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FE ANALYSIS KNUCKLE JOINT USED IN TRACTOR TRAILER

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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 e.g. tie rods, tension links in bridge structure. In this, one of the rods has an eye at the rod end and the other one is forked with eyes at both the legs. A pin is inserted through the rod end eye and fork-end eyes and is secured by a collar and a split pin. Screwed connections often play an important part in the transmission of load through machine assemblies. In large circuit breakers they are subjected intermittently to high impulsive loads transmitted through large-scale linkages. The paper reports on design and analysis of a knuckle joint which is used in power transmission. In this study, modeling and analysis of a knuckle joint was performed by using Finite Element Method. The knuckle joint takes compressive loads often, thus there is a need for quality design tools. The modeling of the knuckle joint is done using 3D software. Here we will be using Creo for modeling. These joints are used for different types of connections e.g. tie rods, tension links in bridge structure.

In this project ,static analysis done at different loads(100N and 110N) with different materials(steel and cast iron)analysis done in ANSYS.

I. INTRODUCTION

In mechanical & automobile domain the joints play very crucial role, depending upon the application the joints are used may be temporary or permanent. For power transmission or motion transfer application we generally uses temporary joints like screwed joint, cotter joint, sleeve cotter joint, universal joint or knuckle joint. The Knuckle joint is a type of joint which is used in steering system in between the steering rod and pinion of the steering gear , as the line of the action/axis of both the mechanical parts are intersecting and lies in different planes, so it is the only joint that we can employ here In order to gain the maximum productivity for the plant, the manufacturing technology must not be stiff; it must have an option of customizability of manufacturing system to gain the agility. For this a term FMS, i.e., Flexible Manufacturing System is used in order to gain the advantage over simple manufacturing system. FMS consists of a group of a processing work stations interconnected by means of an automated material handling and storage system and controlled by integrated computer controlled system. FMS is an arrangement of machines interconnected by a transport system which is accurate, rapid and automatic. The manufacturing plant is located in Gwalior which is a new and developing industry, having a small set up of six milling centers, two turning centers, one drill and a hacksaw machine, with a total employee staff of twenty-five. A small scale industry is manufacturing knuckle joint for automotive applications for his clients in batch production of fifty pieces. A

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mechanical joint is a part of machine which are used to connect the other mechanical part or mechanism. Mechanical joints may be temporary or permanent. Most types are designed to be disassembling when required.

KNUCKLE JOINT

Knuckle joint is a joint between two parts allowing movement in one plane only. It is a kind of hinged joint between two rods, often like a ball and socket joint. There are many situations where two parts of machines are required to be restrained, for example two rods may be joined coaxially and when these rods are pulled apart they should not separate i.e. should not have relative motion and continue to transmit force. Similarly if a cylindrical part is fitted on another cylinder (the internal surface of one contacting the external surface of the other) then there should be no slip along the circle of contact. Such situations of no slip or no displacements are achieved through placing a third part or two parts at the jointing regions. Such parts create positive interference with the jointing parts and thus prevent any relative motion and thus help transmit the force. One should remember that the rivets in a riveted joint had exactly the same role as it prevents the slipping of one plate over the other (in lap joint) and moving away of one plate from other (in butt joint). The rivets provided positive interference against the relative motion of the plate. Knuckle joint is another promising joint to join rods and carry axial force. It is named so because of its freedom to move or rotate around the pin which joins two rods. A knuckle joint is understood to be a hinged joint in which projection in one part enters the recess of the other part and two are held together by passing a pin through coaxial holes in two parts. This joint cannot sustain compressive force because of possible rotation about the pin. There are most common in steering and drive train applications where it needs to move something but also need to allow for offset angles. A knuckle joint is used when two or more rods subjected to tensile and compressive forces are fastened together such that their axes are not in alignment but meet in a point.

DESIGN OF KNUCKLE JOINT

The assembly diagram of knuckle joint is as shown in fig.

