AHMEDABAD UNIVERSITY

DESIGN OF MANUFACTURING PROCESSES

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MANUFACTURING PROCESSES

UNIVERSAL JOINT

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Abstract:

A Universal Joint also known as universal coupling, U joint, Cardan Joint, Hardy-Spicer joint, or Hooke's joint is a joint or coupling in a rigid root that allows the rod to 'bend' in any direction, and is common ly used in shafts that transmit rotary motion. It consists of a pair hinges located close together, oriented at 90° to each other, connected by a cross shafts. The Cardan joint suffers from one major problem: even when the input drive shaft rotates at a constant speed, the output drive shafts rotates at a variable speed, thus causing vibration and were. The variation in the speed of the driven shafts depends on the configuration of the joint. Such configuration can be specified by three variables. The universal (Cardan) joints are associated with power transmission systems. They are commonly used when there needs to be angular deviations in the rotating shafts. It is the purpose of this research to study the dynamics of the universal joints and to propose some practical methods for improving their performance. The task is performed by initially deriving the motion equations associated to the universal joints. That is followed by elaborating on the oscillatory behaviour in the rotational speed and the torque that transmits through the intermediary shaft. The forces in the joint bearings are calculated by using an analytical method that is also supported by the numerical modelling. Such models are also used in order to calculate the rhythm and the amount of the excess loads on the joint. This is suggested as a systematic procedure in the search for the causes of the failures in these popular bearings. With the same purpose in mind some defected bearings with deformed sections were selected for the laboratory examinations. By analysing the loading behaviour and the surface conditions of the defected bearings and by comparison with the known fatigue theories attempts are made in order to dig into the causes for the failures in these joints and their bearing surfaces. With the aim of improving the performance and the life expectancy of these popular elements of the machineries, some practical recommendations are also suggested.

Objective:

The main objectives of this project work are

- ✓ To solve a problem related to universal joint
- ✓ To design that problem
- ✓ To calculate the safe torque on shafts
- ✓ To know about its application.

Simple Brief Introduction About Universal joint:

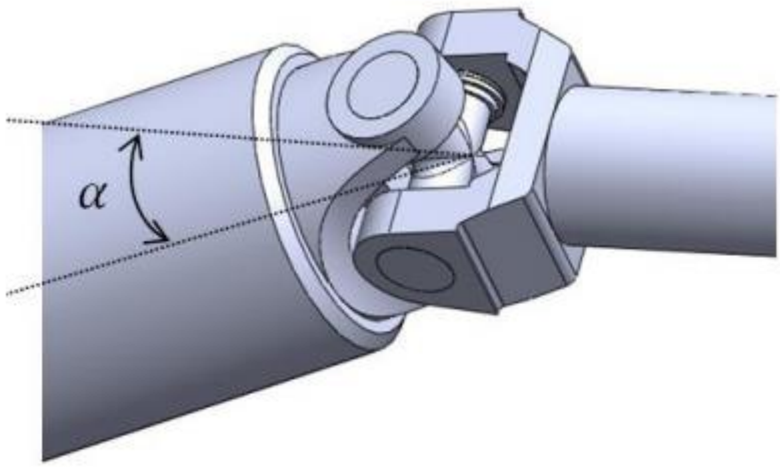
A universal joint, also known as Universal coupling, U-Joint, Cardan Joint, Hardy Spoker joint, or Hooke's joint is a joint or coupling in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shafts.

- Double Carbon Shaft:
  A configuration known as a double Cardan joint drive shaft partially overcomes the problem of jerky rotation. This configuration uses two U-joints joined by an intermediate shaft, with the second U-joint phased in relation to the first U-joint to cancel the changing angular velocity. In this configuration, the angular velocity of the driven shafts will match that of the driving shafts, provided that both the driving shafts and the driven shafts are at equal angles with respect to the intermediate shafts (But not necessarily in the same plane) and that the two universal joints are 90 degrees out of phase. This assembly is commonly employed in rear wheel drive vehicles, where it is known as a driver shaft or propeller (prop) shaft.

