

Royal Commission for Jubail and Yanbu

Jubail University College

Department of Mechanical Engineering



MACHINE DESIGN II

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ME 414

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NINTH EDITION IN SI UNITS

Shigley's Mechanical Engineering Design

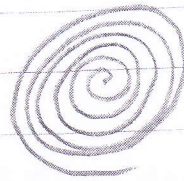
RICHARD G. BUDYNAS
J. KEITH NISBETT



29/11/2014
Wed

Machine Design II

*Chapter 10 : Mechanical Springs



25kg, 50kg

K - spring constant

$$\Rightarrow K = \frac{F}{y} = \frac{N}{mm}$$

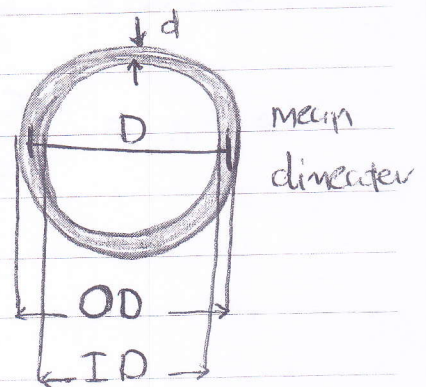
y = deflection of springs

$$K_1 = 20 \text{ N/mm}, \quad K_2 = 10 \text{ N/mm}$$

* Stress in helical springs

$\Rightarrow \tau$ = torsion + Force

$$\Rightarrow \tau_{max} = \frac{\tau r}{J} + \frac{F}{A}$$



$$\Rightarrow D = \frac{ID + OD}{2}$$

$$\Rightarrow D = ID + d \quad \Rightarrow D = OD - d$$

$$\Rightarrow T = \frac{FD}{2} \quad \Rightarrow \frac{r}{d} = \frac{d}{2}$$

$$\Rightarrow T = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$$

$$\Rightarrow \text{spring index} = C = \frac{D}{d}$$

$$\Rightarrow \text{Shear stress correction factor } K_s = \frac{2C+1}{2C}$$

$$\Rightarrow \tau = \left(\frac{My}{I} \right) K_s$$

K_s

Torsion

K_w

K_B

Direct shear

$$\Rightarrow K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C} \quad \text{wahl factor}$$

$$\Rightarrow K_B = \frac{4C+2}{4C-3} \quad \text{Bergstrasser}$$

30/1/2014
Thursday

* Deflection of helical springs:

$$\Rightarrow U = \frac{T^2 L}{2GJ} + \frac{F^2 L}{2AG}$$

$$\Rightarrow T = \frac{FD}{2} \quad \Rightarrow L = \pi DN \quad \Rightarrow$$

$$\Rightarrow J = \frac{\pi d^4}{32} \quad \Rightarrow A = \frac{\pi d^2}{4}$$

$$\Rightarrow y = \frac{\partial U}{\partial F} = \frac{8FD^3N}{d^4G} + \frac{4FDN}{2^2G}$$

$$\Rightarrow y = \frac{8FD^3N}{d^4G} \quad \Rightarrow \text{No of coils}$$

$N_t = \text{Total}$

13.25

كل الدوائر ولواضع دائرة

$N_a = \text{active}$

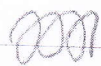
13

الدائرة كالدائرة

$$\Rightarrow \frac{d^4G}{8D^3N_a} = \frac{F}{y} = K$$



Ends of spring

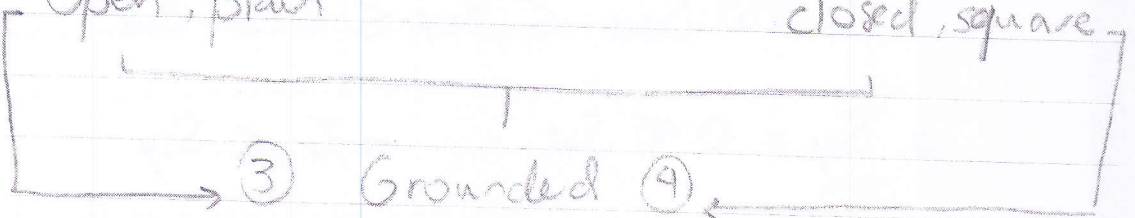


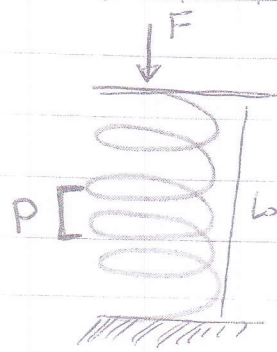
①

Open, plain

②

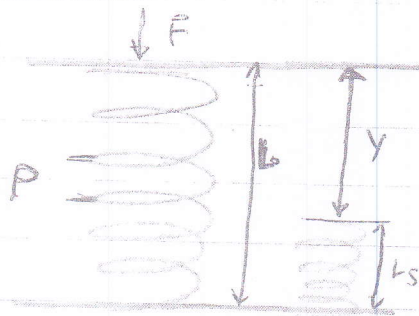
closed, square





Free length = when the load is not applied or before applied

Solid length = when apply load



$$\Rightarrow L_0 = L_s + y$$

page 521

* Set removal or pre setting is a process used in manufacturing to induce desired residual stresses.

$$\Rightarrow (L_0)_{cr} = 2.63 \frac{D}{d}$$

$$\Rightarrow L_0 < (L_0)_{cr} \quad \text{no Buckling}$$

constant

$$\Rightarrow S_{ut} = \frac{A}{d^m}$$

$$\Rightarrow 0.355 S_{ut} \leq S_{sy} \leq 0.52 S_{ut}$$

$$\Rightarrow S_{sy} = 0.45 S_{ut}$$

$$\Rightarrow \tau \leq S_{sy}$$

$$\Rightarrow S_{sy} = 0.577 S_s$$

$$\Rightarrow n_s = \frac{S_{sy}}{T} > 1.2 \quad \text{Solid safe}$$

10.3 page 561:

$d = 2.5 \text{ mm}$; Mat : Music wire ; $OD = 31 \text{ mm}$

$N_t = 14 \text{ coils}$; plain and ground

a) $L_0 = ?$ solid safe ?

$$D = OD - d = 31 - 2.5 = 28.5 \text{ mm}$$

from table 10-1 : page 521

$$\Rightarrow N_t = N_a + 1 \quad \Rightarrow N_a = 14 - 1 = 13 \text{ coils}$$

$$\Rightarrow L_s = d N_t = 2.5 \times 14 = 35 \text{ mm}$$

$\Rightarrow$ Table 10-5 page 526 : Music wire

$$\Rightarrow G = 81 \text{ MPa}$$

$$\Rightarrow K = \frac{d^4 G}{8 D^3 N_a} = \frac{2.5^4 \times 81 \times 10^3}{8 \times (28.5)^3 \times 13} = 1.314 \text{ N/mm}$$

$$\Rightarrow T = K_B \frac{8 F_s D}{\pi d^3}$$

$\rightarrow S_{sy}$ from table 10-6 page 526

$$\Rightarrow S_{sy} = 0.45 S_{ut} \quad (\text{Music wire})$$

$$\Rightarrow S_{ut} = \frac{A}{d^m} \quad \text{from table 10-4 : 525 page}$$

$$\Rightarrow S_{ut} = \frac{2211}{2.5^{0.145}} = 1935.9 \text{ MPa}$$

$$\Rightarrow S_{sy} = 0.45 \times 1935.9 = 871.15 \text{ MPa}$$

$$\Rightarrow \tau = S_{sy} = \frac{8 F_s D}{\pi d^3}$$

$$\Rightarrow 871.15 = \frac{8 \times F_s \times 28.5}{\pi (2.5)^3} \quad \Rightarrow F_s = 187.5 \text{ N}$$

$$\Rightarrow L_0 = \frac{F_s}{k} + L_s$$

$$= \frac{187.5}{1.314} + 35 = 177.7 \text{ mm}$$

$$\Rightarrow (L_0)_{cr} = 2.63 \frac{D}{q} = 2.63 \times \frac{28.5}{0.5} = 149.1 \text{ mm}$$

$$\Rightarrow L_0 > (L_0)_{cr} \therefore \text{spring will buckle in service}$$

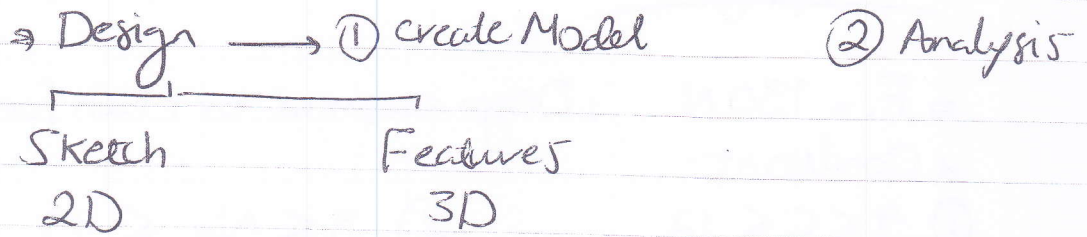
$$\Rightarrow F = \frac{2 \pi d^3}{8 D K_B} \quad \Rightarrow K_B = \frac{4C+2}{4C-3} \quad \Rightarrow C = \frac{28.5}{2.5} = 11.4$$

$$\Rightarrow K_B = \frac{4 \times 11.4 + 2}{4 \times 11.4 - 3} = 1.117$$

$$\Rightarrow \frac{F}{K_B} = \frac{187.5}{1.117} = 167.8 \text{ N} = F_s$$

Lab

3/2/2014
Monday



* FMDT = Feature Manager Design Tree

* Things to remember :

- 1- Set the units
- 2- Select the plane (Top, Front, Right)

* Creating sketch:

* Under defined * Fully defined * Over designed

```
graph LR; UnderDefined["* Under defined"] --> FullyDefined["* Fully defined"]; FullyDefined --- OverDesigned["* Over designed"];
```

- 1- All required measurement
- 2- Define all relations
- 3- Fix the sketch a point in space

Machine Design II

5/3/2014
Wednesday

10.4 page 561:

$\Rightarrow F_i = 130 \text{ N}$; Design assessment or check for static fatigue

Conditions:

① $4 \leq C \leq 12$

② $3 \leq N_a \leq 15$

③ $\xi > 0.15$

④ $n_s \geq 1.2$

① $C = 11.4$ from problem 10.3
 $4 \leq 11.4 \leq 12$ ✓

② $N_a = 13$ from problem 10.3
 $3 \leq 13 \leq 15$ ✓

③ $F_s = (1 + \xi) F_{\max}$

$\Rightarrow F_s (1 + \xi) F_i$

Solid

Static force, applied force

$\Rightarrow \xi = \frac{F_s}{F_i} - 1 = \frac{167.8}{130} - 1 = 0.29 > 0.15$ ✓

$\Rightarrow T_s = K_B \frac{8 F_s D}{\pi d^3}$ at $F_i = 130 \text{ N}$

$\Rightarrow T_i = 1.117 \times \frac{8 \times 130 \times 28.5}{\pi \times 2.5^3} = 674.5 \text{ MPa}$

from problem 10.3 $\Rightarrow S_{sy} = 871.15 \text{ MPa}$

④ $n_s = \frac{S_{sy}}{T_i} = \frac{871.15}{674.5} = 1.29 \geq 1.2$ ✓

Spring is ~~not~~ safe
when solid

$$\Rightarrow \tau_1 = K_B \frac{8F_1 D}{\pi d^3} \Rightarrow \tau_s = K_B \frac{8F_s D}{\pi d^3}$$

$$\Rightarrow \frac{\tau_1}{\tau_s} = \frac{F_1}{F_s} \Rightarrow \tau_s = \frac{F_s}{F_1} \times \tau_1$$

$$\Rightarrow \tau_s = \frac{167.8}{130} \times 674.5 = 870.62 \text{ MPa}$$

$$\Rightarrow n_s = \frac{871.15}{870.62} = 1.0 < 1.2 \text{ Spring is not safe}$$

