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DESIGN OF CENTRIFUGAL CLUTCH BY ALTERNATIVE APPROACHES USED IN DIFFERENT APPLICATIONS

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Abstract: The centrifugal clutch offers many advantages in motor and engine drive applications. Utilizing the centrifugal clutch enables the selection of normal torque motors for running loads rather than the selection of high torque motors for starting loads. The aim of this project is to be describing the torque carrying capacity at different speed which using in transmitting power. The entire work based on conventional design with ferrodo lining, driving shaft, spring , shoe , spider, cover plate, driven shaft. The detail design for various speed is made in the centrifugal clutch to select an operating range of speed under which the application are designed for torque transmission. In this project the design calculation are worked out analytically. Along with this we have introduced a compliant clutch. Compliant clutch is made from polypropylene material and there is no anyone connecting parts. it has rigid body design since revolute joints are replaced by flexible segment. The potential energy store in flexible segment can replace springs and reduction in revolute joints reduces problem with backlash and wear. The compliant clutch includes rigid body mechanism through dimensional synthesis by graphical method. A mechanism is evaluated and synthesized specific force-deflection relationship. In many applications, compliant mechanism can maintain or even improve performance relative to conventional rigid body designs. It is cost benefitted. Also conventional clutch is expensive rather than compliant clutch.

Keywords: Centrifugal clutch, Compliant clutch, Centrifugal force, Normal force

I. INTRODUCTION

A CENTRIFUGAL CLUTCH: A clutch is a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft. A clutch provides an interruptible connection between two shafts. The centrifugal clutch is usually used into motor pulley. It consists of number of shoe on the inside of a rim of pulley. The outer surface of pulley is covered with friction material. These shoes which can move radialy in guides are held against the

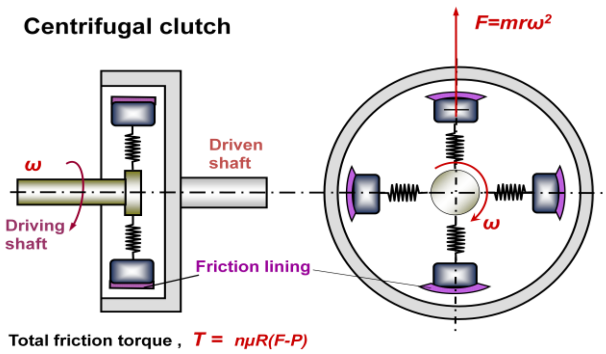

FIG.-1 Centrifugal clutch

boss on the driving shaft by means of springs.The spring exert a radialy inward force which assumed to be constant. The weight shoes when revolving cause it to exert a radialy outward force (centrifugal force).The magnitude of centrifugal force depeded on speed at which shoes is revolving. A little consideration show that when centrifugal force is less than the spring force, the shoes remain same position as when driving shaft was stationary, but when centrifugal force is equal to spring force, spring is floating.

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When centrifugal force exceed the spring force, the shoe moves outward and comes in contact with driven member and press against it. The force with which the shoe press against the driven member is the difference of the centrifugal and spring force. The increase of speed causes the shoe to press harder and enables to be transmitted.

***B COMPLIANT CLUTCH*:** Compliant mechanisms are mechanisms that obtain some or all of their motion through the deflection of their members. In a compliant mechanism, a single flexible link often replaces two or more rigid links of an equivalent rigid-body mechanism. This decreases the mechanism's part count, wear points, and backlash. In the mechanism the centrifugal force is utilised to deflect the members and get friction on rotating drum to synchronise motion.

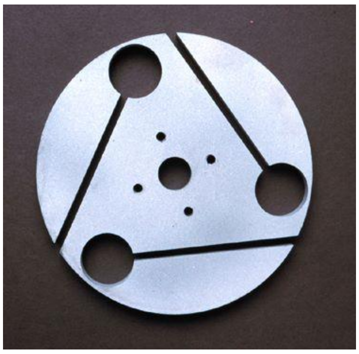

FIG.-2 Compliant clutch

II. LITERATURE SURVEY

FUNCTION OF CLUTCHES:

- A clutch is a mechanical device used to connect or disconnect the driven shaft from the driving shaft.
- A clutch is a device used to transmit the rotary motion of one shaft to another shaft when desired.

TYPES OF CLUTCHES:
There are two types of clutch

1. positive clutch 2. friction clutch

(1) Positive clutch: Simplest type of positive clutch is jaw clutch, which transmit the torque from one shaft to another shaft through interlocking jaws. jaw clutch consists of two segments as shown in fig. one segment is permanently fasted to the driving shaft and the other segment is free to slide axially on the splined driven shaft, thus permitting is to been engaged or disengaged by sliding. The shapes of jaw may be square, gear toothed or spiral.