The dimension of knuckle joints are
Diameter of rod = **d**
Diameter of knuckle pin = $\mathbf{d_p}$
Outside diameter of single eye = $\mathbf{d_{oe}}$
Outside diameter of double eye = $\mathbf{d_{od}}$
Thickness of single eye = **t**
Thickness of fork = $\mathbf{t_1}$
Axial tensile force on rod = **P**

(1) Diameter of rod

Consider the rod is subjected to a direct tensile stress

$$\varsigma = P / \pi d^2$$

From above equation, diameter of rod 'd' is obtained.

(2) Design of pin (d_p)

(a) Consider the failure of pin under double shear due to tensile force.

Therefore, direct shear stress induced in knuckle pin is given by Equation

$$\varsigma = P/ 2A = (P/2) / (\pi/4)d_p^2 = 2P/ \pi d_p^2$$

(b) Failure of knuckle pin in bending

Assume there is no clearance or slack but in actual, knuckle pin is loose in forks to permit angular moment of one with respect to other, so it is subjected to bending moment in addition to shear, consider uniformly distributed load along the portion of pin.

Taking moment about axis XX

$$M = [(-P/2) \times (t/4)] + \{ (P/2) \times [(t/2)+(t_1/3)] \}$$

$$= P/2 [(t_1/3)+(t/2)-(t/4)]$$

$$=P/2 [(t_1/3)+(t/4)]$$

Section modulus,

$$Z=(\pi/ 32)d_p^3$$

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Maximum bending stress, σ_b

σ_b**= M/Z = { P/2 [(**t_1**/3)+(t/4)] } / {(π/ 32)**d_p^3**}**

Here,we check the pin in bending and find the value of d_p

(3) Design of single eye :

(a) To find the outside diameter of single eye (d_{oe}) The single eye is subjected to a direct tensile stress, due to this single eye under tear.

$\sigma t = P/A = P/ (d_{oe}-d_p)\times t$

(b) Due to direct tensile strength, the single eye is subjected to double shear.

Resisting shearing area = 2(d_{oe}**-**d_p**)×(t/2)**

The direct shear stress induced is

$\varsigma = P/(d_{oe}-d_p)\times t$

From this equation the outside diameter of single eye d_{oe} is obtained.

(C) Failure of single eye or pin due to tensile load in crushing

Resisting crushing area = $d_p \times t$

$\sigma_c = P/(d_p\times t)$

Form this equation crushing stress checked if fail, increase the thickness of eye **(t)**.

(4) Design of fork (double eye):

(a) The tearing of the double eye at weakest section due to tension

Area resisting tear = $(d_{of} - d_p) \times 2\, t_1$

$\sigma_t = p/ [(d_{of} - d_p) \times 2\, t_1]$

From this equation, find the outside diameter of fork **(dof)**.

(b) Failure of double eye (fork) in double shear due to tensile load.

Area resisting shear = $4 \times [(d_{of} - d_p)]/2 \times t_1$

$= 2 \times (d_{of} - d_p)\, t_1$

The shear stress is given by,

$\varsigma = p/[(d_{of} - d_p) \times 2\, t_1]$

From this equation, check shear stress if less than design, increase thickness of fork t_1.

(c) Failure double eye in crushing (thickness of fork)

Double eye may fail in crushing due to tensile load

The crushing stress is given by,

$\sigma c = P/(2\times d_p \times t_1)$

Check crushing stress or find t_1

ANALYTICAL DESIGN:

Assumptions:

1. Rod diameter d = 40mm
2. Load applied P = 9810 N (1Ton)
3. Diameter of knuckle pin (dp) = d
dp = 40mm
4. Thickness of single eye (t) = 1.25d
= 1.25x40 t = 50mm
5. Thickness of fork (t1) = 0.75d
= 0.75x40 t1 = 30mm
6. Outer diameter of eye (D) = 2d
= 2x40 D = 80mm
7. Failure of fork end in tension (σt)
σt = 4.0875 N/mm2
8. Failure of fork end in shear (τ)
τ = 4.0875 N/mm2