* Home work 10-5 page 561

10.6 page 561:

$$\Rightarrow d = 4 \text{ mm} \Rightarrow \text{Mat \& Oil temperd} \Rightarrow C = 10 \text{ plain ends}$$

$$\Rightarrow h_0 = 80 \text{ mm} \Rightarrow F_1 = 50 \text{ N} \Rightarrow y_1 = 15 \text{ mm}$$

$$a - k = \frac{F}{y} = \frac{50}{15} = 3.33 \text{ N/mm}$$

b - Min hole diameter = OD of spring coil



$$OD = D + d$$

$$\Rightarrow C = 10 = \frac{D}{d} = \frac{D}{4}$$

$$\Rightarrow D = 10 \times 4 = 40 \text{ mm}$$

$$\Rightarrow OD = 40 + 4 = 44 \text{ mm} = \text{Min hole diameter}$$

from table 10-1 plain ends page 521

$$\Rightarrow N_t = N_a$$

$$\Rightarrow K = \frac{d^4 G}{8 D^3 N_a} \Rightarrow 3.33 = \frac{4^4 \times 77.2 \times 10^3}{8 \times 40^3 \times N_a}$$

$$\Rightarrow N_a = 11.6 \text{ coils} = N_t$$

$$\Rightarrow L_s = d(N_t + 1) \text{ from table 10-1}$$

$$\Rightarrow L_s = 4(11.6 + 1) = 50.4 \text{ mm}$$

$$\Rightarrow S_{sy} = 0.5 S_{ut} \text{ from table 10-6 page}$$

$$\Rightarrow S_{ut} = \frac{A}{d^m} \text{ from table 10-5 page}$$

$$\Rightarrow t_s = \frac{K_B 8 F_s D}{\pi d^3} \Rightarrow K_B = \frac{4C+2}{4C-3} = \frac{4 \times 10 + 2}{4 \times 10 - 3} = \frac{42}{37}$$

$$\Rightarrow F_s = K_y s = K(L_0 - L_s)$$

* Homework K 10-7 page 561

* Homework K 10-8

6/21/2014
Thursday

* 10-9 page 561:

$$\Rightarrow d = 0.15 \Rightarrow OD = 0.9 \Rightarrow L_0 = 16 \text{ mm} \Rightarrow N_t = 40$$
$$\Rightarrow \text{Mat: A228 Music wire} \Rightarrow \text{Square and grounded}$$

$$\Rightarrow D = OD - d = 0.9 - 0.15 = 0.75 \text{ mm}$$

$$\Rightarrow C = \frac{D}{d} = \frac{0.75}{0.15} = 5$$

$$\Rightarrow K_B = \frac{4C+2}{4C-3} = \frac{4 \times 5 + 2}{4 \times 5 - 3} = 1.294$$

$$\Rightarrow F_s = K_y = K(L_0 - L_s) \text{ from table 10-1}$$

$$\Rightarrow L_s = dN_t = 0.15 \times 40 = 6 \text{ mm}$$

$$\Rightarrow N_t = N_a + 2 \Rightarrow N_a = 40 - 2 = 38 \text{ coils}$$

$$\Rightarrow K = \frac{d^4 G}{8D^3 N_a} = \frac{0.15^4 \times 81.7 \times 10^3}{8 \times 0.75^3 \times 38} = 0.326 \text{ N/mm}$$

from table 10-5

$$\Rightarrow F_s = K(L_0 - L_s) = 0.326(16 - 6) = 3.26 \text{ N}$$

$$\Rightarrow \tau_s = K_B \frac{8F_s D}{\pi d^3} = 1.294 \frac{8 \times 3.26 \times 0.75}{\pi \times 0.15^3}$$
$$= 2379.7 \text{ MPa}$$

$$\Rightarrow \text{from table 10-4; music wire} \Rightarrow S_{sy} = 0.45 S_{ut}$$

$$\Rightarrow S_{ut} = \frac{A}{d^m}$$

$$\Rightarrow S_{ut} = \frac{2211}{0.15^{0.145}} = 2911.08 \text{ MPa}$$

$$\Rightarrow S_{sy} = 0.45 \times 2911.08 = 1309.99 \text{ MPa}$$

$\therefore$ Since $S_{sy} < T_s \quad \therefore n_s < 1$ not solid safe

to finding largest free length with $n_s = 1.2$

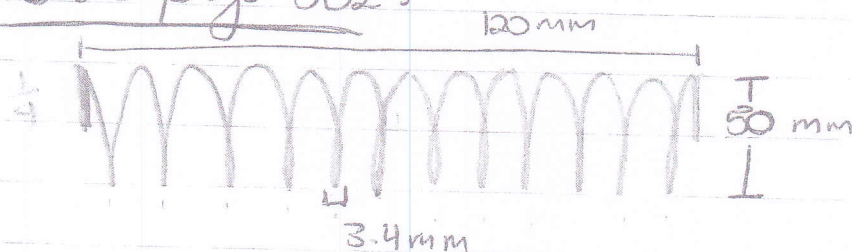
$$\Rightarrow L_0 = L_s + y_s = L_s + \frac{F_s}{k}$$

$$\Rightarrow T_s = K_B \times \frac{8F_s D}{\pi D^3} \Rightarrow \frac{S_{sy}}{n_s} = K_B \frac{8F_s D}{\pi d^3}$$

$$\Rightarrow \frac{1309.99}{1.2} = \frac{1.294 \times 8 \times F_s \times 0.75}{\pi \times 0.15^3} \Rightarrow F_s = 1.49 \text{ N}$$

$$\Rightarrow L_0 = 6 + \frac{1.49}{0.326} = 10.58 \text{ mm}$$

* 10.20 page 562:



$$\Rightarrow N_a = 12 \quad \Rightarrow N_t = 12.5 \quad \Rightarrow N_a \neq N_t \text{ not plane}$$

$$\Rightarrow L_0 = 120 \text{ mm} \quad \Rightarrow OD = 50 \text{ mm} \quad \Rightarrow d = 3.4 \text{ mm}$$

