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# Structural Static Analysis of Knuckle Joint

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## ABSTRACT:

A Knuckle joint is used to connect two rods under tensile load. This joint permits angular misalignment of the rods and may take compressive load if it is guided. These joints are used for different types of connections i.e. tie rods, tension links in bridge structure. In this, one of the rods as an eye at the rod end and other end is forked with eyes at the both the legs. A pin (knuckle pin) is inserted through the rod-end and fork end eyes and is secured by collar and a split pin. Normally, empirical relations are available to find different dimensions of the joint and they are safe from design point of view. The aim of the present paper is to study calculate the stresses in Knuckle joint using analytical method. Further study in this direction can made by using various directions of the pin and the capacity to withstand load.

The present work is concentrating on which type of meshing is preferable for components. Here knuckle joint is modeled by making use of  CATIA V6 R20, later on that model is imported in ANSYS 15.0 and carried out both mesh those are hexahedral and tetra mesh.  Many systems used in industries use knuckle joint which is combination of two materials: cast iron and stainless steel. Here we are proposing the modifications of materials are Steel, AL 6061-T6 and Teflon. Structural analysis was carried out on the Knuckle Joint at loads of 100N, 105N, 110N and 115N. The best combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and weight reduction for knuckle jointwere done in ANSYS software. Teflon has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material.

## 1 INTRODUCTION:

A knuckle joint is a mechanical joint used to connect two rods which are under a tensile load, when there is a requirement of small amount of flexibility, or angular moment is necessary. There is always axial or linear line of action of load.

### 1.1 Parts of a Knuckle Joint:

A typical knuckle joint has the following parts:

1. Fork end
2. Eye end
3. Knuckle pin
4. Collar
5. Taper pin

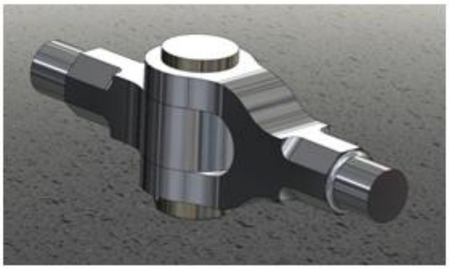

Fig.1.1 Knuckle joint

The steering knuckle on your vehicle is a joint that allows the steering arm to turn the front wheels. The forces exerted on this assembly are of cyclic nature as the steering arm is turned to maneuver the vehicle to the left or to the right and to the centre again. Steering knuckles come in all shapes and sizes. Their designs differ to fit all sorts of applications and suspension types. However, they can be divided into two main types. One comes with a hub and the other comes with a spindle. In this investigation, steering knuckle was used as component for study. Mass or weight reduction is becoming important issue in car manufacturing industry.

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Weight reduction will give substantial impact to fuel efficiency, efforts to reduce emissions and therefore, save environment. Weight can be reduced through several types of technological improvements, such as advances in materials, design and analysis methods, fabrication processes and optimization techniques, etc. Steering Knuckle is subjected to time varying loads during its service life, leading to fatigue failure.

### 1.2 Modes of failure are:

A knuckle joint has nine possible modes of failure. They are:

1. Failure of rod end by tension
2. Failure of rod end by double shear
3. Failure of rod end by crushing
4. Failure of forked ends by tension
5. Failure of forked ends by double shear
6. Failure of forked ends by crushing
7. Failure of knuckle pin by tension
8. Failure of knuckle pin by double shear
9. Failure of knuckle pin by bending.

### 1.3 Possible Failure Modes of Knuckle Joint

Tensile Failure of Rods:
Each rod is subjected to a tensile force P.

$$\text{Tensile stress in the rods} = \sigma_t = \frac{P}{\frac{\pi}{4}D^2} \leq [\sigma]$$

where [σ] = allowable tensile stress for the material selected.
Shear Failure of Pin:
The pin is subjected to double shear as shown in Figure 8.2

$$\text{Shear Stress in the pin,} \quad \tau = \frac{P}{2\left(\frac{\pi}{4}d^2\right)} \leq [\tau]$$

Crushing Failure of Pin in Eye :
Projected Area of Pin in the eye = b d

$$\text{Crushing Stress,} \quad \sigma_{crushing} = \frac{P}{b\,d} \leq [\sigma_c]$$

where $[\sigma_c]$ = allowable compressive stress for the material selected.

