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Performance Evaluation and Analysis of Three Pin Constant Velocity Joint for Parallel and Angular Power Transmission

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ABSTRACT

A coupling is a gadget used to interface 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. by cautious selection, establishment and support of couplings, generous reserve funds can be made in decreased maintenance cost and downtime. 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 and low efficiency (below 70%). The three pin constant velocity joint is an alteration in design that offers upto 12 mm parallel offset and 15 degree angular offset ,at high speeds upto 2000 or 2500 rpm @ 90% efficiency. This design lowers cost of production, space requirement and simply technology of manufacture as compared to present CVJ in market.

Keywords: 3-Pin Constant Velocity Joint, Parallel Offset, Angular Offset, Power Transmission, Von-Mises Stress

I. INTRODUCTION

The essential capacity of a force transmission coupling is to transmit torque from an info shaft to a yield shaft at a given shaft speed and, where important, to accommodate shaft misalignment. Misalignment is the after effect of numerous components including installation errors and tolerance variation. Shaft misalignment can expand the axial and radial forces applied on the coupling. In misaligned applications, undesirable side loads are usually introduced by the coupling. These side loads which are resulting from dynamic behavior of coupling, frictional loads and loads caused by flexing or compressing coupling components. The undesirable results include:

1. Torsional or angular velocity vibrations which diminish system accuracy.
2. Excessive forces and warmth on system bearings which diminish machine life.
3. Expanded system vibration and commotion which unfavorably influences equipment operation.

Disadvantages of Oldham's Coupling are as follows:

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

Oldham's Coupling

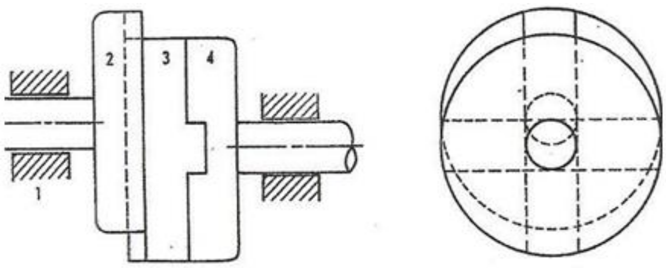


Figure 1. Oldham's Coupling

4. Universal Joint/ Hookes Joint:

The simple and most common solution to the problem of shaft misalignment is using Double universal joints. The double universal joint coupling consists of two universal joints connected to a common central shaft transmitting power from the input shaft to the output shaft.

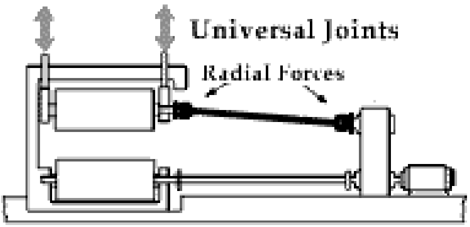


Figure. 2 Universal Joint

Disadvantages of Universal joint are as follows:

- Maximum angular offset means more space required because maximum angle permissible between joints is 18^0
- Maximum efficiency of transmission is 65%
- Radial & axial forces reduce bearing life
- Maximum operating speed 1200 rpm, efficiency drops with increase in speed

II. METHODS AND MATERIAL

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

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.

Design of Input Shaft:

1. Analytical Approach

By using torsional shear formula, torsional shear failure
Material: EN24
Ultimate Tensile Strength: $800 N/mm^2$