* Home work

* 10-21 page 562:

- $\Rightarrow F_i = 90N$ $\Rightarrow \gamma_i = 50 \text{ mm}$ $\Rightarrow l_s \leq 38 \text{ mm}$
 $\Rightarrow l_o \leq 100 \text{ mm}$ $\Rightarrow n_s \geq 1.2$ $\Rightarrow \xi \geq 0.15$
 $\Rightarrow d = 1.9 \text{ mm}$ $\Rightarrow \text{music wire}$ $\Rightarrow \text{rod } d = 2.0 \text{ mm}$
 $\Rightarrow \text{clearance } d = 1.2 \text{ mm}$

	$d = 1.9 \text{ mm}$	$d = 2.0 \text{ mm}$	$d = 2.1 \text{ mm}$
$ID = \text{Rod } d$	$20 + 1.2 = 21.2$	21.2	21.2
+ $\text{Clear } d$			
$D = ID + d$	$21.2 + 1.9 = 23.1$	$21.2 + 2 = 23.2$	$21.2 + 2.1 = 23.3$
$C = \frac{D}{d}$	$\frac{23.1}{1.9} = 12.15$	$\frac{23.2}{2.0} = 11.6$	$\frac{23.3}{2.1} = 11.04$
$4 \leq C \leq 12$	X	✓	✓
$K = \frac{F_i}{\gamma_i}$		$\frac{90}{50} = 1.8$	$\frac{90}{50} = 1.8$
$N_a = \frac{d^4 G}{8 D^3 K}$		$\frac{2^4 \times 81 \times 10^3}{8 \times 23.2^3 \times 1.8}$	$\frac{2.1^4 \times 81 \times 10^3}{8 \times 23.3^3 \times 1.8}$
		$= 7.20 \text{ coils}$	$= 8.6 \text{ coils}$
$3 \leq N_a \leq 15$		✓	✓
$\xi > 0.15$		✓	✓
$S_{ut} = \frac{A}{d^m}$		$\frac{2211}{2^{0.145}} = 1999.5$	$\frac{2211}{2.1^{0.145}} = 1985.48$
$S_{sy} = 0.45 S_{ut}$		899.8 MPa	893.48 MPa

$$K_B = \frac{4C+2}{4C-3}$$

$$\frac{4 \times 11.6 + 2}{4 \times 11.6 - 3} = 1.115$$

$$\frac{4 \times 11.04 + 2}{4 \times 11.04 - 3} = 1.112$$

$$F_s = K y_s$$

$$= K (L_0 - L_s)$$

$$1.8 (100 - 38)$$

$$= 111.6 \text{ N}$$

$$1.8 (100 - 38)$$

$$= 111.6 \text{ N}$$

$$\tau_s = \frac{K_B \times 8 F_s D}{\pi d^3}$$

$$\frac{1.115 \times 8 \times 111.6 \times 23.2}{\pi \times 2^3}$$

$$= 918.9 \text{ MPa}$$

$$\frac{1.12 \times 8 \times 111.6 \times 23.2}{\pi \times 2.1^3}$$

$$= 800.79$$

$$n_s = \frac{S_{sy}}{\tau_s}$$

$$\frac{819.8}{918.9} = 0.891$$

$$\frac{813.46}{800.79} = 1.016$$

$0.891 < 1$ so failed

$n_s \approx 1.2$ so OK

10/2/2004
Monday

Lab

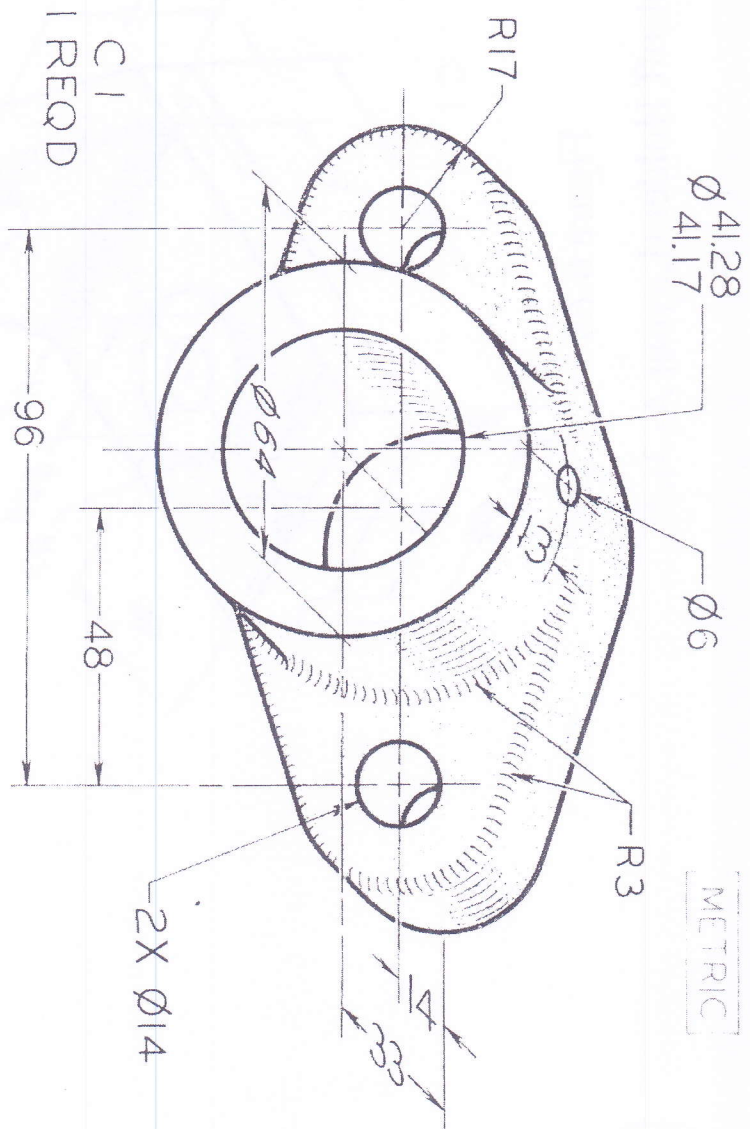


Figure 6-61

Theory

12/2/2014
Wednesday

* 10-23 page 563:

