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Modeling and 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 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 commercial finite element package ANSYS version 15 was used for the solution of the problem. 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 CATIA V5 for modeling. The simulation part will be carried out using the Analysis software, ANSYS. The created model is exported to ANSYS by converting it to IGES format. The imported model is meshed in ANSYS and boundary constrains are defined. With the Boundary constrains and the compressive load applied, the knuckle joint is analyzed and the values are tabulated. This project will also help to learn C ATIA V5 and also ANSYS.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.

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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;

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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 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.

Types of Mechanical Joints:
1. Knuckle Joints
2. Turnbuckle Joints
3. Pin Joints
4. Cotter Joints
5. Bolted joints
6. Screw Joints
7. Welded Joints

2.1. 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. This type of joint allows a small angular movement of one rod relative to another. The joint can be easily connected and disconnected. Knuckle joint is found in valve rods, braced girders, links of suspension chains, elevator chains, etc. The figure of a knuckle joint is shown in Fig.2.6. The knuckle joint assembly consists of following major components:

1. Single eye.
2. Double eye or fork.
3. Knuckle pin.
4. Collar. And
5. Tapper pin.

The end of one of the rods is forged in the form of a fork while the end of the other rod has an eye, which can be inserted in the jaws of the fork. A cylindrical pin is passed through the holes in the forks and the eye. The pin is secured in position by a taper pin, split pin or a thin nut screwed up to shoulder on the end of the pin. The ends of the rods are made octagonal for good hard grip. A knuckle joint is used to connect the two rods which are under the tensile load, when there is requirement of small amount of flexibility or angular moment is necessary. There is always axial or linear line of action of load.

Fig.2.1. SINGLE EYE

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Fig.2.2. DOUBLE EYE OR FORK

Fig.2.3. KNUCKLE PIN

Fig.2.4. COLLAR

Fig.2.5. TAPPER PIN

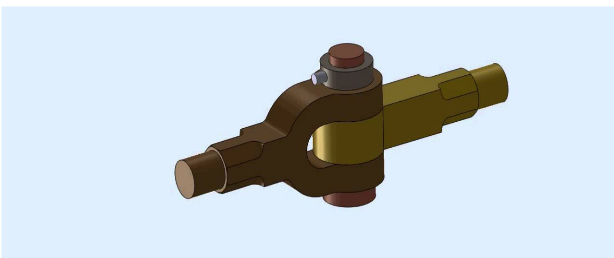

Fig.2.6. KNUCKLE JOINT

At one end of the rod the single eye is formed and double eye is formed at the other end of the rod. Both, single and double eye are connected by a pin inserted through eye. The pin has a head at one end and at other end there is a taper pin or split pin. For gripping purpose the ends of the rod are of octagonal forms. Now, when the two eyes are pulled apart, the pin holds them together. The solid rod portion of the joint in this case is much stronger than the portion through which the pin passes. The knuckle joint is used in many applications such as wiper, tie rod joint of roof truss, tension link in bridge structure, link of roller chain, in tractor, elevators chains, valve rods, wire line tool-string etc.

A knuckle joint may be failed on the following three modes:

1. Shear failure of pin (single shear).
2. Crushing of pin against rod.
3. Tensile failure of flat end bar.

The failure mechanism of knuckle joint has been studied by several investigators. Jones has reported that shear failure due to tensional loading is the normal failure mechanism in many engineering components. Pantazopoulos et.al have studied the failure of a knuckle joint of a universal coupling system. It was mentioned that torsional overload of the knuckle joint is the major cause of failure. However, in many cases it was reported that wear of material due to severe friction leading to delimitation wear.

2.2. KNUCKLE JOINTS USED?

- Two or more rods subjected to tensile and compressive forces are fastened together.
- Their axes are not in alignments but meet in a point.
- The joint allows a small angular moment of one rod relative to another.
- It can be easily connected and disconnected.