Yield Strength: $680 N/mm^2$

$fs_{max} = Uts/fos = 800/2 = 400\ N/mm^2$

Check for torsional shear failure of shaft

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

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

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

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

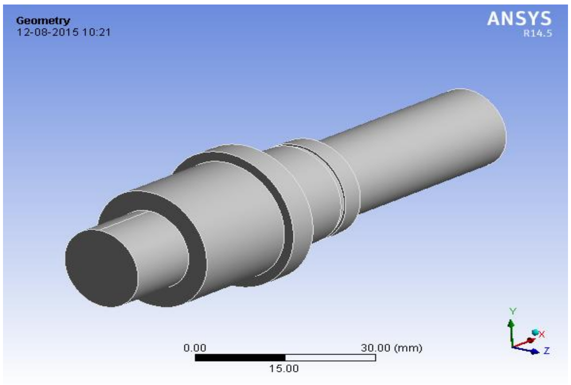


Figure 3. Geometry of Input Shaft

3. Finite Element Analysis

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

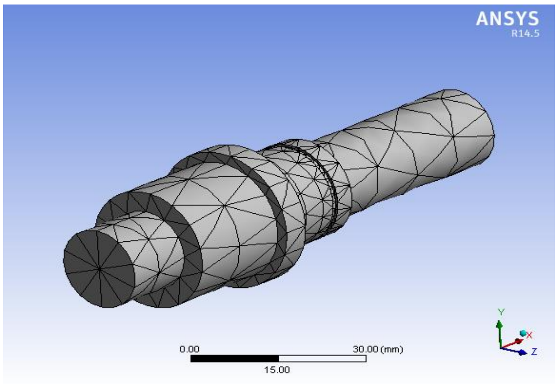


Figure 4. Meshing of Input Shaft

After meshing one fix support and moment 250 N-mm is given to Input Shaft

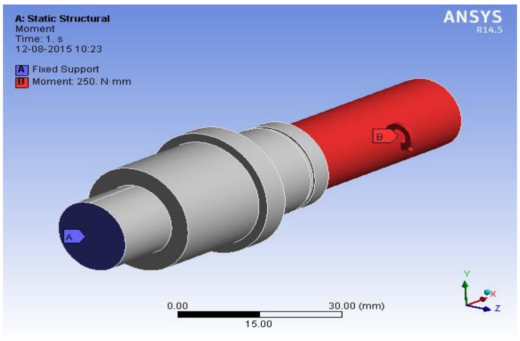


Figure 5. Boundary Conditions of Input Shaft

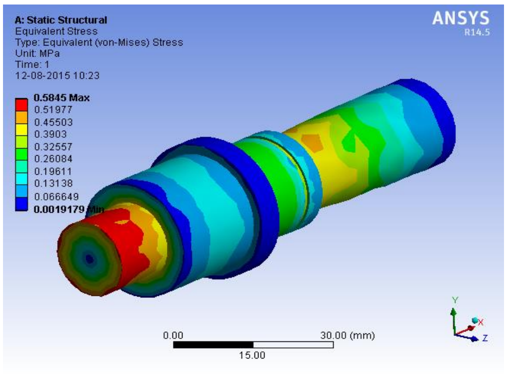


Figure 6. Stress Distribution of Input Shaft

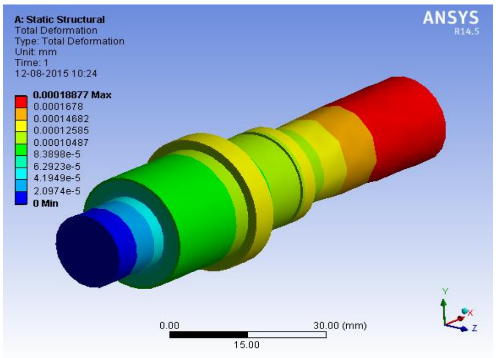


Figure 7. Displacement Plot of Input shaft

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

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

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

Part name	Max. shear stress N/mm^2	Actual Theoretical stress N/mm^2	Von-mises stress N/mm^2	Total deformation 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
Trunion Holder	200	0.2	0.9	0.00023

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

Also the value of Total deformation of all parts is very small so the deformation is neglected.

III. EXPERIMENTAL ANALYSIS

Three pin constant velocity joint consist of assembly of coupler body, coupler ring, coupler female liner & trunion 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 dynobrake 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

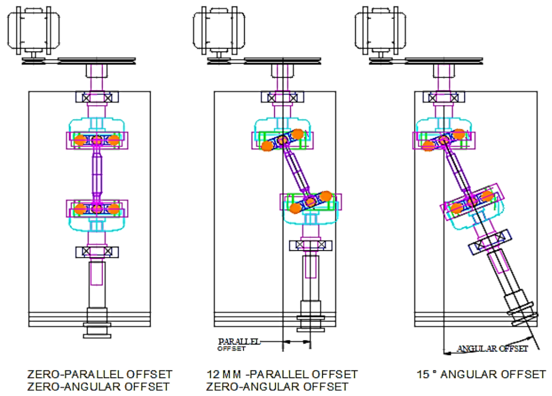


Figure 8. Arrangement of Test Rig

Figure 9. Actual Setup Diagram

Experimental Procedure

1) Start the motor
2) Let mechanism run & stabilize at certain speed (say 1500 rpm)
3) Place the pulley cord on dynobrake 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
7) Plot Torque Vs speed characteristic
   Power Vs speed characteristic
   Efficiency Vs speed characteristic