### Crushing Failure of Pin in Fork:

Projected Area of Pin in the fork = 2 a d

$$\text{Crushing Stress,} \quad \sigma_{crushing} = \frac{P}{2\,a\,d} \leq [\sigma_c]$$

### 1.4 Bending Failure of Pin:

When the pin is tight in the eye and fork, failure occurs due to shear, but when it is loose, it is subjected to bending moment as shown in Figure 8.5. It is assumed that: Load acting on the pin is uniformly distributed in the eye and uniformly varying in the two parts of the fork. Maximum Bending Stress in the pin,

$$\sigma_b = \frac{My}{I} \leq [\sigma]$$

### 1.5 Tensile Failure of Eye:

Area of the weakest section of eye resisting tensile failure = b ($d_0$ – d)
Maximum Tensile Stress in eye,

$$\sigma_t = \frac{P}{b\,(d_0 - d)} \leq [\sigma]$$

### 1.6 Shear Failure of Eye:

The eye is subjected to double shear
Maximum Shear Stress in eye =

$$\tau = \frac{P}{b\,(d_0 - d)} \leq [\tau]$$

### Tensile Failure of Fork :

Area of the weakest section of fork resisting tensile failure = 2a ($d_0$ – d)
Maximum Tensile Stress in fork =

$$\sigma_t = \frac{P}{2a\,(d_0 - d)} \leq [\sigma]$$

### 1.7 Shear Failure of Fork:

Each of the two parts of the fork is subjected to double shear.

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Maximum Shear Stress in fork =

$$\tau = \frac{P}{2a\,(d_0 - d)} \leq [\tau]$$

### 1.8 Design of knuckle joint:

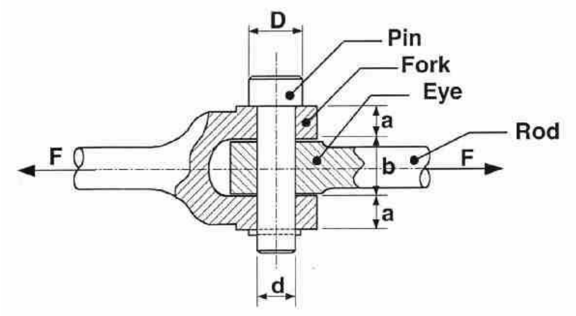


Fig 1.2 Parts of knuckle joint

In order to find out various dimensions of the parts of a knuckle joint, failures in different parts and at different x-sections are considered. The stresses developed in the components should be less than the corresponding permissible values of stress. So, for each type of failure, one strength equation is written and these strength equations are then used to find various dimensions of the knuckle joint. Some empirical relations are also used to find the dimensions. Knuckle joints may be cast or fabricated or forged. In the knuckle joint illustrated, the rods are integral with the eye and fork (forged construction). However, the knuckle joint is often separate to the rods, and the rods need to be welded or screwed into the eye and fork. In the knuckle joint illustrated, there is no separate bearing and rotational or motion occurs between the pin and eye or pin and fork or both. If there is considerable movement, it may be necessary to use bearings to minimise friction and wear. If this is the case, the pin is usually a tight fit in the eye or held to the eye with a grub screw and bearings are provided in the fork. The bearings may be plain bearings or rolling element bearings.

## 2. LITERATURE SURVEY

**Sangamesh B. Herakal et.al. [1]** In his paper they studied the stresses in Knuckle joint using analytical method. Further study in this direction can made by using various directions of the pin and the capacity to withstand load. The present work is concentrating on which type of meshing is preferable for components.

