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Optimization of Thompson Type Coupling for Angular Transmission with Brass and Phosphor Bronze as Alternative Material for Trunion Joint

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Abstract:-- **One of important part in coupling is trunion which is a part of rotating joint where shaft is inserted into. This allows precise tolerances to be maintained along with large surface in contact, so that power is transferred efficiently. Hence there is a vital role of trunion in transmission which outlines the efficiency of transmission system and power transfer is also affected by it.Hence it is necessary to do detail study and analysis of transmission coupling withtrunion.**

To overcome the certainlimitations like excess strain on joint, wearing of joint, Thompson type constant velocity joint (CV) or Thompson coupling with trunion joint is considered under the optimization study ,which may offer features like minimizing side loads, higher misalignment capabilities, more operating speeds, improved efficiency of transmission and many more. This work presents comparative study for optimization of Thompson type coupling for angular transmission with Phosphor Bronze and Brass material for trunion joint over conventional Alloy steel. © 2015 The Authors. Published by Elsevier Ltd.

Keywords:---**Thompson coupling; Trunion;brass; Phosper bronze; EN24;**

I. INTRODUCTION

Power transmission couplings are widely used for modification of stiffness and damping in power transmission systems, both in torsion and in other directions (misalignment compensation). There are attributes that affect the type of coupling best suited for an application. This is a long list of evaluation factors. For any one application there may be only three or four attributes which are extremely important. In fact it would be difficult to satisfy more than a half dozen attributes with any one coupling. It is important to narrow the requirements for an application down to only the most critical attributes that come into play. properly designed, the shudderless tripode joint shows some advantages with respect the classical solution,but it requires higher manufacturing and construction costs[11]. Here we summarize the major coupling types discussed in the materials and provide some ratings of each coupling type against these factors [01].

The rigid power transmission couplings offer good performance but it faces some practical working difficulties like it can’t tolerate misalignment which ultimately causes elastic deformation. 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[12]. Misalignment in a vehicle is due to many factors including manufacturing tolerances, packaging constraints, suspension travel, and engine dynamic movement (pitch and roll). Non-constant velocity (universal joint or Hooke’s joint), constant velocity (CV) joint, and flex couplings have been used in driveshaft vehicle applications for these reasons [08].Backlash offers more forward and back ward movements of couplings which will cause more stress generation; this will lead to premature failure of coupling. Rigid couplings also demands more and frequent lubrication. It requires selecting different couplings for different demands of angular deviations. On the other hand, constant velocity couplings permit maximum power transfer from the input shaft to output shaft over the wide range of angles and speeds. It has also high torque rating than rigid couplings. In case of rigid coupling, the absence of lubrication generate more heat but as CV couplings require less lubrication hence chances of heat generation are less.Constant Velocity Universal Joints (CVJ) have come to be used widely for driveshafts and propeller shafts invehicles, and are now being used for almost 100% of Japanese cars[10]. The findings of this optimisation are discussed with respect to the current design of the Thompson joint. Improvements in induced driveline vibration arepossible, subject to the satisfaction of other coupling design criteria [06]it is concluded that the Thompson CV coupling is a true constant velocity shaftcoupling with all revolute joint in it[09].

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The Thompson constant velocity joint (TCVJ) also known as a Thompson coupling assembles two cardan joints within each other to eliminate the intermediate shaft. A control yoke is added to keep the input and output shafts aligned. The control yoke uses a spherical pantograph scissor mechanism to bisect the angle between the input and output shafts and to maintain the joints at a relative phase angle of zero.

The coupling earned its inventor, Glenn Thompson; the Australian Society for Engineering in Agriculture Engineering Award [2].The graph potted by Glenn Thompson shown in fig.1puts together the comparison of conventional universal joint and Thompson coupling or Thompson constant velocity joint.

It is concluded from graph that for all input rotation angles there is fair constant angular velocity is achieved at output end however input speed is kept constant at 1500 rpm. On the other hand same is recorded for universal joint which gives uneven or cyclic output angular velocity. This built an idea for development of Thompson type velocity joint at company and comparing the performance with three different materials as a frictional element.

