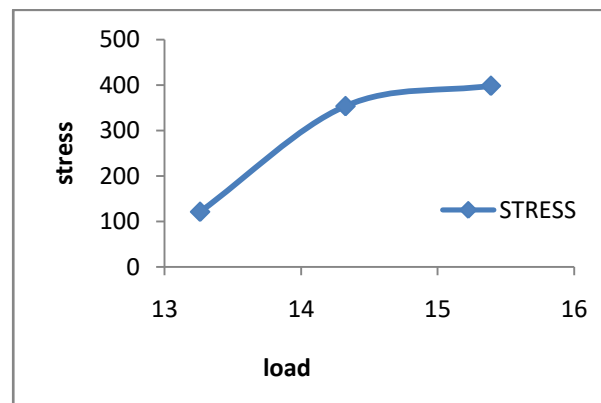At 13.26 KN
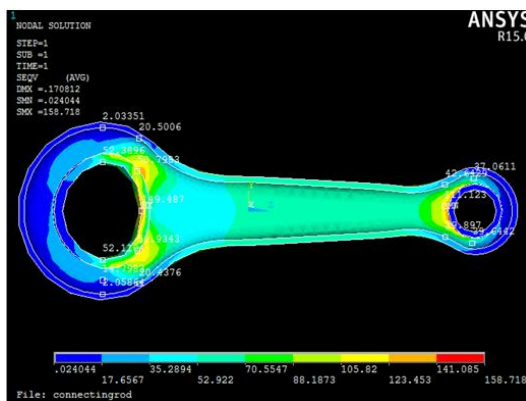
AT 14.325 KN
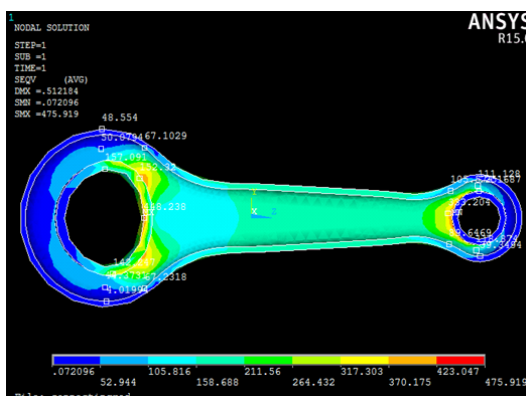
At 15.39 KN

Table: GLASS EPOXY Stress at Different Sections Corresponding to Load
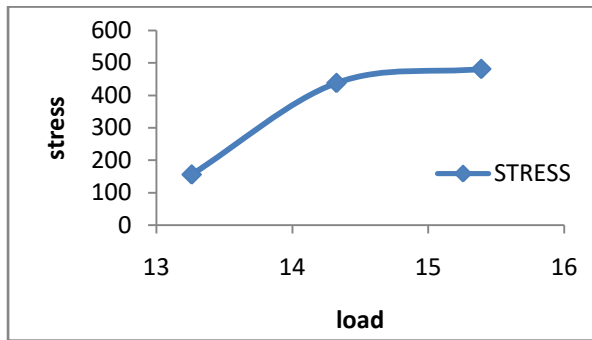
Loads applied (KN)	Max stress on the sections (MPa)			
	A-A	B-B	C-C	D-D
13.26	53.3896	155.487	121.123	41.552
14.325	143.091	438.239	353.204	118.874
15.39	173.856	481.519	397.944	131.436

Graph: Section A-A

Graph: Section B-B

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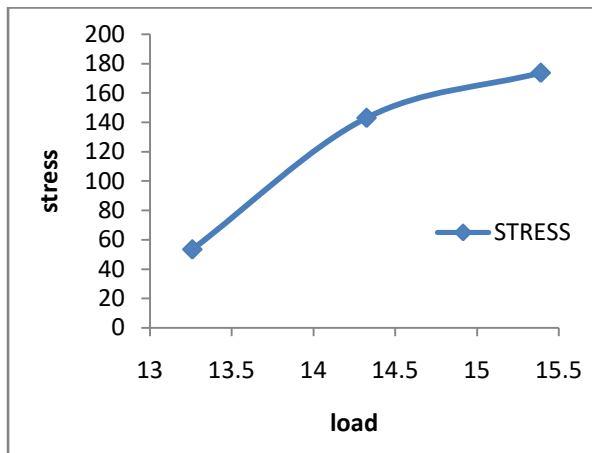
Graph:- Section C-C