II. MATERIALS AND METHODOLOGY

MATERIAL SELECTION

There are several materials used for manufacturing of knuckle joint such as S.G. iron (ductile iron), white cast iron and grey cast iron. But grey cast iron mostly used. Forged steel are most demanding material for this application. For this Structural steel is used Structural Steel

- Modulus of Elasticity : 2.0e5 MPa
- Poisson's ratio : 0.30
- Density : 7.85e-6 kg/mm3
- Yield Strength : 250 MPa

CALCULATIONS OF KNUCKLE JOINT

PROBLEM: Two mild steel rods are connected by a knuckle joint to transmit an axial force of 50kN. Design the joint completely assuming the working stresses for both the pin and rod materials to be 100 MPa in tension, 65MPa in shear and 150 MPa in crushing. Refer to figure For failure of rod in tension, P = π4 d2σy . On substituting P=50 kN, σy = 100 MPa we have d= 25 mm. Let us choose the rod diameter d = 25 mm which is the next standard size.We may now use the empirical relations to find the necessary dimensions and then check the failure criteria .d1= 25 mm t= 32 mm d2 = 50 mm t1= 19 mm; d3 = 38 mm t2= 13 mm; Split pin diameter = 0.25d1 = 10 mm

INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Its use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

INTRODUCTION TO CREO

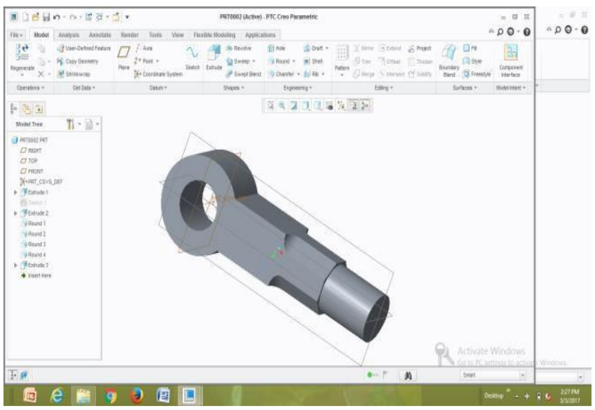
PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

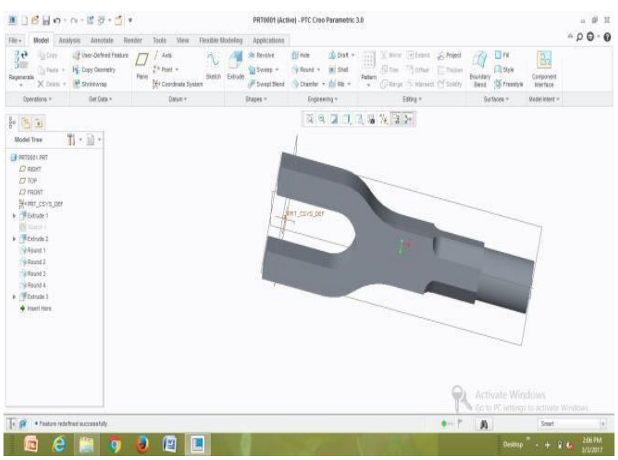
The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assembly modeling, 2D orthographic views for technical drawing, finite element analysis and more.
PTC CREO says it can offer a more efficient design experience than other modeling software because of its unique features including the integration of parametric and direct modeling in one platform. The complete suite of applications spans the spectrum of product development, giving designers options to use in each step of the process. The software also has a more user friendly interface that provides a better experience for designers. It also has collaborative capacities that make it easy to share designs and make changes.
PTC also offers comprehensive training on how to use the software. This can save businesses by eliminating the need to hire new employees. Their training program is available online and