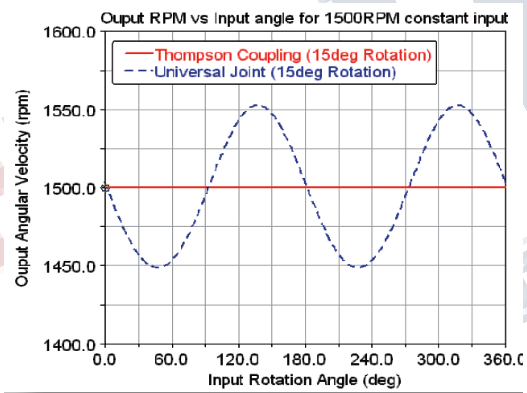

Fig.1- TCVJ Vs Universal Coupling [2]

Features of this TCVJ are listed below [2]

1. It can tolerate axial and radial loads with degradation.
2. Variation of angle is possible up to 30 degree.
3. Unique feature is replaceable bearings and trunions except this no wearing component.
4. Doesn't require any dust boot.
5. It can be designed and constructed to any torque level.

II. MATERIAL RELEVANCE

Copper alloys may be divided into two principle classes – ***Brass and Bronze***

1. Brass

The brasses are commonly alloys of copper and zinc. Brasses possess excellent mechanical properties and are corrosion resistant and also readily machinable.

A. Tin Brasses are alloys made from copper 60 %, zinc (2% to 40%) and tin (0.2% to 3%). This family of alloys includes admiralty brasses, naval brasses and free-machining tin brasses. These alloys are used to make high-strength fasteners, electrical connectors, springs, corrosion resistant mechanical products, marine hardware, pump shafts, and corrosion-resistant screw machine parts. They provide increased corrosion resistance, lower sensitivity to dezincification and higher strength compared with straight brasses. They possess good hot forge ability and good cold formability. These materials have moderate strength, high atmospheric and aqueous corrosion resistance and excellent electrical conductivity. However more than 2 % addition of tin leads to reduction in ductility.

B. Aluminium Brass the amount of Aluminium added to brass doesn't exceed 3% it raises tensile strength but decreases ductility the product has deep golden colour and resist corrosion better than ordinary brass. [04]

C. Lead Brass lead is intended for filing or turning. 1 to 2 % of lead is employed to prevent fouling of tools and to cause the turning to break more readily but lead addition increases the softness of brass thus it reduces ductility and strength. [03]

D. Addition of Zinc into copper plays following roles

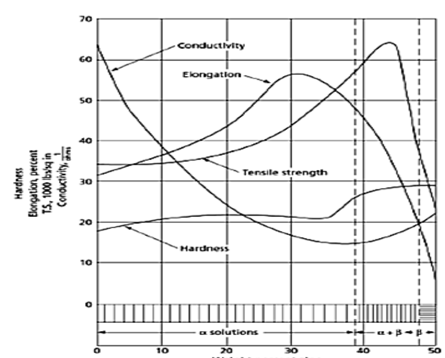

Fig 2: Effect of Addition of Zinc on Mechanical Properties [05]

i. It forms as the corrosion resistance surface or lining
ii. It acts as protective coating
iii. Addition of zinc reduces hardness first again it shows increase in hardness as it crosses 35 %
iv. However it shows increase in Tensile strength up to 40-45 % zinc addition after 45 % it shows reduction in T.S. [05]

Brass containing 39 to 46 % Zinc are stronger however ductility reduces. They have reddish tint alloys of this type has marked resistance to corrosion and wear [03].

E. Muntz metal, therefore which contains 60 % copper and 40% zinc makes the better selection which leads to higher tensile strength and higher hardness as well as addition of zinc leads to forming protective coating.

2. Bronzes-

Bronzes are the alloys of copper and tin. Tensile strength of bronzes increases gradually with addition of tin in it but more than 20 % reduces the strength rapidly. Bronze is most ductile when it contains 5% of tin which will roll it satisfactorily at red heat. [03]

A. Aluminium Bronze-

The Aluminium Bronze has the composition of Cu-88 %, Al-8 %, Fe-3 %, Sn-0.5 % thus sometimes this is called as Copper Aluminium alloy which has high strength and resistance to corrosion but these are difficult to cast due to oxidation also if not free from impurities will lead to segregation of castings. [04]

B. Silicon Bronze

These are copper alloys having 4 % of silicon and up to 1% of manganese with small amount of tin, zinc, iron and aluminium. However they are not the bronzes as tin is very small and possess the strength of soft steel with fair corrosion resistance. [04]

