Design of Constant Velocity Coupling

Prof. A. A. Moghe[1], Mr. Yuvraj Patil[2], Mr. Mayur Pawar[3], Mr. Akshaykumar Thaware[4], Mr. Nitin Thorawade[5]

[1]Assistant Professor, [2,3,4,5]UG Students
Department of Mechanical Engineering
Sppu, PVPIT, Pune, Mahrashtra, India

***ABSTRACT*: A coupling is mechanical device used to connect two shafts together at their ends for the purpose of transmission of power. The basic role of couplings is to join two parts of rotating elements while permitting some degree of misalignment or end movement or both. Presently Oldham's coupling and Universal joints are used for parallel offset power transmission and angular offset transmission. These joints have limitations on maximum offset distance, angle, speed and result in vibrations, noise and low efficiency (below 70%). These limitations can be overcome with Thompson constant velocity (CV) coupling which offers features like minimizing side loads, higher misalignment capabilities, more operating speeds, improved efficiency of transmission and many more. The constant velocity joint is an alteration in design that offers up to 18 mm parallel offset and 21-degree angular offset, at high speeds up to 2000 or 2500 rpm at 90% efficiency. This design lowers cost of production, space requirement and simply technology of manufacture as compared too present CVJ in market. This paper presents review on constant velocity joints/couplings design and optimization.**

***Keywords*: Thompson constant velocity joint, Optimization & design, Constant velocity couplings, Parallel Offset, Angular Offset, Power Transmission.**

[I] INTRODUCTION

The basic function of a power transmission coupling is to transmit torque from an input/driving shaft to an output/driven shaft at a specified shaft speed. In any direct mechanical drive system, there exists a need to couple the variety of driven elements that may be included. The majority of drive elements, including gear reducers, lead screws, and a host of other components, are driven by shafting that is supported by multiple bearings. This allows for shafting to be held extremely straight and rigid while rotating, avoiding any possible balancing and support problems. Because of this rigid support, it is virtually impossible to avoid slight misalignments between a driving and driven shaft when they are connected. The essential capacity of a force transmission coupling is to transmit torque from a drive shaft to a driven shaft at a given speed and, where important, to assist shaft misalignment. Shaft misalignment can expand the axial and radial forces applied on the coupling. In misaligned shaft applications, undesirable side loads are usually introduced by the coupling. Due to misalignment undesirable effects occurs include:

- Torsional or angular velocity vibrations which reduces system accuracy.
- Excessive forces and heat on system bearings which reduce machine life.
- Increased system vibration and noise.

Conventional couplings used for transmission along with misalignment are Oldham's couplings and Universal couplings, but these couplings have some limitations such as maximum angular offset, efficiency of transmission, bearing life, operating speed etc.

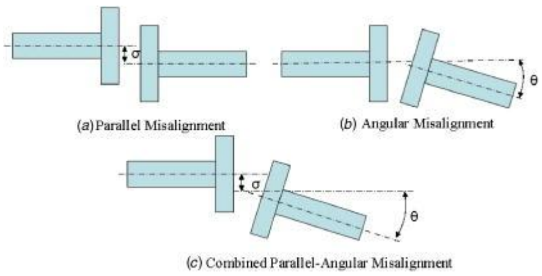


Fig.1 Types of Misalignment

Disadvantages of Oldham's Coupling are as follows:

- Maximum angular offset permissible is 12.5 mm.
- Different coupling required for different offset, e.g. E30 for 2.5 to 3.5 mm, E70 for 8.5 to 10mm etc.
- Maximum efficiency of transmission is 65%.
- Radial & axial forces reduce bearing life.
- Maximum operating speed 1800 rpm.

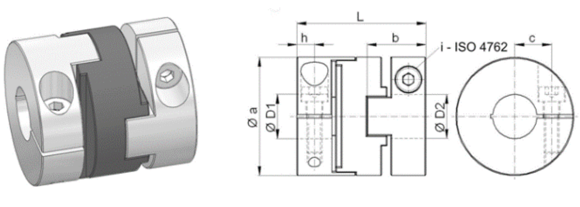


Fig.2 Oldham's Coupling

Universal Coupling:

Universal joint is most frequently used for power transmission along with solution for problem of shaft misalignment. The universal joints connected to a common central shaft transmitting power from the input shaft to the output shaft.