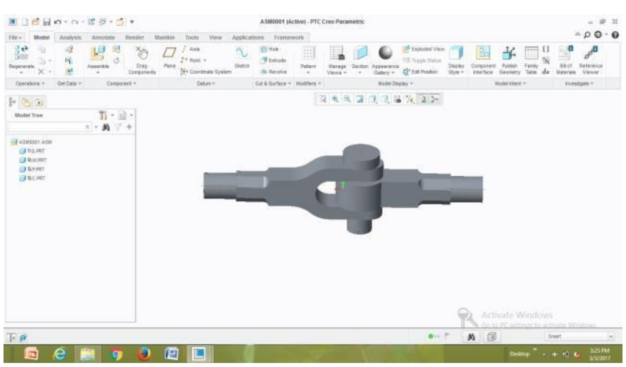
in-person, but materials are available to access anytime.

A unique feature is that the software is available in 10 languages. PTC knows they have people from all over the world using their software, so they offer it in multiple languages so nearly anyone who wants to use it is able to do so.

3D MODEL







INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

One of the first applications of FEA was, indeed, to find the stresses and strains in engineering components under load. FEA, when applied to any realistic model of an engineering component, requires an enormous amount of computation and the development of the method has depended on the availability of suitable digital computers for it to run on. The method is now applied to problems involving a wide range of phenomena, including vibrations, heat conduction, fluid mechanics and electrostatics, and a wide range of material properties, such as linear-elastic (Hookean) behavior and behavior involving deviation from Hooke's law (for example, plasticity or rubber-elasticity).

INTRODUCTION TO ANSYS

Structural Analysis

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

ANSYS Mechanical

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ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of

mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

Fluid Dynamics

ANSYS Fluent, CFD, CFX, FENSAP-ICE and related software are Computational Fluid Dynamics software tools used by engineers for design and analysis. These tools can simulate fluid flows in a virtual environment — for example, the fluid dynamics of ship hulls; gas turbine engines (including the compressors, combustion chamber, turbines and afterburners); aircraft aerodynamics; pumps, fans, HVAC systems, mixingvessels, hydro cyclones, vacuum cleaners, etc.

STATIC ANALYSIS OF KNUCKLE JOINT

MATERIAL-STEEL

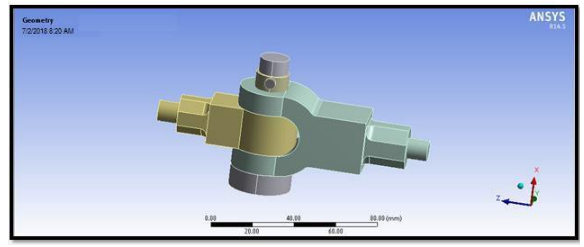
AT LOAD-100N

Save CREO Model as .iges format

→→Ansys → Workbench→ Select analysis system → static structural → double click →→Select geometry → right click → import geometry → select browse →open part → ok →→ Select mesh on work bench → right click →edit

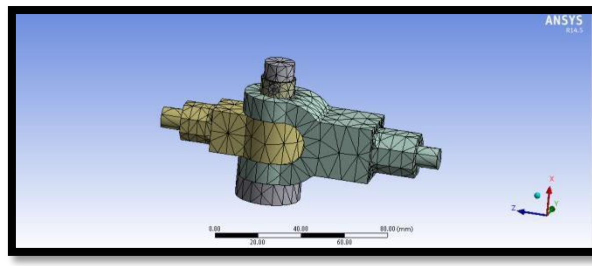
Double click on geometry → select MSBR → edit material →

Imported Model from CREO

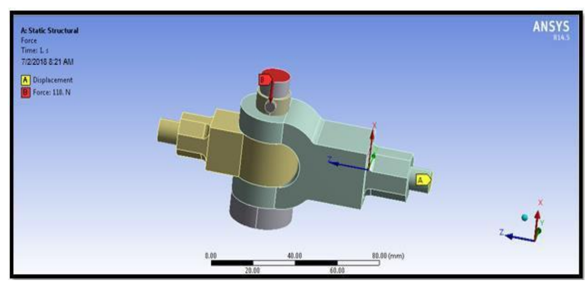


Select mesh on left side part tree → right click → generate mesh →

Meshed Model



Select static structural right click → insert → select rotational velocity and fixed support → Select displacement → select required area → click on apply → put X,Y,Z component zero →



