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Prevention of failure within the working range and enabling a design of automatic flexible cushion coupling

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Abstract— ***Mild steel or wrought iron shaft are available in lengths varying from 6 to 10 meters, so as to make them handy and easy to transport. Lengthier shaft can't be manufactured in correct form to be used for power transmission. In engineering practice shaft of large lengths are required to transmit this torque which can be obtained by joining two or more shaft in order to obtain require length the joining of shaft is done by device is called coupling. At high speed there is failure of coupling due to shear and bearing stresses. So it is costly to replacement of coupling and it also causes damage to connected element. Hence, now a days there is requirement of coupling having less failure and maintenance cost. Tyre coupling is used to connect two shafts which are parallel and it will make up the misalignment and withstand backlash. High misalignment tolerance of one degree per end can be tolerated without damage to the drive shaft or connected equipment bearings tyre coupling are made from high strength composite materials. In tyre coupling if there is failure then there is need of replacement of tyre which cause less cost compared to other coupling. Our task is to design tyre coupling analytically and getting safe working parameter under different operating conditions.***

Keywords —**Coupling, Failure, Misalignment, Power transmission.**

I. INTRODUCTION

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

Tyre coupling:

Tyre coupling provide all the desirable features of an ideal flexible coupling, including grip-lock fixing. The tyre coupling is "torsional elastic" coupling offering versatility to designers and engineers with a choice of flange combinations to suit most applications.

(1) Tyre couplings can accommodate simultaneous maximum misalignment in all planes without imposing undue loads on adjacent bearings and the excellent shock-absorbing properties of the flexible tyre reduce vibrations and torsional oscillations.

(2) With the addition of a spacer flange, the coupling can be used to accommodate standard distance between shaft ends and facilitate pump maintenance.

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Fig. 1 Tyre Coupling

(3) Tyre are available in natural rubber compounds for use in ambient temperatures between -50 C to +50 C. Neoprene rubber compounds are available for use in adverse operating conditions e.g. oil or grease contaminations and can be used in temperatures of -15 C to+70 C.

(4) Main advantage of tyre coupling is sophisticated new device for driving your machines with a flexing body that automatically compensates to considerable degree singly or in any combination; misalignment and end float.

(5) This type of coupling uses synthetic neoprene rubber which gives cushioning effect during parallel and angular misalignment.

II. DESIGN OF COUPLING

A. DESIGN FOR SHAFT

As torque is transmitted by shaft, it is design based on shear failure.

$$P = 2\pi nT / 60$$

$$T = (\pi/16)* \sigma_S * d^3$$

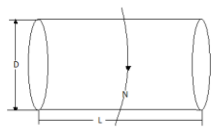

Fig. 2 Coupling Shaft

B. DESIGN FOR SADDLE KEY FOR SHAFT

As torque is transmitted by key, it is design based on shear failure.

$$T=L * w * \sigma_S * (d/2)$$

Let, $L= 1.5d$

Check in crushing for a key:

$$T= L*(t/2)* \sigma_{cr} *(d/2), \quad \sigma_{cr} > \sigma_{cr(safe)}$$

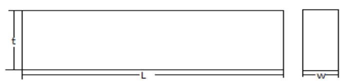

Fig. 3 Saddle Key

Therefore design is not safe. Hence, design is based on crushing.

$$T = \sigma_{cr} *L * (t/2)*(d/2)$$

C. DESIGN FOR HUB

Since, hub is made from cast iron and a torque is transmitted through it. Hub diameter is calculated by following equation:

$T= (\pi/16)* \sigma_{sc} * ((D^4-d^4)/D)$, Also by impirical formula, $D=1.5d$

D. DESIGN FOR FLANGE

A flange is made from cast iron and torque is transmitted through it, flange diameter is calculated by following equation

$$T= \pi *D_2 * t* \sigma_{sc} *(D_2/2)$$

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The flange at the junction of hub is under shear while transmitting the torque. Therefore, the torque is transmitted.
It can also be calculated from following imperical formula: D_2 =2.5 to 3.5 D_3
Thickness of flange is calculated by imperical formula: t = 0.5 d