$\Rightarrow F = 45 \text{ N} \quad \Rightarrow n_s \geq 1.2$

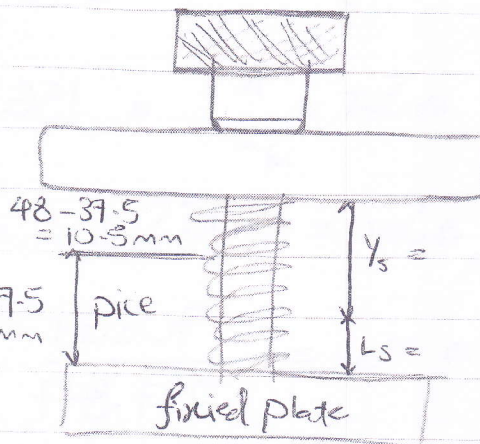
$\Rightarrow \text{Clearance } d = 1.25 \text{ mm}$

$\Rightarrow d = 2 \text{ mm} \quad \Rightarrow \text{Mat: HD 37.5 mm}$

$\Rightarrow d = 2.0 \text{ increment of } 0.2 \text{ mm}$

$\Rightarrow ID = \text{Screw die} + \text{direct}$
 $= 10 + 1.25 = 11.25 \text{ mm}$

$\Rightarrow D = 11.25 + 2 = 13.25 \text{ mm}$



* Short check

$\Rightarrow C = \frac{D}{d} = 6.625 \quad \Rightarrow 4 \leq 6.625 \leq 12 \checkmark$

$\Rightarrow 3 \leq N_A \leq 15 \quad \Rightarrow k = \frac{d^4 G}{8 D^3 N_A} \quad \Rightarrow N_A = 15.93$
 failed

$\Rightarrow k = \frac{F}{y} = \frac{F}{(L_0 - \text{wire piece thick})} = \frac{45}{48 - 37.5}$
 $= 4.28 \text{ N/mm}$

$\Rightarrow \xi = \frac{F_s}{F_i} - 1 \quad \Rightarrow F_s = k y_s = 4.28 \times 16.5$
 $= 70.62$

$\Rightarrow \xi = \frac{70.62}{45} - 1 = 0.5693 > 0.15 \checkmark$

$$\Rightarrow n_s = \frac{S_{sy}}{\tau_s} \Rightarrow \tau_s = K_B \frac{8 F_s D}{\pi d^3} = 297.847 \text{ MPa}$$

$$\Rightarrow S_{ut} = \frac{A}{d^m} = 1563 \text{ MPa} \Rightarrow$$

$$\Rightarrow S_{sy} = 0.45 S_{ut} = 703.34 \text{ MPa}$$

$$\Rightarrow n_s = \frac{703.34}{297.847} = 2.36 \geq 1.2 \checkmark$$

Chapter 17

13/2/2014
Thursday

* Critical Frequency of helical springs

$$\Rightarrow f = \frac{1}{2} \sqrt{\frac{kg}{W}}$$

$$\Rightarrow W = AL\gamma \quad \text{« } \gamma = \text{specific weight »}$$

$$\Rightarrow W = \frac{\pi}{4} d^2 \times \pi D N_s \times \gamma$$

- Chapter 17: Flexible Mechanical Element

- ① Belts ② Ropes ③ Chain

1] Belt:

⇒ Material

Rubber or other material Ex polyimide

Metal

⇒ Shape

Flat



V-Flat



Timing Belt

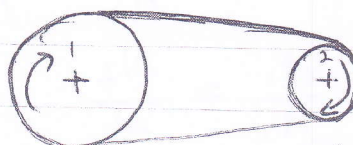


Circular Belt, Round, ropes



* Types of Belt drive:

1- Open Belt drive

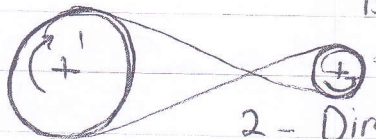


1- Axis of shaft
is parallel

2- Direction

is same

2- Cross Belt drive



1- Axis is ||

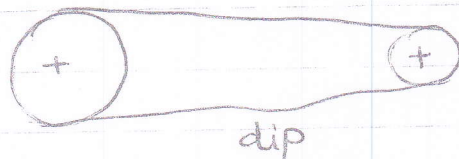
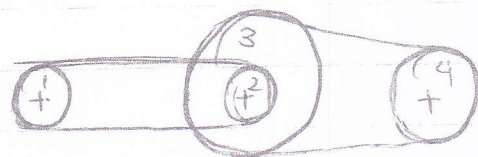
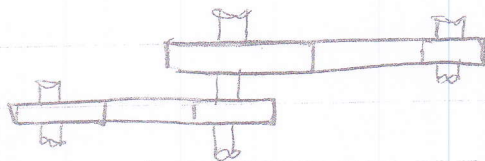
2- Direction is opposite

3 - Quarter turn Belt drive

- 1 - Axis is perpendicular
- 2 - Direction is opposite

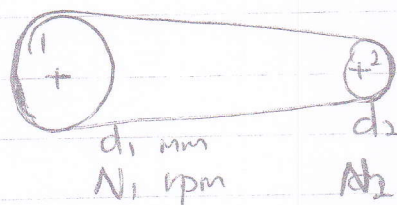


4 - Compound Belt drive



* Velocity Ratio

Distance covered by ① = $\pi d_1 N_1$
by belt on pulley ② = $\pi d_2 N_2$



$$\Rightarrow \pi d_1 N_1 = \pi d_2 N_2$$

$$\Rightarrow V = \frac{d_1}{d_2} = \frac{N_2}{N_1} \quad \text{inverse proportional}$$