**Sanjay Yadav et.al. [2]** In their research paper they have done static analysis of steering knuckle component. The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE

**Mahesh P. Sharma et.al. [3]** In their research they have done static analysis of steering knuckle. We have design a knuckle which accommodates dual caliper mountings for increasing braking efficiency & reducing a stopping distance of a vehicle. CAD modal of knuckle was prepared in CREO2.0. Static analysis was done in ANSYS WORKBENCH by constraining the knuckle, applying loads of braking torque on caliper mounting, longitudinal reaction due to traction, vertical reaction due to vehicle weight and steering reaction.

**AMEYA BHUSARI et.al. [4]** In their research paper they have redesign the steering knuckle in order to reduce the unsprung weight of a single seat All Terrain Vehicle (ATV) while retaining a satisfactory safety factor for better performance of the vehicle. A two step process has been used for the same. First step is modeling the knuckle as per the structural considerations and design constraints set by suspension, steering and brake assemblies & determination of loads acting on the knuckle.

**Purushottam Dumbre et.al. [5]** In their research paper they reduced weight of the vehicle by increasing additional luxurious and safety features. The increasing weight of the vehicle affects the fuel efficiency and overall performance of the vehicle.

**Atul Yadav, et.al.[6]** The aim of their research is to scale down the mass of an existing steering knuckle component of a local car model, using Creo 2.0, and

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performing its shape optimization, using Hyper works as pre and post processor and Nastran as a solver, in order to meet the required strength attributes at the cost of minimum weight.

**Nilesha Patil et.al. [7]** In their paper theystudied and calculated the stresses in Knuckle joint using analytical method. A knuckle joint is used to connect two rods under tensile load. These joints are used for different types of connections e.g. tie rods, tension links in bridge structure.

**S V Dusane et.al. [8]** In this research paper they studies about steering and suspension system, which allows the front wheels to turn and also allow the movement of suspension arms motion. The light weight and high strength component is always in demanding for racecar application.

**B.Babu et.al. [9]** In this research paper they explore performance opportunities, in the design and production of a steering knuckle. This can be achieved by performing a detailed load analysis. Therefore, this study has been dealt with two steps. First part of the study involves modeling of the steering knuckle with the design parameters using the latest modeling software, and also it includes the determination of loads acting on the steering knuckle as a function of time.

**Gondi PrabhuCharan Teja et.al. [10]** In this paper theyhad optimized the steering knuckle targeting reducing weight as objective function with required strength and stiffness. In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension components.

**Dinesh Shinde et al. [11]** in their research paper they have discussed about the Tractor trailer used in agriculture field for carrying heavy goods. To connect trailer to the tractor flexibly, a knuckle joint is used which consist of forks and a pin, a fork is attached to tractor rigidly and another fork is attached to the trailer by a pin.

**Ravindra S. Dharpure et.al. [12]** He has analyzed they problem of the failure of the knuckle pin in a railway coupling due to shearing. As per the functionality of the knuckle pin the pin is suitable for retaining of the knuckle and no loading conditions is determined over it but due to the manufacturability of the knuckle itself the failure of knuckle is undertaken thus the possible solution is presented in this thesis.

**Nishant Vibhav Saxena et.al. [13]** In their research paper they worked on modified system. As a result, this there are reduction in accident and safety has increased. Many systems used in industries use knuckle joint which is combination of two materials: cast iron and stainless steel. Here we are proposing the modification of one of the material that is changing cast iron into a composite polymer material.

## 3. GEOMETRIC MODELLING:

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

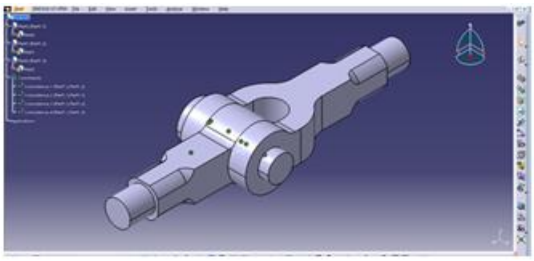

**Fig.3.6 Assembled Knuckle joint**

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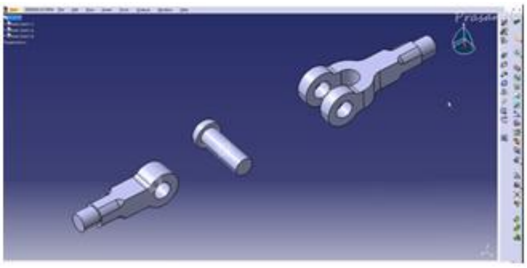

Fig3.6 Separate view of knuckle parts

### 4.Steps involved in analysis using ANSYS

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis.