C. Phosphor Bronzes

It contain between 0.5% and 11% tin and 0.01% to0.35% phosphorous. Tin increases their corrosion resistance and tensile strength; phosphorous increases wear resistance and stiffness. Phosphor bronzes have superb spring qualities, high fatigue resistance, and excellent formability and solder ability, and high corrosion resistance. [03]

D. Addition of Phosphorus will form the Phosphor bronze has following remarkable impact on bronze -[04]

a. It Increases the resistance to fatigue enormously which is very important for trunions subjected to rolling actions
b. It increases Tensile strength of component
c. Optimum elasticity
d. Main purpose of addition of phosphorus is deoxidation which removes 0.08 to 0.025 % of oxygen thus it prevents formation of residues in metal. By considering above general factors discussed in introductory part, the most suggested materials for trunion are

1. Muntze metal (brass)
2. Phosper Bronze

However conventional material for trunion joint is EN 24.

Table 01
Properties of Selected material for Trunion [03]

Sr.	Material for Trunion	Composition	Mechanical Properties	
01	Brass (C28000)	60 %-Cu 40%-Zn	Tensile Strength	370-485 MPa
			Yield Strength	145-345 MPa
02	Phosper Bronze (C51100)	95.6%-Cu 4.2%-Sn 0.2%-P	Tensile Strength	317-710 MPa
			Yield Strength	345-552 MPa
03	Alloy Steel (En24)	0.36/0.44 %-C 0.10/0.35%- SI 0.45/0.70%- MN	Tensile Strength	850-1000 MPa
			Yield Strength	654-680 a

3. Testing of Thompson Coupling

The prototype model of TCVJ developed in order to test it for different conditions with above stated material for trunion joint minimum wear condition ,the prototype model is developed using machining and welding employed to fabricate the- components and these in turn assembled to form the test set –up. The fabrication will be carried out as per layout shown.

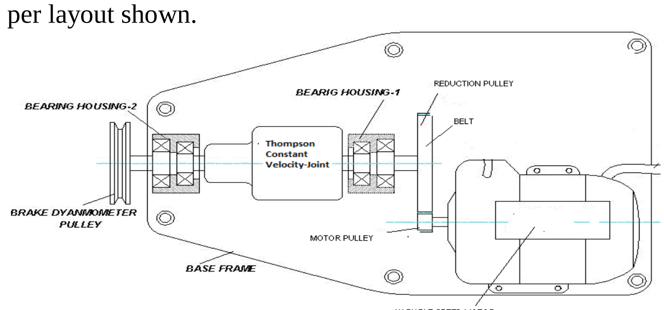

Fig. 03- layout of constant velocity joint drive [07]

The assembly of CVJ is tested for following conditions by varying the angle of output shaft with respect to input shaft concern of design is limited up to five degree additional five degree of variation is incorporated into the assembly i.e. output shaft can incorporate up to 10 degree of angular deviation.

Torque Vs Speed
Power Vs Speed
Efficiency Vs Speed

The testing is carried out by varying the output shaft angle such as 0, 5 and 10 degree plan of test is as follows. For our study we will consider only zero degree of angular variation.

Testing with Phosper Bronze Trunion-

Procedure

1. First electric motor is started.
2. Next step is to allow mechanism to run & stabilize this mechanism at certain speed (say 1500 rpm)
3. In the next step pulley cord is placed on dynmobrake pulley and 0.1 Kg weight is added into the pan, then the output speed is noted down, by means of tachometer.
4. Another 0.1 Kg is added and reading is noted down. Continue the load addition up to 1.0 kg load is added. Reading is noted down for each interval of 0.2 Kg, i.e.0.2 Kg, 0.4 Kg and so one.
5. Second set of speed reading is noted down and mean is calculated for each speed set.
6. Readings are noted down and tabulated in the observation table
7. Next step is to plot Torque Vs speed characteristic, Power Vs speed characteristic, Efficiency Vs speed characteristic.