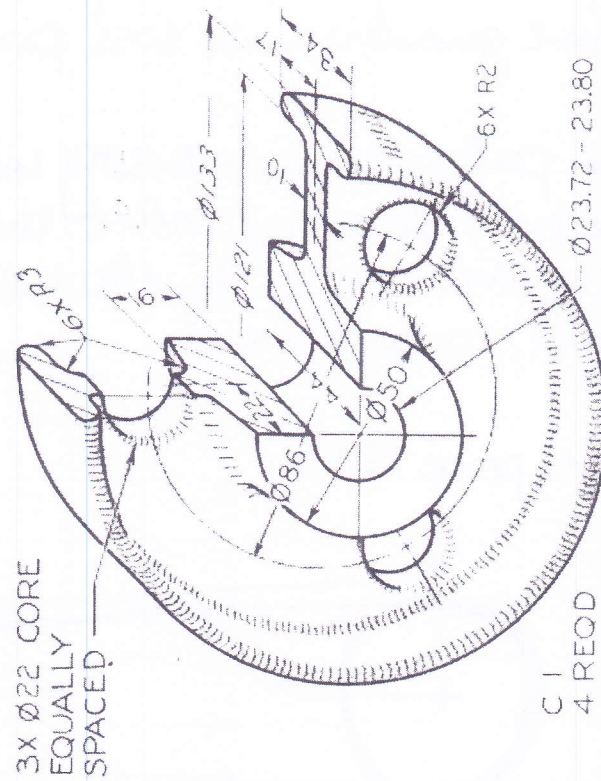
$$\Rightarrow \frac{d_1}{d_2} = \frac{N_2}{N_1} \quad \Rightarrow \frac{d_3}{d_4} = \frac{N_4}{N_3}$$

$$\Rightarrow \frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4} \quad \Rightarrow N_2 = N_3$$

17/2/2014
Monday

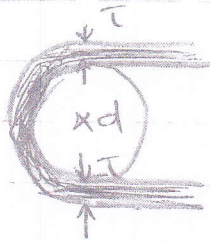
Lab

Truck wheel



Theory

19/2/2014
Wednesday



$$\Rightarrow \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

$$\Rightarrow \frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t} \quad \text{when thickness of belt is considered}$$

- Slip of Belt

the pulley somewhere without move the belt
for Example 1% slip

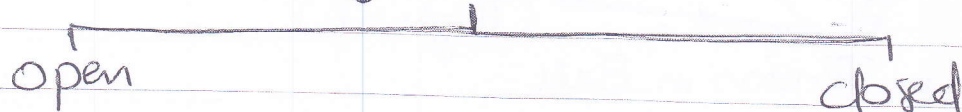
next generation will loss power reduce speed

The pulley moving/rotating without carrying the belt forward called the slip, its measured as percentage. the effect of slip is reduces speed to be delivered

from page 881:



length of Belt



$$L = eq(17-2)$$

$$L = eq(17-4)$$

$\Rightarrow C = \text{center of distance}$

$\Rightarrow \theta = \text{angle contact}$



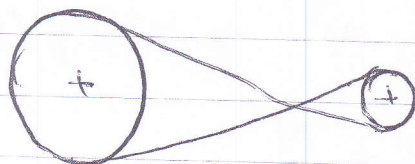
$$\theta = 180$$



open belt drive

$$\Rightarrow \theta_d = \pi - 2 \sin^{-1} \left[\frac{D-d}{2C} \right] \Rightarrow \theta_d = \pi - 2\phi$$

$$\Rightarrow \theta_D = \pi + 2 \sin^{-1} \left[\frac{D-d}{2C} \right] \Rightarrow \theta_D = \pi + 2\phi$$

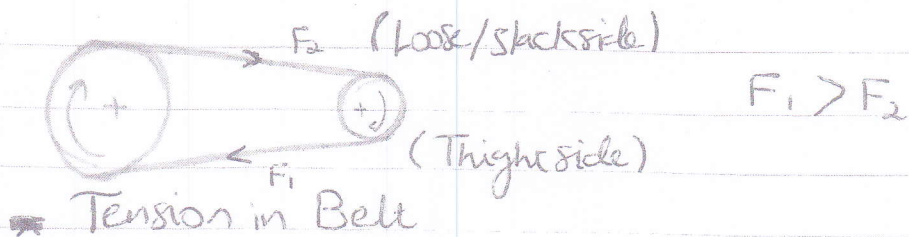


cross belt drive

$$\Rightarrow \theta_d = \theta_D = \theta$$

$$\Rightarrow \theta = \pi + 2 \sin^{-1} \left[\frac{D+d}{2C} \right]$$

20/2/2014
Thursday



$\Rightarrow \frac{F_1}{F_2} = e^{f\theta}$
 $\Rightarrow \theta = \text{angle of contact}$
 $\Rightarrow f = \text{coefficient of friction between belt and pulley}$

Power transmitted

$\Rightarrow P = \frac{2\pi NT}{60}$ $T = Fr$
 $\Rightarrow P = \frac{2\pi N}{60} \cdot (F_1 - F_2) \cdot \frac{d}{2}$

$\Rightarrow P = (F_1 - F_2) \cdot \frac{\pi d N}{60} = (F_1 - F_2) \cdot v$
 $d = \text{diameter of delivering power}$ $N = \frac{m}{s} = W$ velocity

Centrifugal tension (Force):

$\Rightarrow F_c = mv^2 = \frac{W}{g} \cdot v^2 \Rightarrow W = \gamma (bxt)$

$\Rightarrow \gamma = \text{specific weight} = \frac{N}{m^3}$

$\Rightarrow$ Centrifugal tension will be considered if weight of the belt is considered. The effect of centrifugal tension is to reduce the tension on each side of the belt.