Merits of positive clutches:

1. Positive clutch do not slip.
2. No heat is generated during the engagement.

Application of positive clutches: The positive clutches have very limited applications. They are used in some machine tools, power presses, punches, etc.

(2) Friction clutch: Friction clutch transmits torque by virtue of frictional developed. Friction lining is provided on the driven plate .axial force applied by compression spring will hold the two plates together.

Merits of friction clutch:

1. Friction on clutches can be engaged when driving shaft is rotating and driven shaft is stationary or when both shafts are stationary.
2. Frequent engagement and disengagement is possible .
3. Friction clutches are capable of transmitting a partial power.
4. In case of overloads, the friction clutches slip momentarily, thus safeguarding the machine.
5. Friction clutches are easy to operate.

Application of friction clutches:

1. A friction clutch has its application in a transmission system where frequent engagement and disengagement is required and where power is to be transmitted partially or fully.

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2. The common application of friction clutches is in automobiles.

Requirement of good friction clutches:

A good friction clutch should satisfy the following requirement:

1. It should be capable of transmitting the required torque with the minimum amount of the axial force.
2. The energy converted into the frictional heat during the engagement should be dissipated rapidly, so that the temperature rise is kept within the permissible limit.
3. The pressure between the contacting surfaces should be reasonably low and uniform over the entire surface.
4. The coefficient of friction between the contacting surfaces should be sufficiently high and reasonably uniform over the entire surface.
5. The wear characteristics of the contacting surface should be such that they give the acceptable life.
6. The engagement and disengagement mechanism should be simple and easy to operate.
7. The clutch should be as light as possible to minimize the inertia load.
8. The clutch should be easy to dissemble and should have the provision for the wear compensation.
9. The clutch should have no open projecting part.

III. DESIGN FORMULATION

A DESIGN FORMULATION OF CONVENTIONAL CENTRIFUGAL CLUTCH:

1. TRANSMITTED TORQUE

$T = P \times 60 / 2\pi N$

Where, T = Transmitted Torque, N.mm

P = Intensity of Pressure, N/mm²

N = Running speed of Pulley, rpm

2. MASS OF SHOE

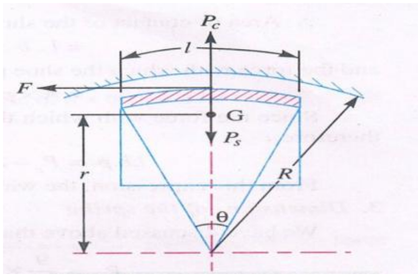

FIG.-3 Forces acting on shoe

Centrifugal force acting on each shoe

$Pc = m.\ \omega^2.r$

Where, Pc =Centrifugal force acting on each shoe ,N

m =Mass on each shoe, Kg

ω = Angular running speed, rad/sec

r = Distance of center of the shoe from the center of the spider, mm

Force exerted on each shoe by the spring

$P_s = m.(\omega_1)^2.r$

$= m(3/4\omega)^2$

$= 9/16 m\omega^2.r$

Where, Ps = Force exerted on each shoe by the spring, N

ω1 = Angular speed at which the engagement begins to take place, rad/sec

Net outward radial force = Pc-Ps

$= m\omega^2 r - 9/16 m\omega^2 r$

$= 7/16 m\omega^2 r$

Frictional force acting on each shoe

$F = \mu(Pc - P_s)$

Where, F=Frictional force, N

μ = Co-efficient of Friction between shoe and rim

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Pc =Centrifugal force acting on each shoe , N
Ps = Force exerted on each shoe by the spring, N

Frictional torque acting on each shoe
= F x R
= $\mu(Pc - P_s)$ R
Where, R=Inside radius of pulley rim, m
μ= Co-efficient of Friction between shoe and rim
Pc =Centrifugal force acting on each shoe, N
Ps = Force exerted on each shoe by the spring, N

Total Frictional torque transmitted
T= $\mu(Pc - P_s)R$ x n
= n.F.R
Where, R =Inside radius of pulley rim, mm
μ = Co-efficient of Friction between shoe and rim
Pc =Centrifugal force acting on each shoe , N
ps = Force exerted on each shoe by the spring, N
T = Transmitted torque, N/mm
n = number of shoes
F =Frictional force, N

3. SIZE OF SHOE
$\Theta = l/r$ or $l = \theta . r$ ($\theta = 60$)
Where l = Contact length of shoe , mm
b = Width of shoe, mm
R = Contact radius of shoe , mm
Θ = Angle subtended by shoe , rad
p = Intensity of pressure on shoe, N/mm^2

Area contact of shoe
A = l b
Where A = Area of contact of shoe, mm^2

Force with which the shoe process against the rim
A . p = l .b .p
Where , A = Area contact of shoe , mm^2
p = Pressure intensity of pressure ,N/mm^2
l = Contact length of shoe , mm
b = Width of shoes , mm