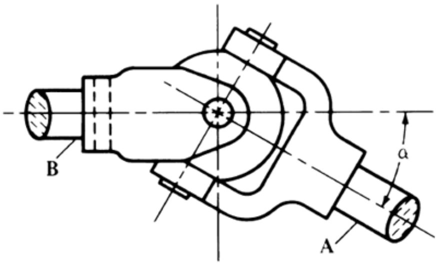


Fig.3 Universal Joint

Disadvantages of Universal joint are as follows:

- Maximum angular offset means more space required because maximum angle permissible between joints is 180
- Maximum efficiency of transmission is 65%
- Radial & axial forces reduce bearing life
- Maximum operating speed 1200 rpm, efficiency drops with increase in speed

LITERATURE REVIEW

[1] Ian Watson, B. GangadharaPrusty and John Olsen have stated in research paper titled "Conceptual design optimization of a constant velocity coupling" that The Thompson Coupling operates using the robust double Cardan mechanism. Constant velocity and determinate linkage kinematics are maintained by a spherical pantograph. This mechanism forms an extra loop attached to the intermediate shaft in the double Cardan linkage, and consequently constrains this shaft to bisect the axis of input and output. Closed-form expressions for its motion and the rotation of the double Cardan joint are derived by consideration of spherical linkage kinematics. These expressions are then used to drive basic conceptual design optimization, whose goal is to reduce induced driveline vibration.

[2] Chul-Hee Lee and Andreas A. Polycarpou has proposed in their research paper titled "A phenomenological friction model of tripod constant velocity (CV) joints" that constant velocity (CV) joints have been favored for automotive applications, compared to universal joints, due to their superiority of constant velocity torque transfer and plunging capability. High speed and sport utility vehicles with large joint articulation angles, demand lower plunging friction inside their CV joints to meet noise and vibration requirements, thus requiring a more thorough understanding of their internal friction characteristics. A phenomenological CV joint friction model was developed to model the friction behavior of tripod CV joints.

[3] Tae-Wan Ku, Lee-Ho Kim and Beom-Soo Kang in their research work titled "Multi-stage cold forging and experimental investigation for the outer race of constant velocity joints" has explored that as an important load-supporting automobile part that transmits torque between the transmission and the driven wheel, the outer race of CV (constant velocity) joints with six inner ball grooves has been conventionally produced by the multi-stage warm forging processes, which involves several operations including forward extrusion, upsetting, backward extrusions, sizing and necking, as well as additional machining. There is still no choice but to produce the complex shaped components other than by this warm forging process. As an alternative, multi-stage cold forging process is presented to replace these traditional warm forging. The multi-stage cold forging procedure is first considered through a process assessment regarding the traditional multistage warm forging one.

[4] Nishant Ramesh Wasatkar Misalignment in shaft may results into undesirable strains on shaft orientation bringing. Couple of ordinary arrangements are available for misalignment issues like Oldham's coupling and widespread joint which have a few confinements. These limitations can be overcome with Thompson constant velocity (CV) coupling which offers highlights like minimizing side loads, higher misalignment capabilities, more operating speeds, improved efficiency of transmission and many more. This paper presents review on constant velocity joints/couplings configuration and advancement. In this paper the examination work of different researchers identified with transmission couplings and constant velocity joints is reviewed.

[II] METHODS AND MATERIAL

The solution to the above problem is an indigenous coupling that gives constant transmission of torque and angular velocity. The following main features of the coupling are;

1. Minimize or even eliminate side loads

2. Higher shaft misalignment capabilities

3. Greater drive accuracy.

Work will be carried out in the following steps.