$\therefore \frac{F_1 - F_c}{F_2 - F_c} = e^{f\theta}$

- Initial Tension « F_c » :

$$\Rightarrow F_c = \frac{F_1 + F_2}{2}$$

$$\Rightarrow F_2 = \frac{F_1 + F_2}{2} - F_c$$

- Nominal Power « H_{nom} » and Design Power « H_d »

$$\Rightarrow \eta_d = \frac{H_d}{(H_{nom}) K_s}$$

$\Rightarrow K_s$ = service factor

$$\Rightarrow H_d = H_{nom} \cdot K_s \cdot \eta_d$$

$\Rightarrow b$ = width

$\Rightarrow F_a$ = manufacture allowed

$$\Rightarrow (F_1)_a = F_a \cdot b \cdot C_p C_v \quad \text{tension } \frac{N}{m}$$

$\Rightarrow C_p$ = pulley correction factor

$\Rightarrow C_v$ = velocity correction factor

$\Rightarrow f' < f$ manufacture claim « sale »
friction developed

$$\Rightarrow f' = \frac{1}{\theta} \ln \left[\frac{(F_1)_a - F_c}{F_2 - F_c} \right]$$

- 17.1 page 925 :

$$\Rightarrow b = 150 \text{ mm} \quad \Rightarrow \text{Mat : Polynide F-1} \quad \Rightarrow K_s = 1.25$$

$$\Rightarrow \text{Type of belt : Flat} \quad \Rightarrow d = 50 \text{ mm} \quad \Rightarrow VR = 0.5$$

$$\Rightarrow C = 2.7 \text{ m} \quad \Rightarrow N_1 = 1750 \text{ rpm} \quad \Rightarrow P_{delivered} = 1.5 \text{ kW}$$

$$\Rightarrow F_c = \frac{W}{g} \times V^2 \quad \Rightarrow V = \frac{\pi d N}{60} = \frac{\pi \times 50 \times 10^{-3} \times 1750}{60}$$

$$= 4.58 \text{ m/sec}$$

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$\Rightarrow W = \gamma(bxt)$ from table 17-2 page 889:

$$\Rightarrow t = 1.3 \Rightarrow \gamma = 9.5 \text{ kN/m}^3 \Rightarrow F_1 = 6 \times 10^3 \text{ N/m}$$

$$\Rightarrow f = 0.5$$

$$\Rightarrow W = 9.5 \times 10^3 (150 \times 10^{-3} \times 1.3 \times 10^{-3}) = 1.85 \text{ N/m}$$

$$\Rightarrow F_c = \frac{1.85}{9.81} \times 4.58^2 = 3.96 \text{ N}$$

$$\Rightarrow F_i = \frac{(F_1 + F_2)}{2} - F_c \Rightarrow (F_1 = F_2 \text{ b } C_p C_v \text{ from table 890})$$

$$\Rightarrow C_p = 0.7 \Rightarrow C_p = 1 \text{ "for all materials except leather belt" from fig 17-9}$$

$$\Rightarrow (F_1)_a = 6 \times 10^3 \times 150 \times 10^{-3} \times 0.7 \times 1 = 630 \text{ N}$$

$$\Rightarrow (F_1)_a - F_2 = \frac{2T}{d} \Rightarrow P = \frac{2\pi NT}{60} \Rightarrow T = \frac{H \times 60}{2\pi N} \quad P=H$$

$$\Rightarrow T = \frac{H_{nom} \times K_s \times n_d \times 60}{2\pi N} = \frac{1.5 \times 10^3 \times 1.25 \times 1 \times 60}{2\pi \times 1730} = 10.23 \text{ Nm}$$

$$\Rightarrow F_2 = 630 - \frac{2 \times 10.23}{50 \times 10^{-3}} = 220.8 \text{ N}$$

$$\Rightarrow F_i = \frac{630 + 220.8}{2} - 3.96 = 421.44 \text{ N}$$

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b-

$$\Rightarrow H_d = H_{nom} \times K_s \times n_d$$

$$= 1.5 \times 1.25 \times 1 = 1.875 \text{ kW}$$

or

$$\Rightarrow H_d = [(f_i)_a - F_v] \times$$

$$= (630 - 220.8) \times 4.58 = 1.875 \text{ kW}$$

$$\Rightarrow n_d = \frac{H_d}{H_{nom} \times K_s} = \frac{1.875}{1.875} = 1 \text{ "as expected"}$$

$$\Rightarrow L_{open} = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\Theta_D + d\Theta_d)$$

$$\begin{aligned} \Rightarrow \Theta_d &= \pi - 2 \sin^{-1} \left[\frac{D-d}{2C} \right] \\ &= \pi - 2 \sin^{-1} \left[\frac{100-50}{2 \times 2.7 \times 10^3} \right] = 3.123 \text{ rad} \end{aligned}$$

$$\begin{aligned} \Rightarrow \Theta_D &= \pi + 2 \sin^{-1} \left[\frac{D-d}{2C} \right] \\ &= \pi + 2 \sin^{-1} \left[\frac{100+50}{2 \times 2.7 \times 10^3} \right] = 3.16 \text{ rad} \end{aligned}$$

$$\Rightarrow L = \sqrt{4(2.7 \times 10^3)^2 - (100-50)^2} + \frac{1}{2}(100 \times 3.16 + 50 \times 3.123)$$

$$\Rightarrow L = 5.635 \text{ m}$$

$$c - \text{dip} = \frac{C^2 w}{8Fl} = \frac{(2.7 \times 10^3)^2 \times 1.85}{8 \times 421.44 \times 10^3} = 4 \text{ mm}$$

⇒ To design belt, first select material and then choose width then the friction coefficient

$$\Rightarrow b = \frac{1}{q_0 - q_2} \times \frac{H_d}{v} \times \frac{\exp(f\theta)}{\exp(f\theta) - 1}$$

$$\Rightarrow q_2 = q, v^2 = Y_t \cdot v^2$$

$$\Rightarrow b_{\min} = \left[\frac{1}{F_a C_p C_v - Y_t v^2} \right] \left[\frac{H_d}{v} \cdot \frac{\exp(f\theta)}{\exp(f\theta) - 1} \right]$$

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= 17.3 page 926:

$$\Rightarrow d = D = 1.2 \text{ m} \quad \Rightarrow N = 380 \text{ rpm} \quad \Rightarrow K_s = 1.1$$
$$\Rightarrow n_d = 1 \quad \Rightarrow C = 4.8 \text{ m} \quad \Rightarrow H_{nom} = 45 \text{ kW}$$