Force with which shoe pres against the rim at running speed
l .b .p = Pc – Ps
Where , A = Area contact of shoe , mm^2
p = Pressure intensity of pressure ,N/mm^2
l = Contact length of shoe , mm
b = Width of shoes , mm
Pc = Centrifugal force acitng on each shoe N
Ps = Force extered on each shoe by spring N

4. DIMENSION OF SPRING

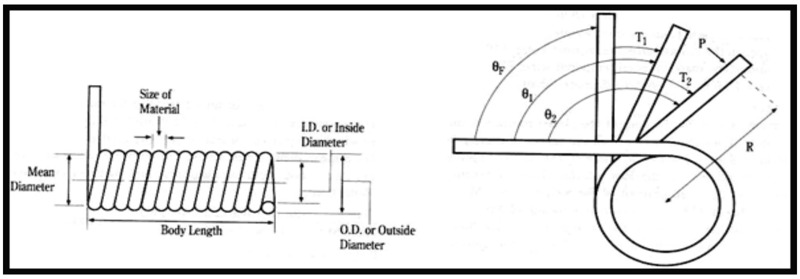

FIG.-4 Spring used in clutch

Pc $= 9/16\ mw^2r$

Where Ps = force extered on shoe by spring, N

m = mass of shoe, kg

w = angular running speed, rad/sec

r = distance of center of shoe from the center of the spider, mm

B DESIGN FORMULATION OF COMPLIANT CENTRIFUGAL CLUTCH:

A design of compliant clutch is based on empirical formulas. Here centrifugal and normal force is derived graphically from force diagram. A force which is acting on a shoe has force components in different direction at the point of contact. Here tangential and normal forces are considered in the design.

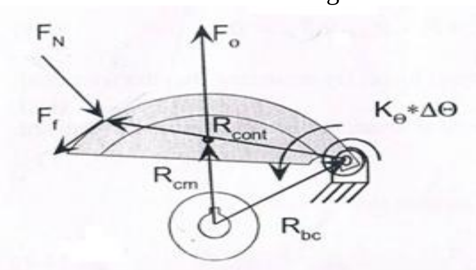

FIG.-5 Forces acting on a member of compliant clutch

1.DIAMETER OF CLUTCH

Dclutch = 11.91x Dhole

2.DIAMETER OF DRUM

Ddrum=12.80 x Dhole

3 HOLE DIAMETER OF SHAFT

Dhole =d, mm

4 NO OF ARM IN A CLUTCH

n=3

5 ANGLE OF HOLE FROM CENTER OF SHAFT

$\Theta = 37°$

6 WIDTH OF SLOT IN A CLUTCH

W =0.675d

Where, d = Diameter of shaft,mm

Centrifugal force on clutch:

$Fo = M \times Rcm \times \omega^2$

Where, Fo = Centrifugal force arm, N

M = mass of arm, Kg.

ω = Speed of clutch, rad/sec

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Normal force on clutch:

$$F = \frac{K\Delta\theta k + (Rcm - Rbc) \times Fo}{-Rcont \times \mu - Rcont}$$

Where, F= Normal force on arm, N
K=Torsional spring constant
θ=Deflection of arm
μ=co-efficent of friction

Torque transmitted by a clutch:
T=F×□×Rdrum×n
Where, T= torque, N.mm

IV. CALCULATION

A CALCULATION BY ANALYTICAL METHOD FOR A CONVENTIONAL CLUTCH:

Given Data for Sample Calculation of Loan mover:

P= 1119 w
N=2800 Rpm
n=3;
R=42.5mm=0.0425m;
μ=0.28

1. TORQUE TRANSMITTED
$T = P \times 60 / 2\pi N$
$= 1119 \times 60 / 2\pi \times 2800 \quad = 3.81 Nm$

2. MASS OF THE SHOES
M= mass of shoes
ω= Angular running speed,
$\omega = 2\pi N/60$
$= 2\pi \times 2800/60 = 293.21$ rad/sec
$\omega 1 = 3/4\ \omega$
$= 3/4 \times 94.26 = 219.90$ rad/sec

Assuming the center of shoes lies at distance 5 mm less then R.
r = 37.5mm = 0.0375m
Centrifugal force acting on each shoe
$Pc = m.\ \omega^2.r$
$= m\ (293.21)^2 \times 0.0375 = 3223.95m$ N

Force exerted by spring
$P_s = m.(\omega_1)^2.r$
$= m\ (219.90)^2 \times 0.0375 = 1813.35m$ N

Frictional torque acting on each shoe,
$T = \mu\ (Pc - P_s)\ R \times n$
3.81=0.28 (3223.95 m-1813.35 m) 0.0.425 x 3
3.81=50.36m
m= 3.81. /50.36 =0.076 kg