E. DESIGN OF BOLTS

Number of bolts are considered from shaft diameter
Number of bolts =4 or 6
Pitch circle diameter of bolt is calculated based on imperical formula:

PCD $D_3=3d$

Bolt is subjected to twisting moment and hence Dia. of bolt is calculated by following formula:

$T= (\pi/4) *d_b{}^2* \sigma_s *(D_3/2) *4$

F. DESIGN FOR TYRE

Inner Diameter of tyre = diameter of flange
Remaining dimensions are based on following imperical formula:
If, 1000<=N<3000 --- Distance between backing plate =20mm;
If, 3000<=N<=4000 --Distance between backing plate =30mm and
Distance between flange and backing plate=40mm
From the formula,

$T = \sigma_R * (\pi d_i t) * (d_i/2)$, If, $\sigma_R <, \sigma_{std}$ Design is failed and If, $\sigma_R > \sigma_{std}$ Design is safe.

G. DESIGN FOR BACKING PLATE

Diameter of backing plate = diameter of flange
Thickness is calculated based on following empirical formula:
1000<=N<=4000; Thickness of backing plate = 20mm

III. PROGRAMMING FOR DESIGN

```
Clc;
clear all;
close all;
format long;
for i=1:60
p=input('enter a value of power in kw = ');
n=input('enter rpm of shaft = ');
t=(60000000*p)/(2*pi*n);
fprintf('torque(t) in N-mm = %g\n',t);
d=((16*t)/(pi*55))^(1/3);
fprintf('diameter of shaft (d) in mm = %g\n',int16(d));
l=(1.5*d);
fprintf('length of saddle key for shaft in mm (l)= %g\n',int16(l));
f2=42;
w=(2*t)/(l*f2*d);
fprintf('width of saddle key for shaft in mm (w)= %g\n',int16(w));
fprintf('check for crushing\n');
fcr1=112;
fcr=(2*6*t)/(1.5*d*d*w);
if(fcr>=fcr1)
fprintf('design of saddle key for shaft is not safe\n');
else
fprintf('design of saddle key for shaft is safe\n');
end
```