2.3.APPLICATIONS OF KNUCKLE JOINT

Knuckle joints find a wide variety of applications. They are used in:

1.Bicycle chains
2.Tractors
3.Trusses

4.Automobile wipers
5.Cranes
6.Chain straps of watches
7.Earth movers
8.Robotic joints
9.Structural members
In general, the materials used for making knuckle joint are:

3.6. STAINLESS STEEL: MECHANICAL PROPERTIES:

Mechanical property	Value	units
Density	7850	Kg/m3
Coefficient of thermal expansion	1.7e-005	i/c
Specific heat	480	j/kg/c
Thermal conductivity	15.1	w/m/c
Resistivity	7.7e-007	Ohm m
Compressive yield stress	2.07e+008	Pa
Tensile yield strength	2.07e+008	Pa
Tensile ultimate strength	5.86e+008	Pa
Reference temperature	22	c
Young's modulus	1.93e+011	Pa
Poisson's ratio	0.31	
Bulk modulus	1.693e+011	Pa
Shear modulus	7.366e+010	Pa

3.7. GRAY CAST IRON MECHANICAL PROPERTIES:

Mechanical property	Value	units
Density	7200	Kg/m3
Coefficient of thermal expansion	1.7e-005	I/C
Tensile yield strength	190	Pa
Reference temperature	22	c
Young's modulus	1e+006	Pa
Poisson's ratio	0.23	
Bulk modulus	6.1728e+005	Pa
Shear modulus	4.065e+005	Pa

3.8.TEFLON MECHANICAL PROPERTIES:

Mechanical property	Value	units
Density	2.1	Kg/m3
Compressive yield stress	1.5e+007	Pa
Tensile ultimate strength	2.07e+007	Pa
Reference temperature	22	c
Young's modulus	5e+008	Pa
Poisson's ratio	0.46	
Bulk modulus	2.0833e+009	Pa
Shear modulus	1.7123e+008	Pa

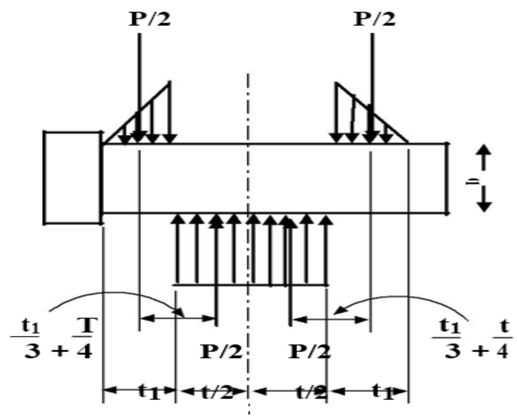

Fig.6.2. BENDING OF A KNUCKLEPIN

CALCULATIONS OF KNUCKLE JOINT

7.1. 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, $P = \pi 4\ d2\sigma y$. 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

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To check the failure modes:

1.Failure of knuckle pin in shear:

$$P \Big/ \left(2.\frac{\pi}{4}d_1^2\right) = \tau_y$$

which gives τy = 50.79 MPa. This is less than the yield shear stress.

2.For failure of knuckle pin in

$$\sigma_y = \frac{16P\left(\frac{t_1}{3}+\frac{t}{4}\right)}{\pi d_1^{\,3}}.$$

bending substitution this gives σy = 234 MPa which is more than the allowable tensile yield stress of 100 MPa. We therefore increase the knuckle pin diameter to35 mm which gives σy = 85 MPa that is well within the tensile yield stress.

3.For failure of rod eye in shear: (d2-d1)tτ = P. On substitution d1 = 35mm τ= 104.1 MPa which exceeds the yield shear stress of 65 MPa. So d2 should be at least 59.01 mm. Let d2 be 60 mm.

4.For failure of rod eye in crushing: d1tσc = P which gives σc = 44.64 MPa that is well within the crushing strength of 150 MPa.

5.Failure of rod eye in tension: (d2-d1)tσt = P. Tensile stress developed at the rod eye is then σt = 62.5 MPa which is safe.

6.Failure of forked end in shear: 2(d2-d1)t1τ = P. Thus shear stress developed in the forked end is τ = 52.63 MPa which is safe.

7.Failure of forked end in tension: 2(d2-d1)t1σy = P. Tensile strength developed in the forked end is then σy= 52.63 MPa which is safe.

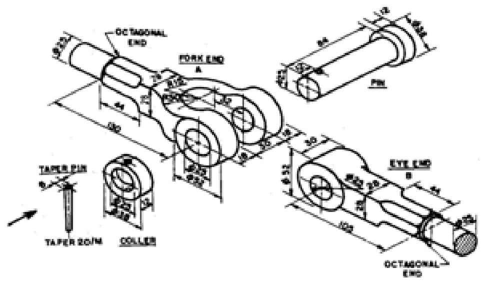
8.Failure of forked end in crushing: 2d1t1σc = P which gives the crushing stress developed in the forked end as σc = 37.59 MPa. This is well within the crushing strength of 150 MPa.