3. SIZE OF THE SHOE
l= contact length of the shoe
b= Width of shoe
$l = \theta.R = \pi/3\ R$
$= \pi/3 \times 42.5 = 44.50$ mm
Area(A) = l.b = 44.5b mm^2
p=Intensity of pressure exerted on shoe=0.1N/mm^2
F= A .p
= 44.5b X 0.1 = 2.5b N ………………………..............……..…..(i)

Net outward radial force
$P_c - P_s = 3223.95\ m - 1813.35\ m$
$= 1410.6m$
$= 1410.6x\ 0.076 = 107.20$ N ……………………………………..(ii)
From (i) and (ii)
b = 107.20/4.45 = 24.09mm

4. DIMENSION OF SPRING
$Pc = m.\ \omega^2.r$
$=0.076\times (293.21)^2 \text{ x } 0.0375 = 241.75$ N
$Ps = m\ (\omega 1)^2\ r$
$= 0.076 \times (219.90)^2 \text{ x } 0.0375 = 137.81$ N

B CALCULATION BY GRAPHICAL METHOD FOR A COMPLIANT CLUTCH:

1 DIAMETER OF CLUTCH
Dclutch=75 mm

2 DIAMETER OF DRUM
Ddrum= 85 mm

3 HOLE DIAMETER OF SHAFT
Dhole= d = 25 mm

4 NO OF ARM IN A CLUTCH
n=3

5 ANGLE OF HOLE FROM CENTER OF SHAFT
$\theta=37°$

6 WIDTH OF SLOT IN A CLUTCH
W(cut)=2.15 mm

Centrifugal force on clutch
$Fo = M\times Rdrum\times\omega^2$
$=0.076\times0.0425\times (293.21)^2 = 277.7$ N
Normal force on clutch

$$F= \frac{K\Delta\theta k + (Rcm - Rbc)\times Fo}{-Rcont \times\mu - Rcont}$$

$$K= \gamma\ k\phi \frac{EI}{l}$$

$$= 0.85 \times 2.62\left(\frac{2\times 10^5 \times 4.32\times10^{-9}}{4.5 \times10^3}\right)$$

$= 0.4325$

E= Modulus of elasticity

I= Polar Moment of Inertia
kϕ= Stiffness coefficient

$$I= \frac{bh^3}{12}$$

$$= \frac{0.0448\times (105\times 0.001)^3}{12}$$

$= 4.32 \times 10^{-9}$

b= length of arm
h= width of arm

$$= \frac{(0.4325)(0.157)+(0.01685 - 0.028)(277.7)}{(-0.0448)(1.28)} = 53.77 \text{ N}$$

Torque transmitted by a clutch
T=F×μ×Rdrum×n
=53.77×0.28×0.0425×3 = 2 N.m

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V. RESULTS AND DISCUSSION

A. CALCULATED VALUES FOR CONVENTIONAL CLUTCH:

A conventional clutch is design analytically to determine torque transmitting capacity from given power and speed for particular application. Mass of shoe is calculated from centrifugal force and spring force. The table shows calculated values of required parameters for clutch as given below.

Sr. No.	Applications	Transmitted torque (Nm)	Mass of the shoe (Kg)	Centrifugal Force (N)	Spring Force (N)
1	Lawn mover	3.81	0.076	241.75	137.81
2	Chain saw	2.675	0.0150	25.38	181.51
3	String Trimmer	1.011	0.00498	118.54	66.78
4	TVS Moped	4.96	0.0306	328.64	798

B. CALCULATED VALUES FOR COMPLIANT CLUTCH:

A compliant clutch is designed graphically to determine torque transmitting capacity from force analysis on arm of clutch for particular application. The transmitted torque is calculated from centrifugal force and normal force acting on a contact point of drum and rotating arm. The table shows calculated values of required parameters for clutch as given below.

Sr. No.	Applications	Transmitted torque (Nm)	Centrifugal force Fo (N)	Normal force Fn (N)
1	Lawn mover	2	277.7	53.77
2	Chain saw	9	739.47	134.83
3	String Trimmer	0.856	137.75	29.130
4	TVS Moped	3.36	377.125	88.79

VI. CONCLUSION

Here we have calculated torque by Conventional analytical method for clutch used in different applications like Lawn mower, Chain saw, String Trimmer, TVS Moped. Then we introduced compliant clutch in place of conventional one. It is design graphically and compared their capabilities with respect to torque transmitting capacity.

The shaft diameter and drum diameter are considered same for both the methods for comparison of clutch used in different applications. Further the power and rotational speed of shaft are taken as specified in standard applications.

From this comparison we conclude that compliant clutch is more efficient if we used in chain saw and in other applications, it gives nearly same value of torque than conventional clutch. The main advantage of compliant clutch is cost benefitted and having no movable component in its design. The problem of backlash and wear is eliminated by using this type of clutch.

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