Observation Tables

Table 2 Observation Table of Zero Offset

Sr No	Loading		Unloding		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		Unloding		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		Unloding		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

Calculations

Sample calculation for Zero offset

1) Average Speed

$$N = \frac{N_1 + N_2}{2} = \frac{1495 + 1485}{2} = 1490 \text{ rpm}$$

2) Output Torque:-

T_o = Weight in pan x Radius of Dynobrake Pulley

= (0. 2x 9.81) x 25

= 49.05 N-mm

T_o = 0.04905 N-m

3) Input Power (Pi) = 29.6 WATT

4) OutPut Power (P_o)

$$P_o = \frac{2\pi N T_o}{60}$$

$$P_o = \frac{2 \times \pi \times 1490 \times 0.04905}{60}$$

$$P_o = 7.65\ Watt$$

5) Efficiency

$$\eta = \frac{Output\ Power}{Input\ Power}$$

$$= \frac{7.65}{29.6}$$

$$\eta = 25.8594\%$$

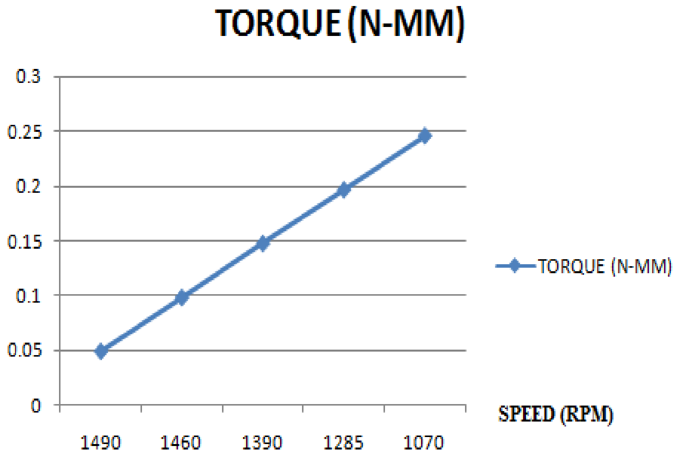
Efficiency of transmission of gear drive at 0. 2 kg load is 25.8594 %

IV. RESULTS AND DISCUSSION

1. Zero Offset

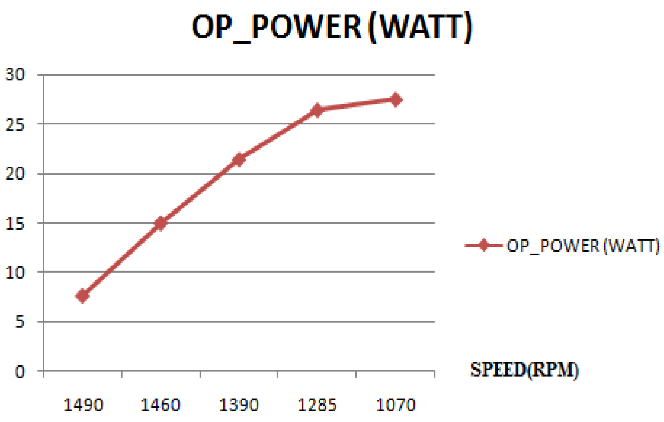
Table 5. Result table of zero offset

Sr No	Load (Kg)	Speed (Rpm)	Torque (N-m)	Power (Watt)	Efficiency
1.	0.2	1490	0.04905	7.6543833	25.8594
2.	0.4	1460	0.0981	15.0005364	50.67749
3.	0.6	1390	0.14715	21.4219989	72.37162
4.	0.8	1285	0.1962	26.4050538	89.20626
5.	1.0	2140	0.24525	27.4838595	92.85088



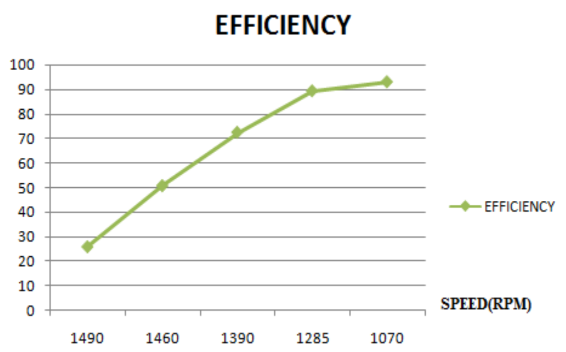
Graph 1 Torque vs Speed Characteristics of Zero offset

Graph shows that torque increases with decrease in output speed of coupling .