A typical ANSYS analysis consists of the following steps:
Build the model using key points, lines, areas and volume commands.

- Giving material properties.
- Choosing proper element.
- Meshing the model to discritise it into elements.
- Applying the given loads.
- Applying the boundary conditions.
- Running the solution phase.

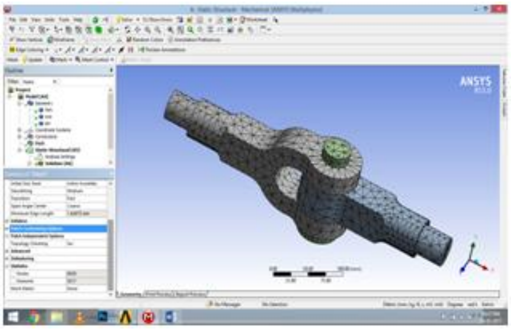


Fig.4.1Coarse Meshed model of Knuckle joint

### 5. RESULTS AND DISCUSSIONS:

The main objective of this investigation is to do the structural analysis on knuckle joint with different materials at various loads and find out the behaviour of the knuckle joint at various loads.

Here in this analysis various factors were calculated by applying loads at appropriate sections of the knuckle joint. Structural analysis was carried out on the Knuckle Joint at loads of 100N, 105N, 110N and 115N on three types of materials Stainless Steel, AL 6061-T6 and Teflon and the action of various stress and strains on the knuckle joint at various loads were investigated.

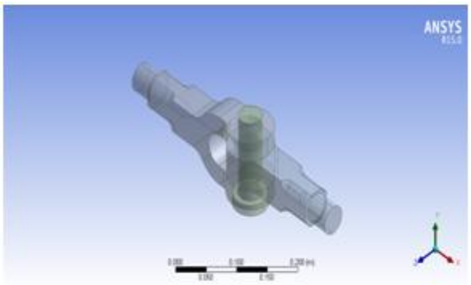


Fig 5.1 Various Parts in Knuckle Joint

### Case -1: Investigation on Stainless Steel at various loads

#### 1.1 At a load of 100N

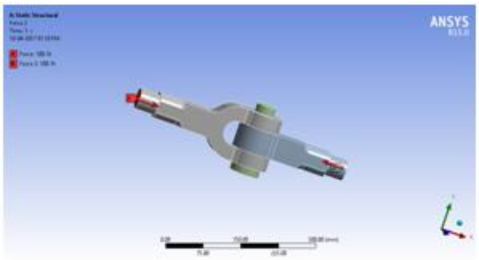


Fig 5.2 Knuckle joint at 100N load

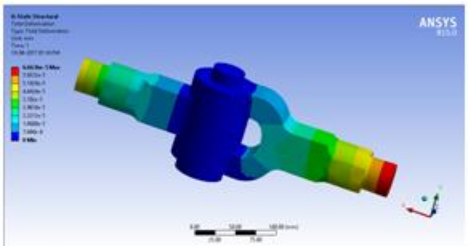


Fig 5.3 Total deformation in Knuckle joint at 100N

Here in this case the material used is stainless steel and the load acted upon the knuckle joint is about 100N and the structural analysis is done in order to find out total deformation in the knuckle joint. And the results were clearly shown in the figure.

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The above analysis was conducted on all parts of the knuckle joint and the results explains the same

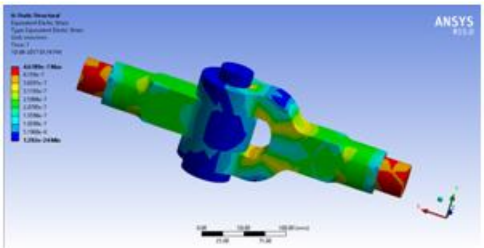


Fig 5.4 Equivalent elastic strain

Here in this analysis also the material used, the geometries and the load are same as that of the above analysis, but in this analysis we calculated equivalent elastic strain under the structural analysis as we already know that the material chosen for this analysis has yield strength and so elastic strain can be calculated and the results of the elastic strain were shown in the figure.