Table 02
Phosper Bronze trunion observation table

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

Calculations

The parameters are calculated for load of 0.8 Kg as a sample calculation. According to process followed in sample calculation rest of the results are calculated and tabulated into result sheet.

a. Average Speed (N1)

$$N_1 = \frac{n_1 + n_2}{2}$$

$$N_1 = \frac{1210 + 1190}{2}$$

$$N_1 = 1200 \text{ rpm}$$

b. Output Torque:-(Drum Pulley)

T DP = Weight in pan x Radius of Dynmobrake Pulley
= (0.8x 9.81) x 25

= 196.2 N.mm

T DP=0.1962 N.m

c. Input Power(Pi) = 29.6 WATT

d. Output Power (Po)

$$P_o = \frac{2\,\pi\, N\, To}{60}$$

$$P_o = \frac{2 \times \pi \times 0.1962 \times 1200}{60}$$

$$P_o = 24.6 \text{ watt}$$

e. Efficiency (η)

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\eta = \frac{24.6}{29.6}$$

η =83.30%

Table 03
Result Table -Different Loads for PB Trunion Joint at Zero Degree

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	14.43545	48.7684
3	0.6	1330	0.14715	20.49731	69.24766
4	0.8	1200	0.1962	24.65842	83.30546
5	1.0	940	0.24525	24.1447	81.56993

Testing with Brass Trunion (For Zero Degree)

The second material selected for experimentation is brass as a trunion joint material test is conducted in order to determine –Speed, Torque, Power, and Efficiency. The procedure of test is explained as follows.

Procedure:-

1. First electric motor is started.
2. Next step is to allow mechanism to run & stabilize this mechanism at certain speed (say 1500 rpm)
3. In next step pulley cord is placed on dynmobrake pulley and 0.1 Kg weight is added into the pan, then the output speed is noted down, by means of tachometer.
4. Another 0.1 Kg is added and reading is noted down. Continue the load addition up to 1.0 kg load is added.

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Reading is noted down for each interval of 0.2 Kg, i.e.0.2 Kg, 0.4 Kg and so one.

5. Second set of speed reading is noted down and mean is calculated for each speed set.

6. Readings are noted down and tabulated in the observation table

7. Next step is to plot Torque Vs speed characteristic, Power Vs speed characteristic, Efficiency Vs speed characteristic

Table 04

Brass trunion observation table

Sr.No.	Loading			Mean Speed (rpm)
	Weight (Kg)	Speed (rpm)		
1	0.2	1440	1460	1450
2	0.4	1380	1388	1384
3	0.6	1316	1300	1308
4	0.8	1174	1178	1176
5	1.0	910	918	914

CALCULATION-

A. AVERAGE SPEED (N1)

$$N_1 = \frac{N_1 + N_2}{2}$$

$$N_1 = \frac{1174 + 1178}{2}$$

N_1 **= 1176 RPM**

B. OUTPUT TORQUE:-(DRUM PULLEY)

T DP = Weight in pan x Radius of Dynmobrake Pulley

= (0.8x 9.81) x 25

= 196.2 N.mm

TDP =0.1962 N.m

C. INPUT POWER(PI) = 29.6 WATT

D. OUTPUT POWER (PO)

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

$$P_o = \frac{2 \times \pi \times 0.1962 \times 1176}{60}$$

$P_o = 24.16$ watt

E. EFFICIENCY (H)

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\eta = \frac{24.16}{29.6}$$

η =81.42 %

Table 05- Result Table -Different Loads For Brass Trunion Joint At Zero Degree

Sr. No.	Load(Kg)	Speed(rpm)	Torque (N-m)	Power (Watt)	Efficiency (%)
1	0.2	1450	0.04905	7.447948	25.09257
2	0.4	1384	0.0981	14.21788	47.96395
3	0.6	1308	0.14715	20.15569	67.88531
4	0.8	1176	0.1962	24.16217	81.42072
5	1.0	914	0.24525	23.47388	79.04335

Testing with EN24 Trunion –

The existing material for trunion joint is EN24-Alloy steel , which is through hardening alloy steel which has excellent machinability, this is conventional material for trunion joint material by the Anil industries apart from machinability if we want minimum wear then surface hardening treatment is required otherwise it would lead to prescheduled scrap of joint, even more it was found that it creates chatter and noise while in operation, also it was observed that more variation in power and torque transmission hence drop in efficiency. With same construction the following results are available with Anil industry. Trial on TCVJ is conducted with EN24 as trunion joint material in order to determine –Speed, Torque, Power, Efficiency, following procedure is adopted for testing.