Graph 2. Output Power Vs Speed Characteristics of Zero offset

Graph shows that maximum power is delivered by the coupling at clos to 1100 rpm .thus this is recommended speed at zero offset condition.



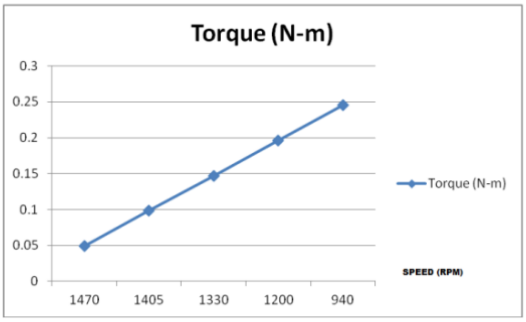
Graph 3 Efficiency Vs Speed Characteristics of Zero offset

Graph shows that maximum efficiency is attained by the coupling at close to 1200 rpm .thus this is recommended speed at maximum parallel offset condition for mximum efficiency.

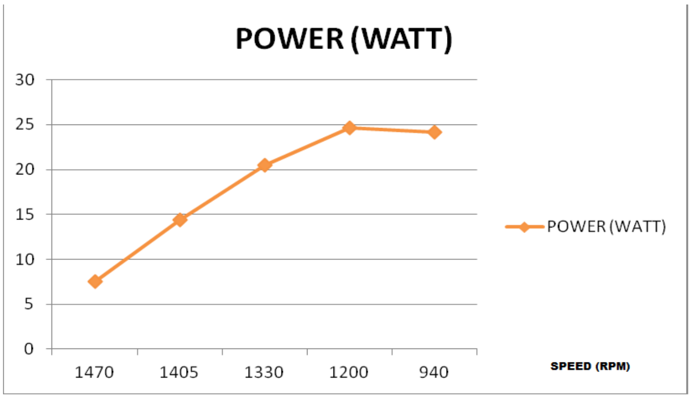
2. Parallel Offset : 12MM

Table 5. Power and Efficiency of 12mm Parallel Offset

Sr. No.	Load (kg)	Speed (rpm)	Torque (N.m)	Power (Watt)	Efficiency
1	0.2	1470	0.04905	7.55164	25.5123
2	0.4	1405	0.0981	14.4354	48.7684
3	0.6	1330	0.14715	20.4973	69.2476
4	0.8	1200	0.1962	24.6584	83.3054
5	1.0	940	0.24525	24.1447	81.5699

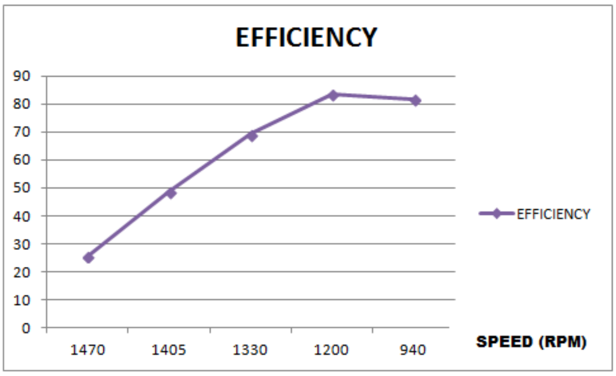


Graph 4. Torque vs Speed Characteristics of Parallel offset Graph demonstrates that torque increases with reduction in output speed of coupling



Graph 5. Power Vs Speed Characteristics of Parallel offet

Graph demonstrates that maximum power is conveyed by the coupling at close to 1200 rpm .So this is suggested speed at maximum parallel offset condition.