Select force → select required area → click on apply → pressure

Select solution right click → solve →

Solution right click → insert → deformation → total → Solution right click → insert → strain → equivalent (von-mises) → Solution right click → insert → stress → equivalent (von-mises) →

Right click on deformation → evaluate all result

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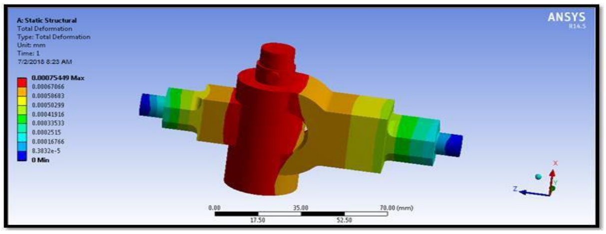
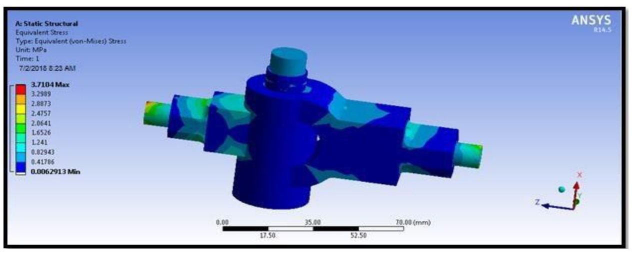
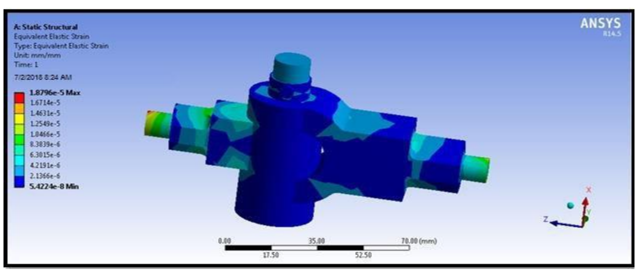
TOTAL DEFORMATION