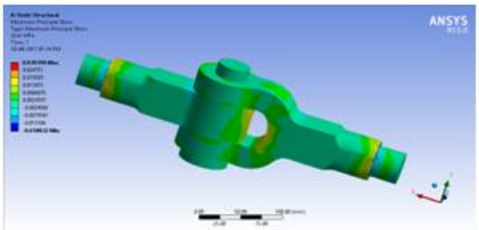


Fig 5.5 Maximum principle stress

Here in this analysis also the material used, the geometries and the load are same as that of the above analysis, but in this analysis we calculated maximum principle stress under the structural analysis here after conducting structural analysis we got maximum principle stress of about 0.0301MPa and a minimum of -0.0188 MPa and that were clearly shown in the figure.

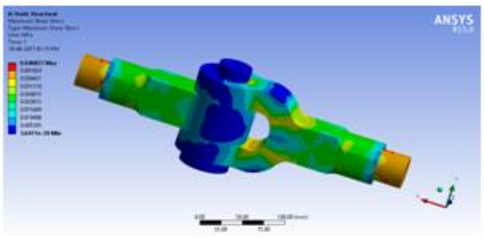


Fig 5.6 Maximum shear stress

Here in this analysis also the material used, the geometries and the load are same as that of the above analysis, but in this analysis we calculated maximum shear stress under the structural analysis here after conducting structural analysis we got maximum shear stress of about 0.0468 MPa and a minimum of 0.0252MPa and that were clearly shown in the figure.

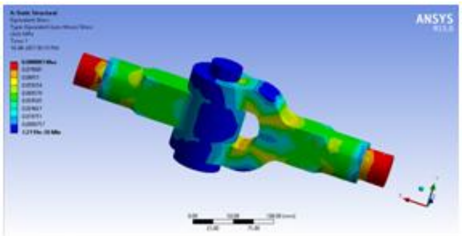


Fig 5.7 Equivalent von-mises stress

Here in this analysis also the material used, the geometries and the load are same as that of the above analysis, but in this analysis we calculated equivalent Von-Mises stress under the structural analysis here after conducting structural analysis we got maximum shear stress of about 0.0888 MPa and a minimum of 0.009 MPa and that were clearly shown in the figure here the maximum load is obtained at fixed supports