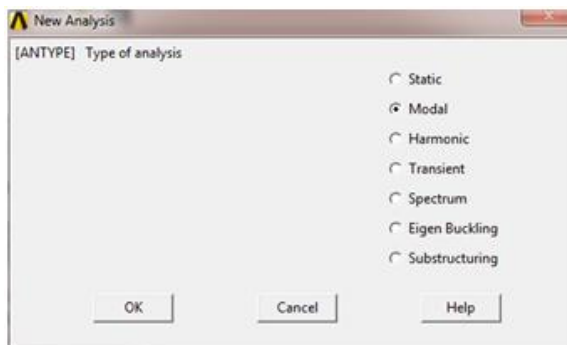

Graph: Section D-D

Modal Analysis

- Remove all the applied boundary conditions and loads which are taken during the static analysis and further proceed for generating solutions.

Step 5:-Processing (Solving):

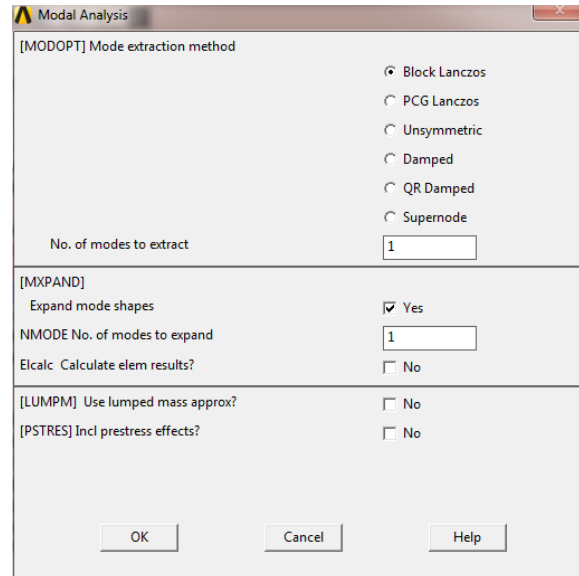Main Menu>Solution>Analysis Type>New Analysis

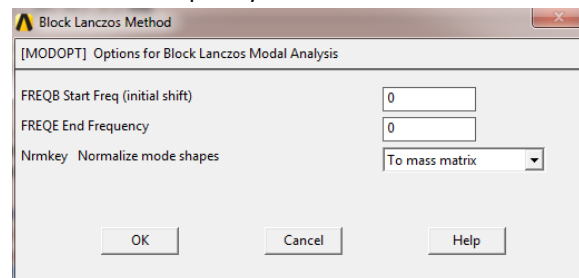- This brings up the window below and select Modal, and click OK.

- Make sure that `Modal' is selected. Click OK.

Main Menu>Solution>Analysis Type>Analysis Options

- This brings up the window below and select one of the Mode extraction method and assaign no of modes to extract, and click OK.
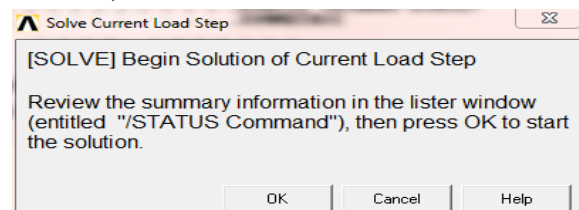

- This brings up the window below, Assaign the Frequency values and click OK.

Main Menu>Solution>Solve>Current LS

- Check your solution options listed in the `/STATUS Command' window.

Click the OK button in the `Solve Current Load Step' window

- Click the Yes button in the `Verify' window.