PROCEDURE:-

1. First electric motor is started.
2. Next step is to allow mechanism to run & stabilize this mechanism at certain speed (say 1500 rpm)
3. In next step pulley cord is placed on dynmobrake pulley and 0.1 kg weight is added into the pan, then the output speed is noted down, by means of tachometer.
4. Another 0.1 kg is added and reading is noted down. Continue the load addition up to 1.0 kg load is added. Reading is noted down for each interval of 0.2 kg, i.e.0.2 kg, 0.4 kg and so one.
5. Second set of speed reading is noted down and mean is calculated for each speed set.
6. Readings are noted down and tabulated in the observation table
7. Next step is to plot torque vs speed characteristic, power vs speed characteristic, efficiency vs speed characteristic

Table 06–
EN24 trunion observation table

Sr.No.	Loading Weight (Kg)	Speed (rpm)		Mean Speed (rpm)
1	0.2	1420	1440	1430
2	0.4	1300	1330	1315
3	0.6	1220	1240	1230
4	0.8	1071	1069	1070
5	1.0	888	892	890

CALCULATIONS

A. AVERAGE SPEED (N1)

$$N_1 = \frac{N_1 + N_2}{2}$$

$$N_1 = \frac{890 + 892}{2}$$

$$N_1 = 890 \text{ RPM}$$

B. OUTPUT TORQUE:-(DRUM PULLEY)

T DP = Weight in pan x Radius of Dynmobrake Pulley
= (1.0 x 9.81) x 25
= 245.25 N.mm
T DP =0.245 N.m

C. INPUT POWER(PI) = 29.6 WATT

D. OUTPUT POWER (P_o)

$$P_o = \frac{2\Pi N T_O}{60}$$

$$P_o = \frac{2 X \Pi X 0.24525 X 890}{60}$$

P_o = 22.86 WATT

E. EFFICIENCY (N)

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\eta = \frac{22.86}{29.6}$$

η = 77.23%

Table 07 -
Result table - different loads for en24 trunion joint at zero degree

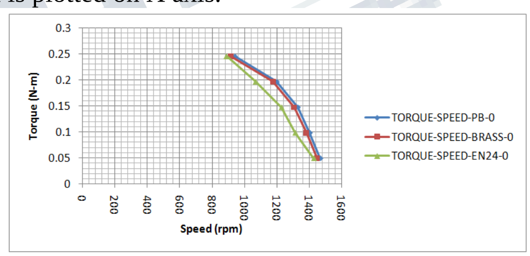
Sr. No.	Load (Kg)	Speed (rpm)	Torque (N-m)	Power (Watt)	Efficiency (%)
1	0.2	1430	0.04905	7.346153	24.81808
2	0.4	1315	0.0981	13.51076	45.64445
3	0.6	1230	0.14715	18.95616	64.04107
4	0.8	1070	0.1962	21.98709	74.2807
5	1.0	890	0.24525	22.86041	77.2311

1. Experimental Evaluation and Optimization

Testing is carried out as per the steps stated above and graphs have been plotted for the respective parameters. In order to carryout evaluation of the TCVJ the graphs has been plotted on combined scale for power, torque, and efficiency.

Torque Vs Speed

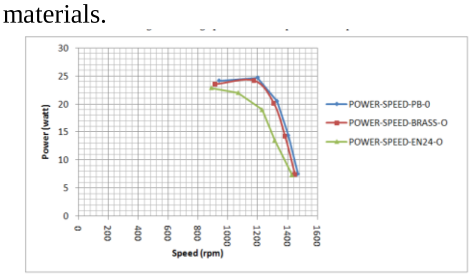
From the result tables available in testing section the graph of Torque Vs Speed has been plotted for different trunion materials and torque domain is plotted on Y axis and speed is plotted on X axis.



Graph No.01 - Torque Vs speed for different trunion materials

Power Vs Speed

From the result tables available in testing section the graph of Power Vs Speed has been plotted for different trunion materials.