### 1.2 At a load of 105N

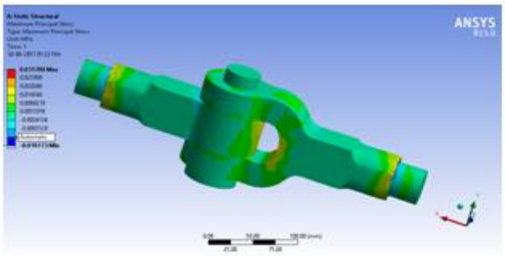


Fig 5.8 Maximum principle stress

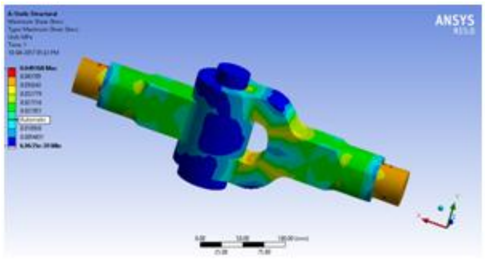


Fig 5.9 Maximum shear stress

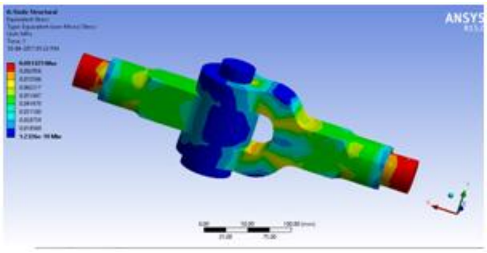

Fig 5.10 Equivalent Von-Mises stress

**1.3 At a load of 110N**

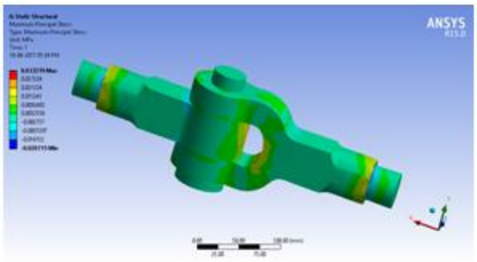

Fig 5.11 Maximum principle stress

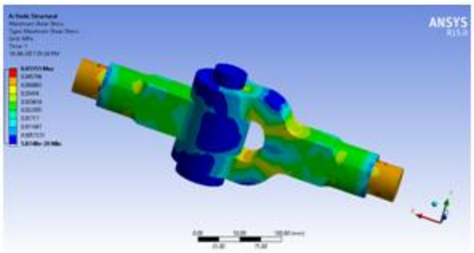

Fig 5.12 Maximum shear stress

**1.4 At a load of 115N**

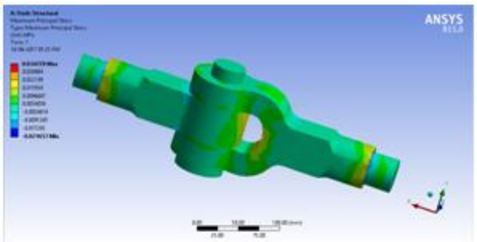

Fig.5.13 Maximum principle stress

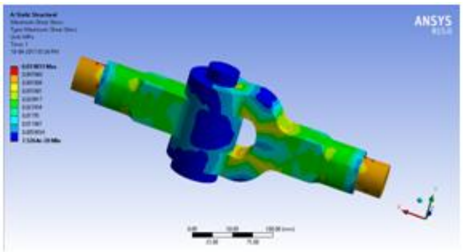

Fig 5.14 Maximum shear stress

**Case -2: Investigation on AL6061-T6at various loads**

**1.5 At a load of 100N**

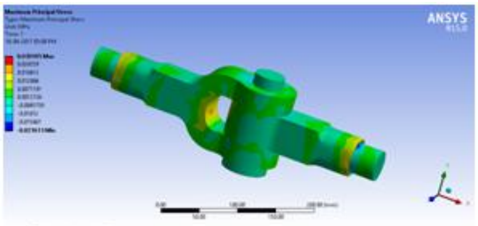

Fig.5.15 Maximum principle stress

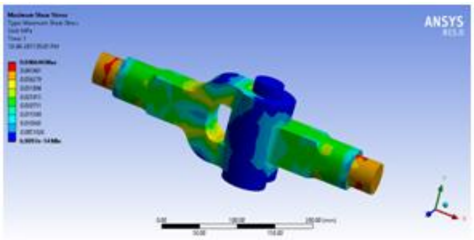

Fig 5.16 Maximum shear stress

**At a load of 105N**

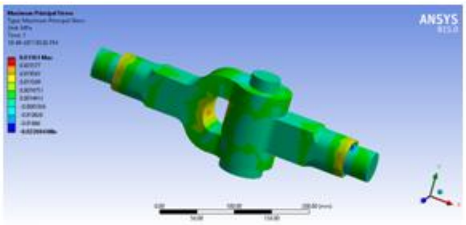

Fig.5.17 maximum principle stress

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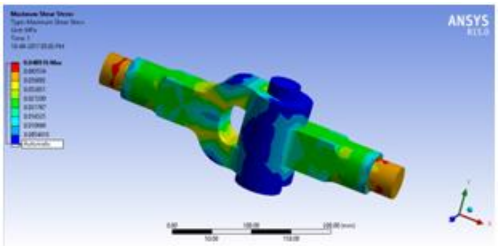