  Even when the driving and driven shafts are at equal angles with respect to the intermediate shafts, if these angles are greater than zero, oscillating moments are applied to the three shafts as they rotate. These tend them in a direction perpendicular to the common plane of the shafts. This applies forces to the support bearing and can cause 'Launch shudder' in rear wheel drive vehicles. The intermediate shaft will also have a sinusoidal component to its angular velocity, which contributes to vibration and stresses.

The universal joint mechanism:

In 1904, Clarence Spicer, a young engineering graduate from Cornell University, registered his invention of a mechanism. Since then, the mechanism that was called the Cardan joint has found widespread industrial applications. The Cardan Joint is amongst the most popular universal joints, It is widely used in the mechanical coupling and joints with the pre-condition that the input drive shafts and output drive shafts are not aligned. It may also be desired to permit some angular deviations along the axis of rotation which is shown in this figure.



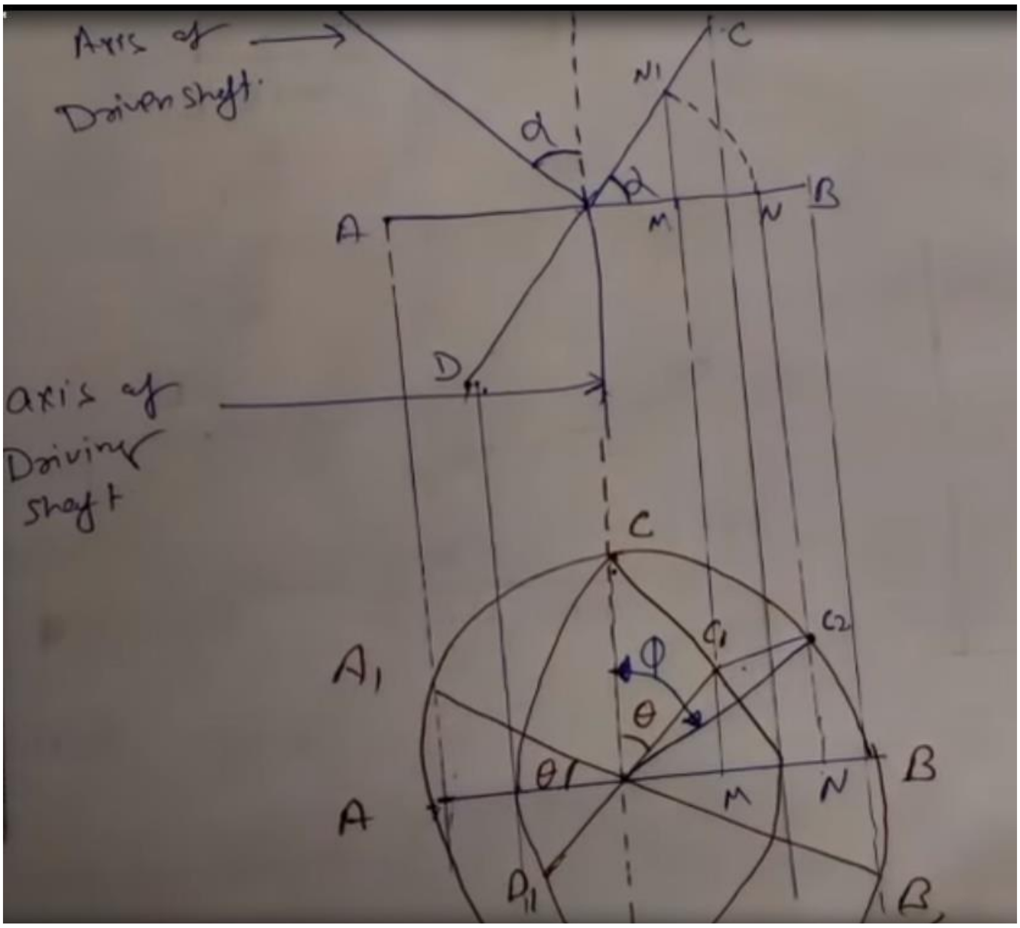
Schematic of the Cardan joint

The Cardan joint comprises of the three main parts including the input drive shafts, the output drive shafts and the cross like piece. Two points of the cross piece connect to the input drive shaft and two other points connect to the output drive shaft. Connections are provided by needle bearings.