Selection of Motor:

The metric system uses kilowatts (kW) for driver ratings. Converting kW to torque:

$$0.3 = \frac{(\,kW \times 9550)}{1200}$$

= 0.038 (min. input power)

Drive Motor: -

Type: -	SINGLE PHASE AC MOTOR.
Power: -	1 /15 HP (50 WATTS)
Voltage: -	230 VOLTS, 50 Hz
Current: -	0.5 amps
Speed: -	Min = O rpm
	Max = 9500 rpm

DESIGN OF INPUT SHAFT:

1. Analytical Approach

By using torsional shear formula, torsional shear failure Material: EN24 Ultimate Tensile Strength: 800N/mm2 Yield Strength: 680N/mm2 fs max = Uts/fos = 800/2 = 400 N/mm2 Check for torsional shear failure of shaf

$$Te = \frac{\pi \times fs \times d^3}{16}$$

$$fs = \frac{16 \times 0.25 \times 10^3}{\pi \times 16^3}$$

$fs_{act} = 0.310\ N/mm^2$

As; $fs_{act} < fs_{all}$

Input shaft is safe under torsional load

2. Modelling of Input shaft

We generate 3D model of input shaft by using using CATIA V5R17 software & then it is imported to Ansys Workbench

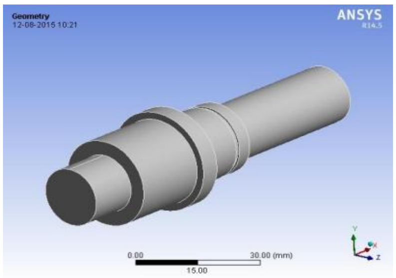


Fig.4 Geometry of Input Shaft

3. Finite Element Analysis

Input shaft is meshed with triangular surface mesher with 3170 nodes and 1771 number of elements.

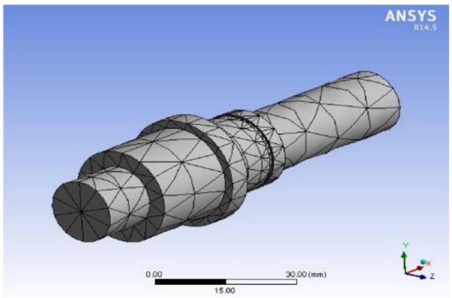


Fig.5 Meshing of Input Shaft

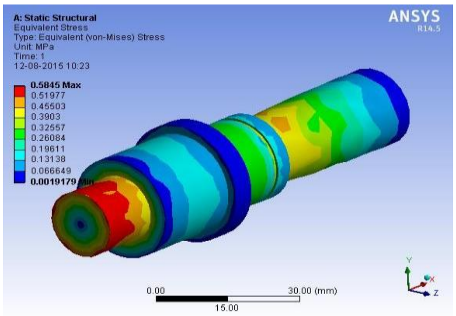
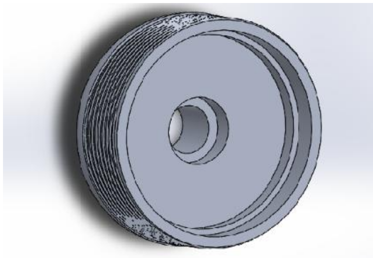


Fig.6 Stress Distribution

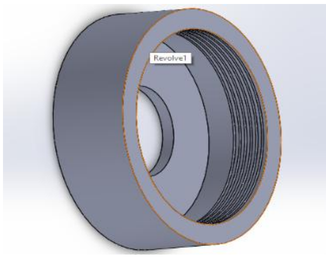
The maximum Von Mises stress for input shaft is 0.5845 MPa and total deformation is 0.00018877 mm.

Modelling of all other parts:

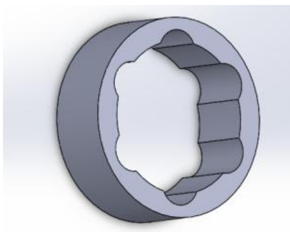
Modelling of Input Coupler Body:



Modeling of Input Coupler Ring:



Modeling of Input Coupler Female Liner



Modeling of Coupler Pin

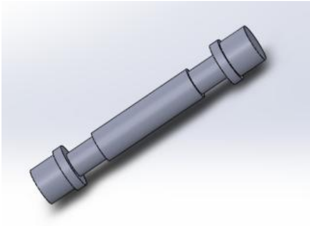


Table 1. Von Mises Stress and Total Deformation of all Design Parts

The Finite element analysis results of all other parts are given below

Part name	Max. shear stress N/mm^2	Actual Theoretical stress N/mm^2	Von-mises stress N/mm^2	Total deforma-tion mm
Input Shaft	400	0.310	0.5845	0.0001887
Input Coupler Body	200	0.15	0.098	9.06×10^{-6}
Input Coupler Ring	400	0.0035	0.013	1.045×10^{-6}
Input Coupler Female Liner	400	0.0113	0.40	1.045×10^{-6}
Coupler Pin	400	2.486	5.02	0.0011
Trunnion Holder	200	0.2	0.9	0.00023

Theoretical Actual stress and Von-misses stress of all parts are well below the allowable limit, hence all the parts are safe.

[III] EXPERIMENTAL ANALYSIS

The constant velocity joint consist of assembly of coupler body, coupler ring, coupler female liner & trunnion having three spherical grooves in which three coupler pin are fitted. This joint is fitted to input and output shaft. At input side motor is fitted with the help of pulley. At output side dyno brake pulley is fitted on which we can place a pulley cord for taking readings by holding various weights. Schematic showing the arrangement of test rig in three condition of testing namely:

a) Zero offset condition

b) Parallel offset condition

c) Angular offset condition

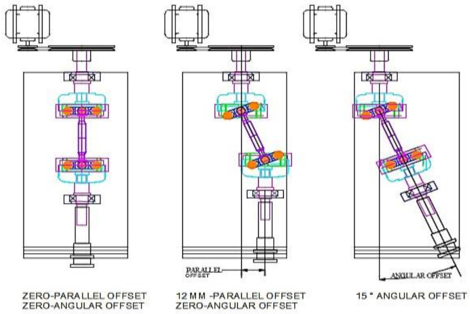


Fig.7 Arrangement of Test Rig

Fig.8Constant Velocity Joint

Fig.9 Trunnion Joint

Experimental Procedure

1) Start the motor
2) Let mechanism run & stabilize at certain speed (say 1500 rpm)
3) Place the pulley cord on dyno brake pulley and add 0.1 Kg weight into the pan, note down the output speed for this load by means of tachometer
4) Add another 0.1Kg cut & take reading
5) After that take readings for Parallel offset & Angular offset by shifting the output shaft with the help of spanner
6) Tabulate the readings in the observation table

Observation Tables:

Table 2. Observation Table of Zero Offset

Sr No	Loading		unloading		Mean Speed
	Weight (Kg)	Speed Rpm	Weight (Kg)	Speed Rpm	

1.	0.2	1495	2	1485	1490
2.	0.4	1460	4	1460	1460
3.	0.6	1390	6	1390	1390
4.	0.8	1280	8	1290	1285
5.	1.0	1060	10	1080	2140

Table 3 Observation Table of 12mm Parallel Offset

Sr No	Loading		unloading		Mean Speed
	Weight (Kg)	Speed Rpm	Weight (Kg)	Speed Rpm	
1.	0.2	1480	2	1460	1470
2.	0.4	1400	4	1410	1405
3.	0.6	1320	6	1340	1330
4.	0.8	1210	8	1190	1200
5.	1.0	960	10	920	940

Table 4 Observation Table of 14 Degree Angular Offset

Sr No	Loading		Unloading		Mean Speed
	Weight (Kg)	Speed Rpm	Weight (Kg)	Speed Rpm	
1.	0.2	1440	2	1420	1430
2.	0.4	1320	4	1310	1315
3.	0.6	1220	6	1240	1230
4.	0.8	1090	8	1080	1070
5.	1.0	900	10	880	890

CONCLUSION:

- The maximum efficiency transmit power between parallel but inline shaft with the help of Constant velocity coupling
- Constant velocity coupling can transmit power between parallel but offset shafts, maximum offset being 12mm
- Constant velocity coupling can transmit power between angular offset shafts, maximum offset being 15 degrees.
- Vibration and noise free power transmission.

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