Graph No. 02- Power Vs speed for different trunion materials

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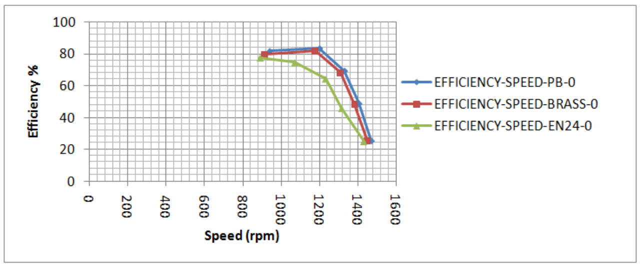
Efficiency Vs Speed

From the result tables available in testing section the graph of Efficiency Vs Speed has been plotted for different trunion materials.



Graph No. 03- Efficiency Vs speed for different trunion materials

5. Discussion-

1. From the graphs plotted above (Graph No.01 - Torque Vs Speed) it can be said that for Torque transfer even it is transferring the same torque for all trunion materials i.e. 0.24525 N-m and for maximum load condition of 1kg , effect of friction wear can be observed by varied speed condition for same load and torque conditions, as speed is reduced due to some work is lost in overcoming friction and wear, for Phosper bronze the variation in speed is 940 with maximum load of 1 kg however for the same conditions EN 24 has results as 890 hence speed is quite less than PB. For Brass the variation in speed is 914 with maximum load of 1 kg however for the same conditions EN 24 has results as 890 hence speed is quite less than Brass. Hence common fact can be drawn as PB is more effective than Brass and EN24; also Brass is less effective than PB and more effective than EN24 in terms of torque transmission at maximum load conditions.

2. To calculate power for each load rise from 0.1 Kg to 1.0 Kg speed is noted down as soon as fairly constant speed of motor is achieved. It is determined that, maximum power is transferred by P.B.trunion coupling at load of 0.8 Kg and which is indicated as 24.65 Watt and EN24 indicated as 21.98 Watt which is less than PB and Brass also, hence optimum material is PB and load is 0.8 Kg, in case of EN24 power is lost in overcoming friction and wear which is minimum for PB and brass. It is marked that power is fairly constant for PB and Brass irrespective angle variations even after 0.8 kg load there is very fine deviation in power. (Graph No. 02- Power Vs Speed)

3. Efficiency is nothing but the ratio of Output power to input power means any trunion which is transferring the same power as it is initially offered to it will have highest efficiency. The efficiency for each case is calculated and tabulated in table shown the graphs are plotted as above for different trunion materials like PB Brass and EN24. (Graph No. 03- Efficiency Vs Speed).It is found that, maximum efficiency of this prototype is achieved with PB as trunion materials and indicated as 83.30 % for load of 0.8 Kg and speed of 1200 rpm. It may be noted that there is huge drop in efficiency of EN24 which may rise down up to 74.28 %. Also it is noted that efficiency is fairly maintained even after 0.8 Kg load. In case of EN24 power is lost while overcoming wear and friction inside hence it drops down.

VI. CONCLUSION

a) PB is the best material to select as it has least power drop to overcome friction and wear.
   - It transfers maximum power and torque with rated speed.
   - It gives the highest efficiency.
   - It also shows very less chatter in operation than Brass and EN24.

b) Brass is second option to select
   - It transfers more power torque with rated speed than EN24 but less than PB.
   - Its efficiency is less than PB and more than EN24.
   - Less chatter in operation than EN24 but slightly more than PB.

c) EN24 alloy steel is not recommended because;
   - It lost the power taken from motor in overcoming friction and wear.
   - It also shows more chatter than brass and PB

d) Maximum power and torque is transferred at zero deviation, however fairly constant parameters are maintained with Five and ten degree of maximum angular deviations

e) Highest efficiency can be achieved with PB and zero angular deviations.0.8 Kg is the load condition where all parameter are showing their highest value.

f) Henceforth if prototype is allowed for constant 0.8-1.0 Kg load, Zero angular deviations and PB as trunion material then it creates Maximum efficiency condition.

g) The recommended speed is 900-1100rpm where it can transfer maximum power and torque as well as gives fairly highest efficiency.

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7. Scope for Future Work -

a) For this study, total six trunion joint elements are used in input and output joint for future study, one can use total eight or ten trunion joint elements in Input and output joint for further improvement.
b) Analysis can be carried out by increasing hardness of alloy steel and results can be compared with PB and Brass.
c) Phosphor bronze can be replaced with Aluminum bronze and results can be compared.

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