It is an important aspect of these bearings that while in action they never go through complete cycles. In other words, each of these bearings revolves only a few degrees around its axis before returning to its original position. Therefore, there are only a group of balls in these bearings that take the bearing load. On the other hand, even if the angular speed of the output drive shafts is constant, the angular speed of the output drive shafts oscillates. The size of such oscillation depends on the amount of the angular derivation of the output drive shaft.

These joint or couplings are widely used in the automobile power transmission systems. However, they are prone to wear and malfunction and need to be replaced in comparatively short intervals of time. Naturally, it means that such parts have limited life span.

Design Calculation:



∴ From angle OC_1M,

$\tan\theta = OM / MC_1$ …..(1)

∴ From angle OC_2M,

$\tan\varphi = ON / NC_2 = ON / MC_1$ (Here $NC_2 = MC_1$) …..(2)

Divide Eq. (1) / Eq. (2)

$\tan\theta / \tan\varphi = OM / ON$

∴ $OM = ON_1\cos\alpha$

∴ $OM = ON\cos\alpha$

So that,

$\tan\theta = \tan\varphi.\ \cos\alpha$…..(3)

Let,

ω = Angular velocity of driving Shaft

ω_1 = Angular velocity of driving Shaft

Now Differentiate Eq. (3) with t (Time) and solve that Equation we get,

$\omega_1 / \omega = 1 / Cos^2\theta \ . Sec^2\varphi . \mathrm{Cos}\alpha$ …..(4)

And we know that,

$Sec^2\varphi = 1 + Tan^2\varphi$

And simplify above Eq. we get

$Sec^2\varphi = 1 - Cos^2\theta \ . Sin^2\varphi \ / \ (Cos^2\theta \ . Cos^2\varphi)$ ….(5)

Put the value of Eq. (5) into Eq. (4)

We'll get,

$\omega_1 / \omega = \mathrm{Cos}\alpha \ / \ (1 - Cos^2\theta \ . Sec^2\varphi)$…..(6)

Eq. (6) is the ratio of angular velocity of Driven to the Driving

We can write same for Speed.

Design of Universal Joint:

To transmit 6050N force at 550 KW and 1000 rpm through universal joint in the Car. We have taken mild steel material.

DRIVING SHAFT (D_1)	71.25 mm
YOKE DIAMETER (D)	42 mm
PIN DIAMETER(d)	14.49 mm
YOKE THICKNESS(t)	3.62 mm

Yield strength of MS = 370 MPa

Factor of safety = 2.5

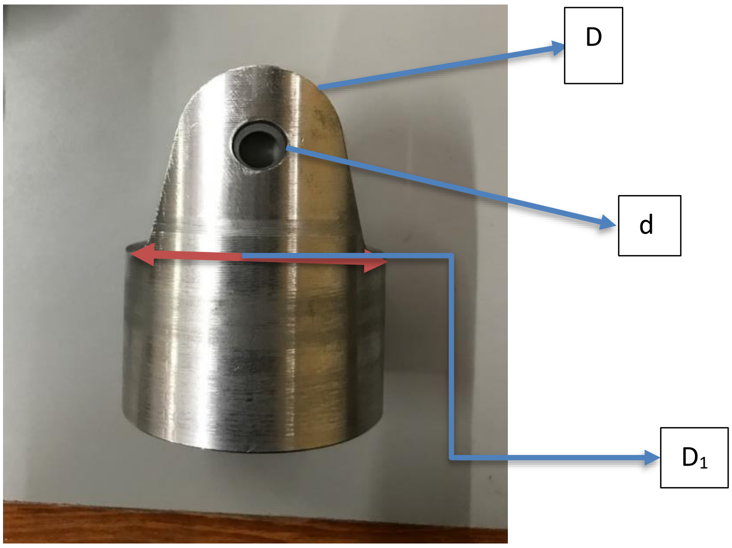
- Allowable tensile strength = 370/2.5

  = 148 MPa

- Allowable shear stress = 370/2 * 2.5

  = 74 MPa (from maximum principle theory)

Design of yoke:



- **TESILE FAILURE**

- Area = (R-r)t = 49.779 mm^2
- Force = Area * tensile stress

  Tensile stress = 6050/49.779

  = 121.54 N/mm^2 < 148 N/mm^2

- **SHEAR FAILURE**

- Area = πrt = 164.7 mm^2
- Force = Area * shear stress
- Shear stress = 6050/164.7

  = 36.73 MPa < 74 MPa

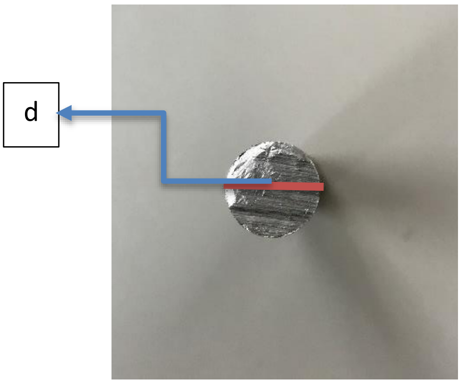
Design of pin:

- **SHEAR FAILURE**

- Area = πr^2 = 164.8 mm^2
- Force = Area * shear stress

  = 6050/164.8

  = 36.71 MPa < 74 MPa



Design of centre joint:

- Width of centre joint = $D_1 - 2t$

$$= 71.25 - 2(3.62)$$

$$= 64 \text{ mm}$$

Machining Processes:

a. External operation:

- ✓ **Turning:** Turing is a form of machining, a material removal processes, which is used to create rotational parts by cutting away unwanted material. The turning process require a turning machine or lathe, work-piece, fixture, and cutting tool.

- ✓ **Facing:** A single-point turning tool moves radially, along the end of the work-piece, removing a thin layer of material to provide a smooth flat surface. The depth of the face, typically very small, may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes.

b. Internal Operation:

✓ **VMC**: We used computerised vertical milling machine. Vertical milling is the cutting operation that removes metal by feeding the work against a rotating, cutter having single or multiple cutting edges. Flat or curved surfaces of many shapes can be machined by milling with good finish and accuracy.

Advantage and Disadvantage:

- **Advantages:**
  - Eliminate alignment problems: Flexible Shafts have no need for the tight tolerances that solid shafts require
  - Provide greater design freedom: Limitless possibilities in positioning motor and driven components.
  - Have higher efficiency: Flexible Shafts are 85% - 90% efficient. Gears, U-Joints Belts and Pulleys give much lower performance due to greater frictional losses.
  - Are light weight and powerful: Flexible Shafts have a good weight advantage over other design solutions while transmitting greater power loads
  - Have lower installation cost: Flexible shafts install in minutes without special tools or skills. Solid shafts, Gears, Pulleys, and Universal Joints require precise alignment and skilled mechanics for their installations.
  - Reduce parts cost: Bearing and Housings for solid shafts and Gears require precise machining operation. Flexible Shafts eliminate the need for such demanding tolerances and their excessive costs.
  - Are easy install: Need no special installation tools.
  - Can be designed at the latter stages of a project: Unlike other rotary motion device that need to be designed around because of their rigidness, defined configuration, and large mass. Flexible shafts allow greater design freedom since engineers have only one piece to work on, eliminating complex coordination of multiple pieces.

- **Disadvantages:**

The Cardan Joint suffers from one major problem: even when the input drive shafts axle rotates at a constant speed, the output drive shaft axle rotate at a variable speed, thus causing vibration and wear. Velocity and acceleration fluctuation increases with operating angle. Other disadvantage are as follows:

- Lubrication is required to reduce wear.
- Shafts must lie in precisely the same plane.
- Blacklash difficult to control.

Application:

- Aircarft
  - ✓ Thrust Reverser Actuation System
  - ✓ Variable Bleed Valve
  - ✓ Flap & Slat Actuation System

- Automotive
  - ✓ Pedal Adjuster
  - ✓ Power Sliding Door
  - ✓ Power Seat track
  - ✓ Tilt Steering

- Industrial
  - ✓ Road Spike
  - ✓ Power Sander
  - ✓ Power Tools

- Medical
  - ✓ Breast Biopsy
  - ✓ MRI Drug Delivery
  - ✓ Control Flap Maker

- Lawn & Garden
  - ✓ String Trimmer

Acknowledgement:

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