VON-MISES STRESS

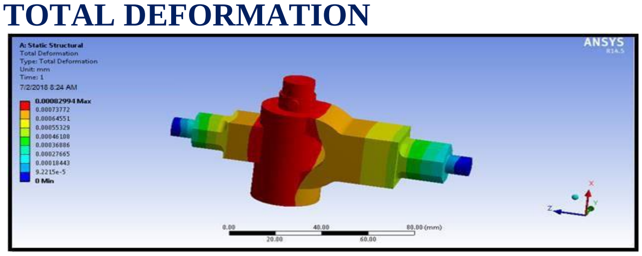


VON-MISES STRAIN

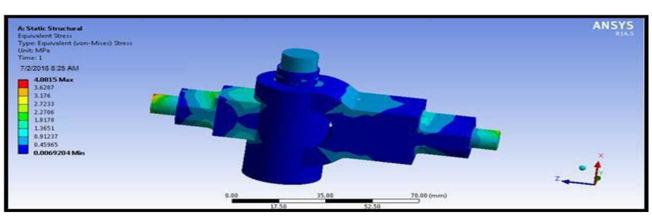


AT LOAD-110N

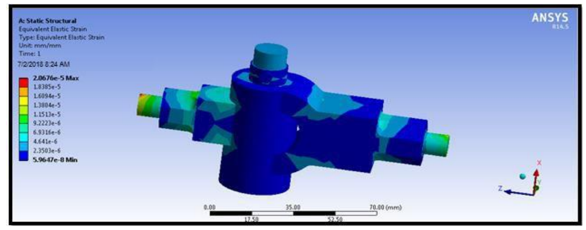
TOTAL DEFORMATION



VON-MISES STRESS



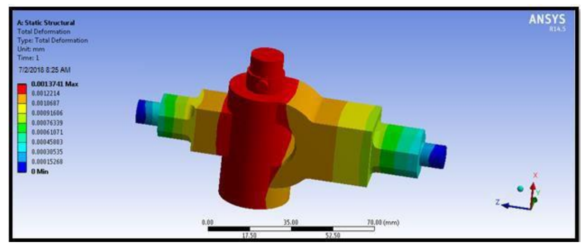
VON-MISES STRAIN



MATERIAL-CASTIRON

AT LOAD-100N

TOTAL DEFORMATION



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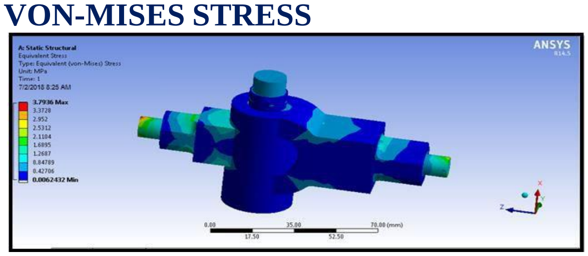

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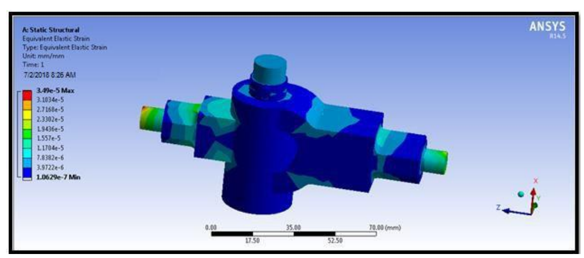
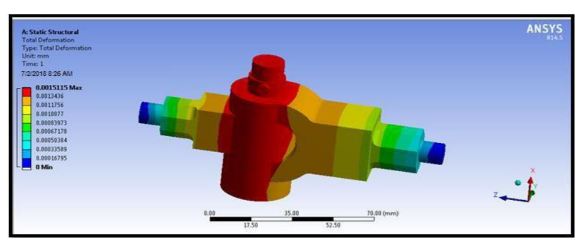


AT LOAD-110N

TOTAL DEFORMATION



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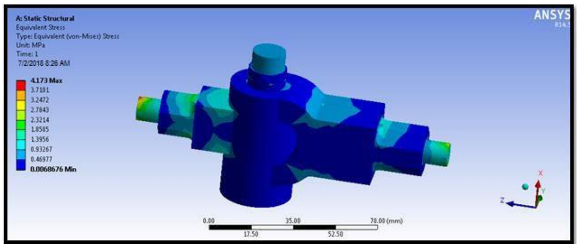
VON-MISES STRESS



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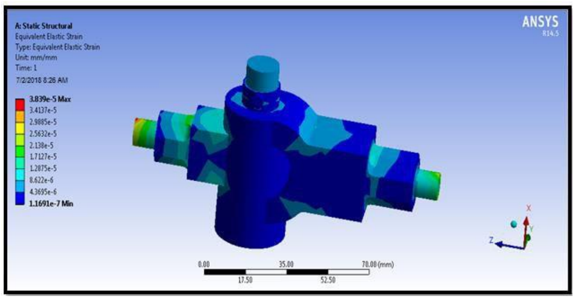

RESULT TABLES

Material	Load (N)	Deformation (mm)	Stress (N/mm^2)	Strain
Steel	100	0.00075499	3.7014	1.87e-5
	110	0.00082994	4.0815	2.06e-5
Cast iron	100	0.0013741	3.7936	3.49e-5
	110	0.0015115	4.173	3.839e-5

V. CONCLUSION

From the above results and discussion, Knuckle joint was design for 100N and 110N axial load by theoretical calculation. Final dimensions from theoretical calculation, model of Knuckle joint is made in CREO.

In this project ,static analysis done at different loads(100N and 110N) with different materials(steel and cast iron)

in static analysis, observed the stress values are less steel compared with cast iron at 100N load.

so it can be concluded that the better material for steel.

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