- You should see the message `Solution is done!' in the `Note' window that comes up. Close the `Note' and `/STATUS Command' windows.
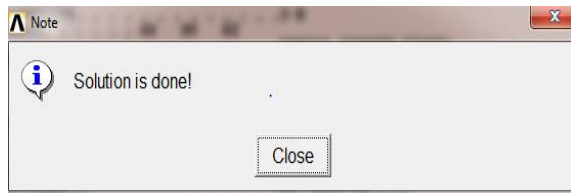
- The Graphical view of connecting rod with Displacement Vector sum for both the Steel and Glass Epoxy Materials is shown below.
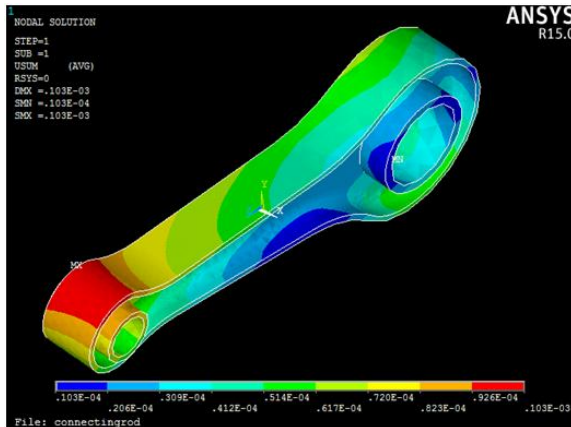
Steel

Table: Max Displacement at various Nodes

	UX	UY	UZ	USUM
Node	7682	3198	3188	5072
Displacement	0.97745×10^{-04}	0.54472×10^{-04}	0.11266×10^{-04}	0.10292×10^{-03}

From the above table the maximum Displacement is 0.10292×10^{-03} at the Node 5072.
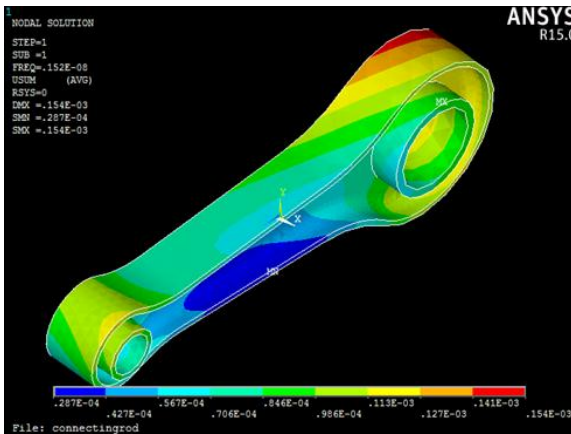
Glass Epoxy

Table:-Max Displacement at various Node From the above table the maximum Displacement is 0.15464×10^{-03} at the Node 4992.

	UX	UY	UZ	USUM
Node	4988	4996	4987	4992
Displacement	-0.83241×10^{-04}	0.14283×10^{-03}	0.74982×-04	0.15464×10^{-03}

Conclusion

Finite element methodology is one of the best tools to analyse any mechanical structure. Utilizing ANSYS, as the software for FEM among all the available software's, connecting rod model in 3 dimensions has been analysed by suitably discretizing it using Structural solid elements. The model is subjected to rigorous static and modal analysis to generate the subsequent displacement and stress vectors. The values taken for the process has been taken from the data available on the dimensions and conditions of the connecting rod. The values previously generated have been compared with the current analysed model, and the results were found in accordance with the available values. Computed results are illustrated both in numerical and graphical form.

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1. R.S. Khurmi, A Textbook of Machine Design, S.Chand publishers, 25th Revised edition edition India.2005.ISBN: 978-8121925372
2. NPTEL lectures
3. K. Sudershan Kumar, Dr. K. Tirupathi Reddy, Syed Altaf Hussain, "Modeling and Analysis of Two Wheeler Connecting Rod", International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.5, Sep- Oct. 2012 pp-3367.Nandyal, India"
4. Ram Bansal, Dynamic Simulation of a Connecting Rod made of Aluminium Alloy using Finite Element Analysis Approach, IOSR journal of mechanical and civil engineering volume 5 issue 2 pp01-05
5. P. K. Sharma, B. Rajendra, Fatigue Analysis and Optimization of connecting rod using Finite Element Analysis. International Journal Of advance research in Science and Engineering, Vol. No.1, Issue No. I, pp-3367-3371, September 2012.

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