Therefore the final chosen values of dimensions are:

d_1 = 25 mm	t= 32 mm
d_2 = 50 mm	t_1= 19 mm
d_3 = 38 mm	t_2= 13 mm

Split pin diameter = 0.25d1 = 10 mm

7.2. CAD MODEL:



7.3. ASSEMBLE MODEL:

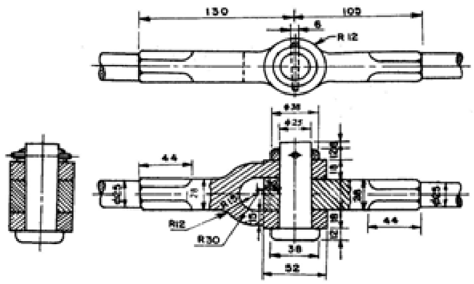
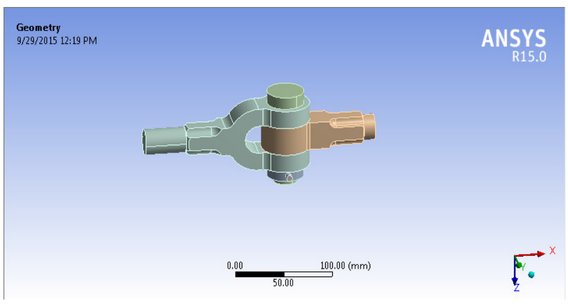


Fig.7.1. ASSEMBLE MODEL OF KNUCKLE JOINT

RESULTS AND DISCUSSION:

8.1. CATIAMODELS:



Geometry Model from ansys

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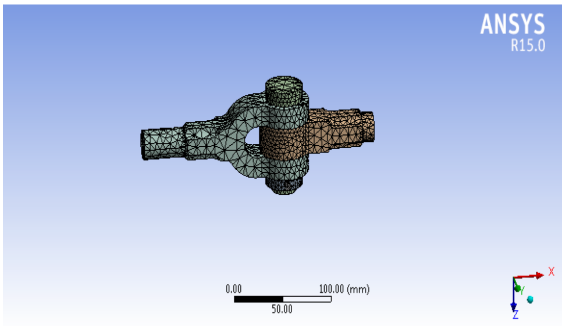


Mesh model

8.2: AT AXIAL LOAD APPLIED ON BOTH ENDS OF KNUCKLE JOINT.

9.1. FOR LOAD 50KN:

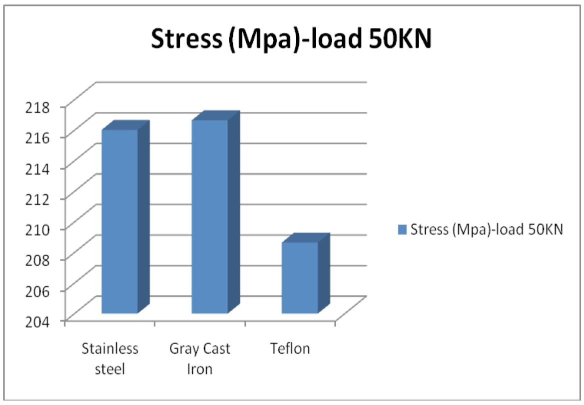
S no	Material	Deformation (mm)	Stress(Mpa)	Strain
1	Stainless steel	0.05678	216.02	0.0011
2	Gray Cast Iron	0.09982	216.65	0.00198
3	Teflon	21.672	208.65	0.42085

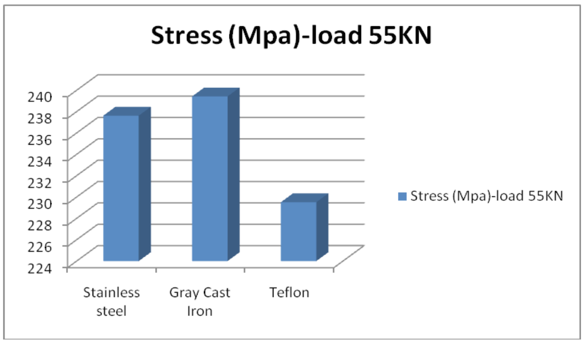
9.2. FOR LOAD 55KN:

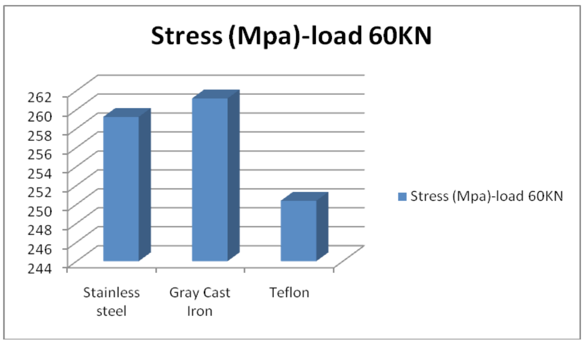
S no	Material	Deformation (mm)	Stress (Mpa)	Strain
1	Stainless steel	0.06246	237.62	0.001234
2	Gray Cast Iron	0.10981	239.42	0.062180
3	Teflon	23.84	229.51	0.4629

9.3. FOR LOAD 60KN:

S no	Material	Deformation (mm)	Stress (Mpa)	Strain
1	Stainless steel	0.068139	259.23	0.0013463
2	Gray Cast Iron	0.11979	261.18	0.0023788
3	Teflon	26.007	250.38	0.50503







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CONCLUSION:

From the above results and discussion, Knuckle joint was design for 50KN axial load by theoretical calculation. Final dimensions from theoretical calculation, model of Knuckle joint is made in CATIA V5 and model is taken to ANSYS and simulated with various material and check for best material which suit for given design load.

From result table it gives output was Teflon is best for design and it is close to stress got for stainless steel and cast iron.By varying load from 55KN to 65KN, it shown result table that stress formed in Teflon material is very close to stain steel and cast iron.

REFERENCES:

1)Knuckle structure for coupler by Horst Thomas Kaufhold, Chicago on 31st Dec., 1974

2) Knuckle structure to prevent knuckle pin failure in a railway coupler presented by William O. Elliott & Pittsburgh on 3rd Feb., 1987

3) Knuckle structure to ensure failure at Knuckle throat portion by William O. Elliott & Pittsburgh on 14th March, 1989

4) Coupler knuckle pin protector structure and stress reliever by Russell G. Altherr 8449 Moraine Ave. Munster, Ind. 46321 on 15th Feb. 1994

5)Railroad coupling knuckle hoist and method by E. B. Delcambre and Fort Smith on 25th July. 1995

6) Knuckle coupler pin by Jeffrey D. Wurzer, Turtle Crec, PA(US), Joseph L. Gagliardino, Oakdale, PA (US) on 3rd Dec., 2002

7) Central Datum feature on railroad coupler body and corresponding gauges by Jerry R. Smerecky, Roselle, IL (US); F. Andrew Nibouar, Chicago, IL (US); Edward T. Eaton, Eola, IL (US); Thomas A. Marchese, Schaumburg, IL (US); Eric W. Larson, Pecatonica, IL (US); Ronald P. Sellberg, Naperville, IL (US) on 2nd April, 2013

8)Dominick Rosato and Donald Rosato, Plastics Engineered Product Design, ELSEVIER

9)R.J. Crawford, BSc, PhD, DSC, FEng, FIMechE, FIM_ Butterworth H einemann. PLASTICS ENGINEERING_ Third Edition_

10)K.l.Narayan, P,kannaiah, K.Venkatareddy, Machine drawing.

11)H. Gradin Jr. Macmillan, Newyork, Xvi + 528pp, 1986, Fundamental of FEM,

12)Irvin L. Rubin(1990).Dry-as-Molded/Moisturized, Adapted from: Handbook of Plastic Materials and Technology,

13)SAE J328 Revised 1994: knuckle joint of car and truck performance requirements and test procedures.

14)Khurmi R.S., (2007), Machine design,, S Chand Publishers, Delhi.

15)Stuart B. H.: Tribological studies of composite material. Tribology International, 31, 647-651(1998).

16)YijunLiiu., Introduction to the finite element method

17)Mechanical and structural properties of Ductile Cast Iron- M.A.Kenaawy, A.M. Abdel Fattah, N. Okasha and M.EL-Gazery, Egypt. Sol, vol. (24), No. (2), 2001.

18)MIL-HDBK-17- 5 volume 5 of 5, 17 june 2002, composite material hand book.

19)V. A. Soloukhin, W. Posthumus, J.C.M. Brokken-Z jip, J. Loos, and G. de With: Polymer, Vol. 43 (2002), p. 6169.

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