Fig5.18Maximum shear stress

### 1.6 At a load of 110N

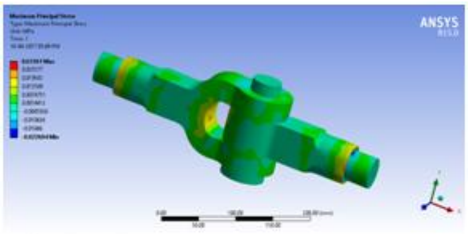


Fig 5.19 Maximum principle stress

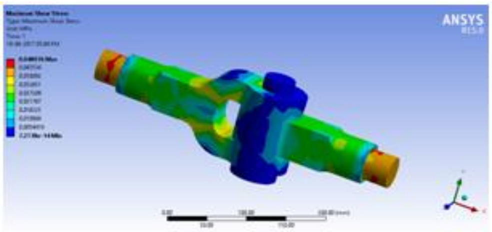


Fig 5.20 Maximum shear stress

### 1.7 At a load of 115 N

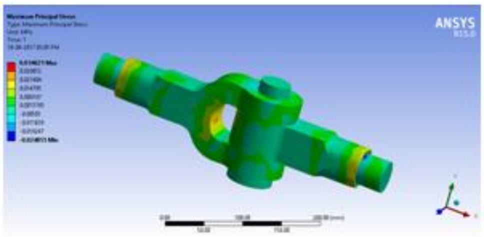


Fig 5.21 Maximum principle stress

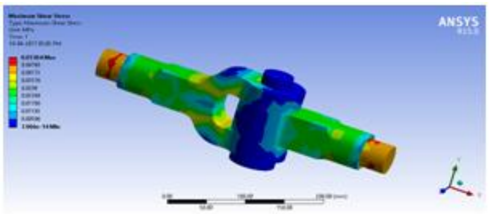


Fig 5.22 Maximum shear stress

## Case -3: Investigation on Teflon at various loads

### 1.8 At a Load of 100 N

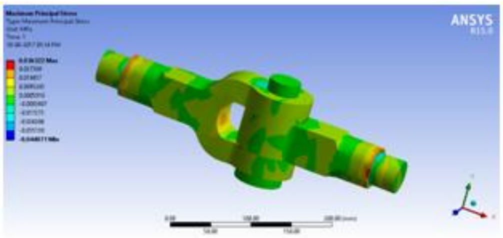


Fig 5.23Maximum principle stress

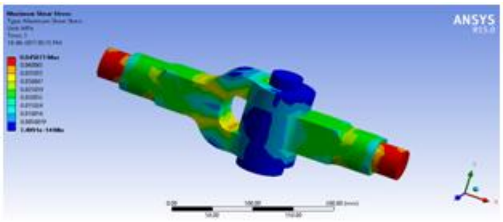


Fig 5.24 Maximum shear stress

### 1.9 At a Load of 105 N

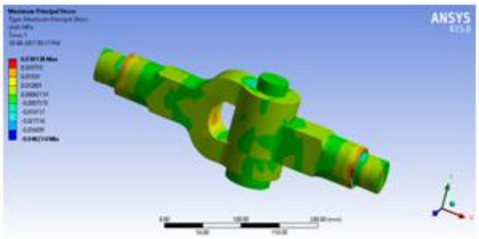


Fig 5.25 Maximum principle stress

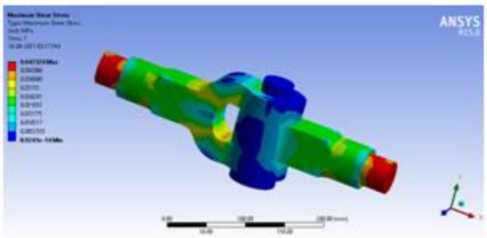


Fig 5.26 Maximum shear stress

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### 1.10 At a Load of 110 N

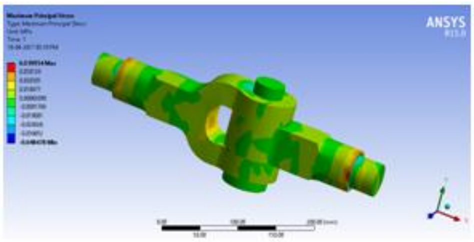


Fig 5.27.Maximum principle stress

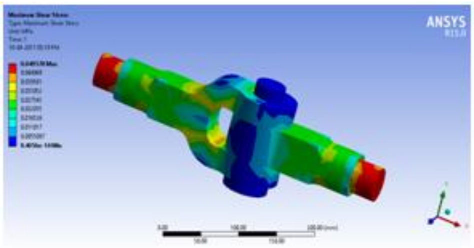


Fig 5.28 Maximum shear stress

### 1.11 At a Load of 115 N

**Table summary of all resulis**

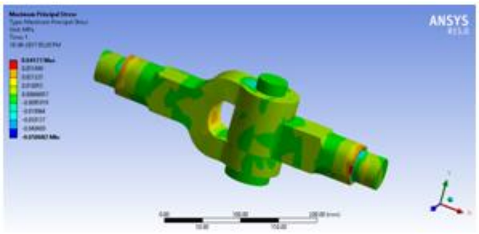


Fig 5.29 Maximum principle stress

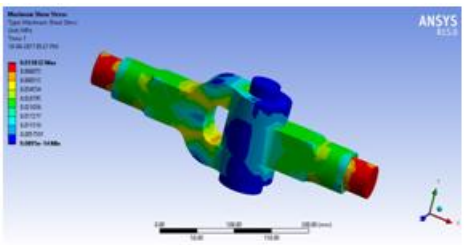


Fig 5.30.Maximum shear stress

| S.NO | MATERIAL | Load Kn | Case | Max (Mpa) | Min (Mpa) |
|---|---|---|---|---|---|
| 1 | Stainless steel | 100 | Max Principle stress | 0.0301 | -0.0188 |
| | | | Max Shear Stress | 0.0468 | 0.0252 |
| | | 105 | Max Principle stress | 0.0317 | -0.0192 |
| | | | Max Shear Stress | 0.0491 | 6.963e-20 |
| | | 110 | Max Principle stress | 0.0332 | -0.0207 |
| | | | Max Shear Stress | 0.05151 | 5.874e-20 |
| | | 115 | Max Principle stress | 0.0347 | -0.0216 |
| | | | Max Shear Stress | 0.0538 | 7.524e-20 |