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```
w=(2*6*t)/(112*1.5*d*d);
l=1.5*d;
t1=w/3;
fprintf('length of saddle key for shaft in mm (l)= %g\n',int16(l));
fprintf('width of saddle key for shaft in mm (w)= %g\n',int16(w));
fprintf('thickness of saddle key for shaft in mm (t1)= %g\n',int16(t1));
D=1.5*d;
fprintf('diameter of hub in mm (D)= %g\n',int16(D));
d2=3.5*d;
t2=0.5*d;
fprintf('diameter of flange in mm (d2)= %g\n',int16(d2));
fprintf('thickness of flange in mm (t2)= %g\n',int16(t2));
pcd=3*d;
fprintf('pitch circle diameter of bolts in mm = %g\n',int16(pcd));
d3=sqrt((2*4*t)/(pi*40*4*pcd));
fprintf('diameter of bolt in mm (d3)= %g\n', int16(d3));
fprintf('diameter of backing plate(do) = %g\n', int16(d2));
fprintf('thickness of backing plate = 20mm\n');
fprintf('inner diameter of tyre is =%g\n',int16(d2));
if(n<=4000)
fprintf('distance between backing plate is = 20mm\n');
fprintf('distance between flange and  backing plate is = 30mm\n');
fprintf('width of tyre is = 100mm\n');
else
fprintf('distance between backing plate is = 30mm\n');
fprintf('distance between flange and backing plate is = 40mm\n');
fprintf('width of tyre is = 130mm\n');
end
fprintf('Maximum Ultimate stress for Rubber in N/mm2 = 15\n');
fprintf('Factor of safety for Rubber = 9\n');
fprintf('Working stress in N/mm2 = 1.67\n');
fr=(2*t)/(pi*d2*d2*56);
if(fr>=1.67)
fprintf('design of tyre is fail\n')
else
fprintf('design of tyre is safe\n')
end
z= fr-1.67;
fprintf('difference = %g\n',z);
fprintf('stress in tyre IN N/mm2 =%g \n',fr);
fprintf('\n\n\n');
end
```

IV. RESULT AND DISCUSSION

In the present work, tyre coupling is design analytically. In such coupling, tyre is the most significant component. Tyre is designed based on internal pressure applied on inner surface of tyre groove and centrifugal force on outer circumference. It is designed under power range from 1KW to 5000 KW. A speed range is from 1000 rpm to 4000 rpm. For particular power, speed range is taken in step of 1000 rpm. The table 1 and 2 shows overall calculated parameters of parts used in coupling.

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Table 1: Calculated values of parameters for different parts

POWER (KW)	SPEED (rpm)	TORQUE (Nm)	DIA. OF SHAFT (mm)	LENGTH OF KEY (mm)	WIDTH OF KEY (mm)	THICKNESS OF KEY (mm)
1	1000	9.549	10	14	7	2
	2000	4.775	8	11	6	2
	3000	3.183	7	10	5	2
	4000	2.387	6	9	5	2
10	1000	95.493	21	31	16	5
	2000	47.746	16	25	13	4
	3000	31.831	14	22	11	4
	4000	23.87	13	20	10	3
100	1000	954.93	45	67	34	11
	2000	477.5	35	53	27	9
	3000	318.3	31	46	24	8
	4000	238.7	28	42	22	7
500	1000	4774.64	76	114	54	20
	2000	2387	60	91	47	16
	3000	1592	53	79	41	14
	4000	1194	48	72	37	12
1000	1000	9549.3	96	144	74	25
	2000	4775	76	114	59	20
	3000	3183	67	100	51	17
	4000	2387	60	91	47	16
2000	1000	19098	121	181	93	31
	2000	9549	96	144	74	25
	3000	6366	84	126	65	22
	4000	4775	76	114	59	20
3000	1000	28647.9	138	201	107	36
	2000	14324	110	165	85	28
	3000	9549	96	144	74	25
	4000	7162	87	131	67	22
4000	1000	38197.2	152	229	118	39
	2000	19099	121	181	93	31
	3000	12732	106	158	81	27
	4000	9549	96	144	74	25
5000	1000	47745.7	164	246	127	42
	2000	23873	130	195	100	33
	3000	15915	114	171	88	29
	4000	11936	103	155	80	27