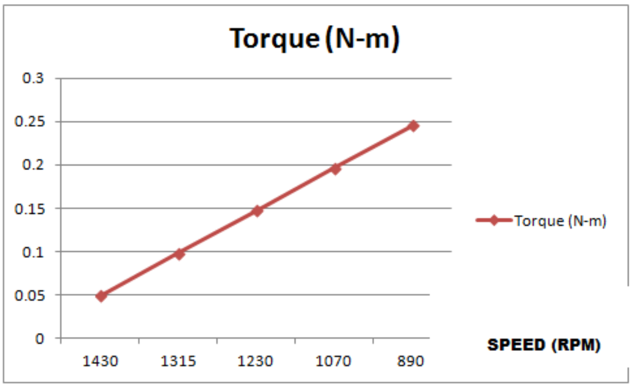
Graph 5. Efficiency Vs Speed Characteristics of Parallel offset

Graph demonstrates that max. efficiency is achieved by the coupling at near 1200 rpm .In this way this is suggested speed at greatest parallel offset condition for mximum efficiency.

2. Angular Offset : 14 DEGREE MAXIMUM

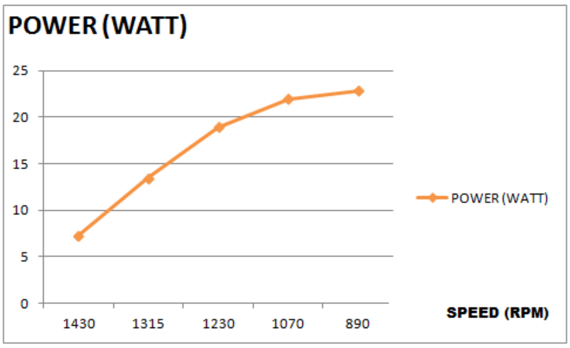
Table 6. Power and Efficiency of 12mm Angular Offset

Sr. No.	Load (kg)	Speed (rpm)	Torque (N.m)	Power (Watt)	Efficiency
1	0.2	1430	0.04905	7.3462	24.8181
2	0.4	1315	0.0981	13.5108	45.6445
3	0.6	1230	0.14715	18.9562	64.0411
4	0.8	1070	0.1962	21.9871	74.2807
5	1.0	890	0.24525	22.8604	77.2311



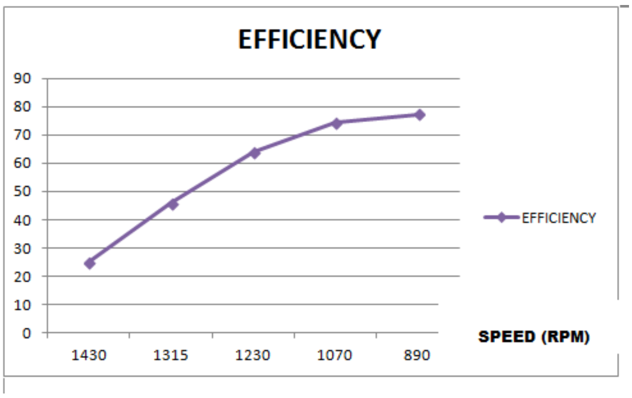
Graph 6 Torque vs Speed Characteristics of Angular offset

Graph demonstrates that torque increases with decrease in output speed of coupling



Graph 7. Power Vs Speed Characteristics of Angular offet

Graph demonstrates that most extreme force is conveyed by the coupling at close to 900 rpm .subsequently this is suggested speed at maximum parallel offset condition.



Graph 8. Efficiency Vs Speed Characteristics of Parallel offset

Graph demonstrates that maximum efficiency is achieved by the coupling at near 900 rpm .so this is recommended speed at maximum angular offset condition for mximum efficiency.

V. CONCLUSION

- ✓ Three Pin CVJ can transmit power between parallel but inline shaft with maximum efficiency
- ✓ Three pin CVJ can transmit power between parallel but offset shafts, maximum offset being 12mm
- ✓ Three pin CVJ can transmit power between angular offset shafts, maximum offset being 15 degree.
- ✓ High speeds upto 5000 rpm can be attained.
- ✓ Vibration and noise free power transmission.
- ✓ Setting time for parallel offset is less than 3 minutes
- ✓ Setting time for angular offset is less than 5 minutes

VI. ACKNOWLEDGEMENT

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