| 2 | AL6061-T6 | 100 | Max Principle stress | 0.0301 | -0.0216 |
| | | | Max Shear Stress | 0.0466 | 6.909e-14 |
| | | 105 | Max Principle stress | 0.0316 | -0.022 |
| | | | Max Shear Stress | 0.0489 | 0.0054 |
| | | 110 | Max Principle stress | 0.03161 | -0.02269 |
| | | | Max Shear Stress | 0.0489 | 0.00544 |
| | | 115 | Max Principle stress | 0.0346 | -0.0182 |
| | | | Max Shear Stress | 0.0536 | 0.00596 |
| 3 | TEFLON | 100 | Max Principle stress | 0.0363 | -0.0440 |
| | | | Max Shear Stress | 0.0450 | 0.0050 |
| | | 105 | Max Principle stress | 0.0381 | -0.0462 |
| | | | Max Shear Stress | 0.0472 | 0.0252 |
| | | 110 | Max Principle stress | 0.0399 | -0.0386 |
| | | | Max Shear Stress | 0.0495 | 0.0255 |
| | | 115 | Max Principle stress | 0.0417 | -0.0404 |
| | | | Max Shear Stress | 0.051 | 0.0054 |

## 6. CONCLUSION:

A Knuckle joint is used to connect two rods under tensile load. This joint permits angular misalignment of the rods and may take compressive load if it is guided. Normally, empirical relations are available to find different dimensions of the joint and they are safe from design point of view. The aim of the present paper is to study calculate the stresses in Knuckle joint using analytical method. In this thesis we performed Structural analysis on the Knuckle Joint at loads of 100N, 105N, 110N and 115N on three types of materials Stainless Steel, AL 6061-T6 and Teflon and the action of various combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and strains on the knuckle joint at various loads were investigated. From the investigation, it is known that Teflon have the better performance than that of the remaining two materials. Teflon has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material.

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