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Table 2: Calculated values of parameters for different parts

POWER (KW)	SPEED (rpm)	DIA. OF HUB (mm)	DIA. OF FLANGE (mm)	THICKNESS OF FLANGE (mm)	PCD (mm)	DIA. OF BOLT (mm)	ID OF TYRE (mm)
1	1000	14	34	5	29	2	34
	2000	11	27	4	23	2	23
	3000	10	23	3	20	2	20
	4000	9	21	3	18	1	18
10	1000	31	72	10	62	5	72
	2000	25	57	8	49	4	57
	3000	22	50	7	43	3	50
	4000	20	46	7	39	3	46
100	1000	67	156	22	134	11	156
	2000	53	124	18	106	8	106
	3000	46	108	15	93	7	93
	4000	42	98	14	84	7	84
500	1000	114	267	38	229	18	267
	2000	91	212	30	181	14	181
	3000	79	185	26	158	14	158
	4000	72	168	24	144	11	144
1000	1000	144	336	48	288	23	336
	2000	114	267	38	229	18	229
	3000	100	233	33	200	16	200
	4000	91	212	30	181	14	181
2000	1000	181	432	60	363	29	423
	2000	144	336	48	288	23	288
	3000	126	293	42	252	20	252
	4000	114	267	38	229	18	229
3000	1000	208	485	69	415	33	485
	2000	165	385	55	330	26	330
	3000	144	336	48	288	23	288
	4000	131	305	44	262	21	262
4000	1000	229	533	76	457	36	533
	2000	181	423	60	363	29	363
	3000	158	370	53	317	25	317
	4000	144	336	48	288	23	288
5000	1000	246	574	82	592	39	574
	2000	195	456	65	391	31	391
	3000	171	398	57	341	27	341
	4000	155	362	52	310	25	310

Table 3: Critical thickness for tyre

Speed (rpm)	Power (KW)	Critical Thickness Of Tyre (mm)
1000	1	4
	10	6
	100	16
	500	24
	1000	32

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	2000	40
	3000	46
	4000	50
	5000	54
2000	1	4
	10	4
	100	12
	500	20
	1000	24
	2000	32
	3000	36
	4000	40
	5000	42
3000	1	4
	10	4
	100	10
	500	16
	1000	22
	2000	28
	3000	32
	4000	34
	5000	38
4000	1	4
	10	4
	100	8
	500	16
	1000	20
	2000	24
	3000	28
	4000	32
	5000	34

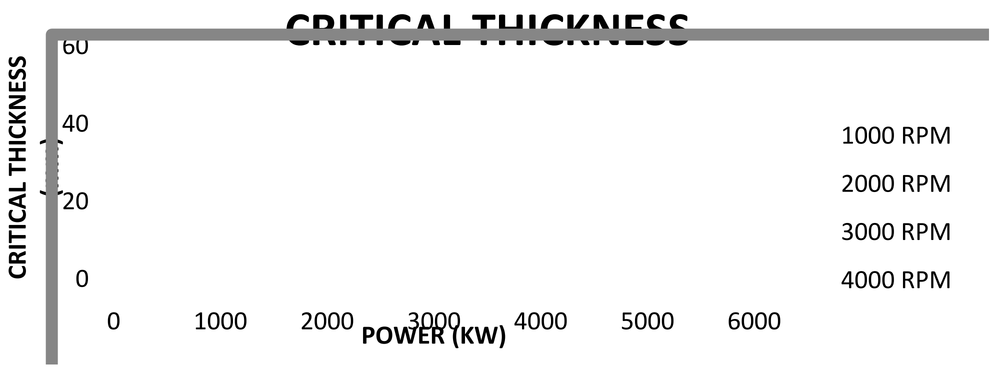

Fig 4: Critical Thickness for different speed

Table 4: Safe thickness for tyre

Thickness (t)				Speed (rpm)	Power (KW)	σ_r	σ_{std}	Difference
Up to 56mm require				1000	1	0.09	1.67	-1.57
					10	0.20		-1.46
					100	0.44		-1.22
					500	0.76		-0.90
					1000	0.96		-0.70
					2000	1.21		-0.45
					3000	1.38		-0.28

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					4000	1.52		-0.14
					5000	1.64		-0.02
	Up to 44mm require			2000	1	0.07	1.67	-0.59
					10	0.16		-1.50
					100	0.35		-1.31
					500	0.60		-1.06
					1000	0.76		-0.90
					2000	0.96		-0.70
					3000	1.10		-0.56
					4000	1.21		-0.45
					5000	1.30		-0.36
		Up to 40mm require		3000	1	0.06	1.67	-1.60
					10	0.14		-1.52
					100	0.30		-1.36
					500	0.52		-1.14
					1000	0.66		-1.00
					2000	0.84		-0.82
					3000	0.96		-0.70
					4000	1.05		-0.61
					5000	1.14		-0.52
			Up to 36mm require	4000	1	0.06	1.67	-1.6
					10	0.13		-1.53
					100	0.28		-1.33
					500	0.48		-1.18
					1000	0.60		-1.06
					2000	0.76		-0.90
					3000	0.87		-0.79
					4000	0.96		-0.70
					5000	1.03		-0.63

V. CONCLUSION

The results are obtained by analytical method and calculations by metlab programming. It is said as per theoretical design that coupling is safe in operating range. The internal diameter of tyre is increased with increase in operating power. Here, for a particular speed, as power is increased, critical thickness is also increased. While as speed is decreased, thickness of tyre is increased. i.e. for 4000rpm- up to 36mm and for 1000rpm up to 56mm.

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