* Design Steps

- ① $d = D = 1.2$
- ② $VR = 1, N = 380 \text{ rpm}$
- ③ $K_s = 1.1, n_d = 1$
- ④ $H_{nom} = 45 \text{ kW}$
- ⑤ Material
- ⑥ Type of belt drive
- ⑦ Design belt 'b'
- ⑧ Check for friction

we select polyamide F2, A2

$$\Rightarrow F_2: t = 1.8 \text{ mm} \quad \Rightarrow f = 0.5$$

$$\gamma = 13.8 \text{ kN/m}^3, F_a = 10 \times 10^3 \text{ N/m}$$

$$\Rightarrow (F_1)_a = F_a b C_p C_v$$
$$= 10 \times 10^3 \times b \times 1 \times 1 = 10000 b \text{ N}$$

$$\Rightarrow F_c = \frac{w}{g} v^2$$

$$\Rightarrow w = \gamma b t \quad \Rightarrow v = \frac{\pi d N}{60}$$

$$\Rightarrow F_c = \frac{13.8 \times 10^3 \times b \times 1.8 \times 10^{-3}}{9.8} \times \left[\frac{\pi \times 1.2 \times 380}{60} \right]^2$$
$$= 1443.95 b \text{ N}$$

$$\Rightarrow T = \frac{H_d \times 60}{2\pi N} = \frac{4.5 \times 10^3 \times 1.1 \times 1 \times 60}{2\pi \times 380} = 1243.9 \text{ Nm}$$

$$\Rightarrow (F_1)_a = F_2 = \frac{2T}{d} \quad \Rightarrow F_2 = (F_1)_a - \frac{2T}{d}$$

$$\Rightarrow F_2 = 10000 b - \frac{2 \times 1243.9}{1.2}$$

$$= 10000 b - 2073.15$$

$$\Rightarrow f' = \frac{1}{\Theta} \ln \left[\frac{(F_1)_q - F_c}{F_2 - F_c} \right]$$

$$\Rightarrow \frac{(F_1)_q - F_c}{F_2 - F_c} = e^{f'\Theta}$$

$$\Rightarrow \frac{10000b - 1443.95b}{10000b - 2073.16 - 1443.956b} = e^{(0.5 \times 3.14)}$$

$$\Rightarrow \frac{8556.05b}{8556.05b - 2073.16} = 4.806$$

$$\Rightarrow 8556.05b(4.806 - 1) = 2.703.16 \times 4.806$$

$$\Rightarrow b = 0.306 \text{ m} = 306 \text{ mm}$$

for A2: $t = 2.8 \text{ mm}$; $f = 0.8$
 $\gamma = 10 \text{ kN/m}^3 \Rightarrow F_q = 10 \times 10^3 \text{ N/m}$

$$\Rightarrow (F_1)_q = F_q b C_p C_v$$

$$= 10 \times 10^3 \times b \times 1 \times 1 = 10000b \text{ N}$$

$$\Rightarrow F_c = \frac{w}{g} v^2 = \frac{\gamma b t}{g} \cdot \left[\frac{\pi d N}{60} \right]^2$$

$$= \frac{10 \times 10^3 \times b \times 2.8 \times 10^{-3}}{9.81} \times \left[\frac{\pi \times 1.2 \times 380}{60} \right]^2$$

$$= 1627.106b \text{ N}$$

$$\Rightarrow T = \frac{Hd \times 60}{2\pi N} = 1243.9 \text{ Nm}$$

$$\Rightarrow F_2 = (F_1)_a - \frac{2T}{d} = 10000b - 2073.16$$

$$\Rightarrow f' = \frac{1}{\theta} \ln \left[\frac{(F_1)_a - F_c}{F_2 - F_c} \right] \Rightarrow \frac{(F_1)_a - F_c}{F_2 - F_c} = e^{f'\theta}$$

$$\Rightarrow \frac{10000b - 1627.106b}{10000b - 2073.16 - 1627.106b} = e^{(0.8 \times 3.14)}$$

$$\Rightarrow \frac{8372.894b}{8372.894b - 2073.16} = 12.329$$

$$\Rightarrow 8372.894b(12.329 - 1) = 25561.16$$

$$\Rightarrow b = 0.269 \text{ m} \quad \Rightarrow b = 269 \text{ mm}$$

$\Rightarrow$ Since belt 1 and belt 2 will produce friction of 0.5, 0.8 respectively. Then for to reduce the friction the width of belt should have or be increased. This mean be done retring to manufactureres catalog for the next available width assuming that belt width 350, 300 mm and is available for belt ① we check the friction developed

Belt ① 350 mm

$$\Rightarrow f_1/a = 10000 \times 0.350 \\ = 3500 \text{ N}$$

$$\Rightarrow F_c = 1443.95 \times 0.35 \\ = 505.3 \text{ N}$$

$$\Rightarrow F_2 = 10000 \times 0.35 \\ - 2073.16 \\ = 1426.84 \text{ N}$$

$$\Rightarrow f' = \frac{1}{\theta} \ln \left[\frac{F_1/a - F_c}{F_2 - F_c} \right] \\ = \frac{1}{3.14} \ln \left[\frac{3500 - 505.3}{1426.84 - 505.3} \right] \\ = 0.375$$

$$\Rightarrow f' < f = 0.375 < 0.5$$

✓

Belt ② 300 mm

$$\Rightarrow f_1/a = 10000 \times 0.3 \\ = 3000 \text{ N}$$

$$\Rightarrow F_c = 1627.106 \times 0.3 \\ = 488.13 \text{ N}$$

$$\Rightarrow F_2 = 10000 \times 0.3 \\ - 2073.16 \\ = 926.84 \text{ N}$$

$$\Rightarrow f' = \frac{1}{3.14} \ln \left[\frac{3000 - 488.13}{926.84 - 488.13} \right] \\ = 0.555$$

$$\Rightarrow f' < f = 0.555 < 0.8$$

✓

Homework 17-5 - 17-10

Lab

24/2/2014
Monday

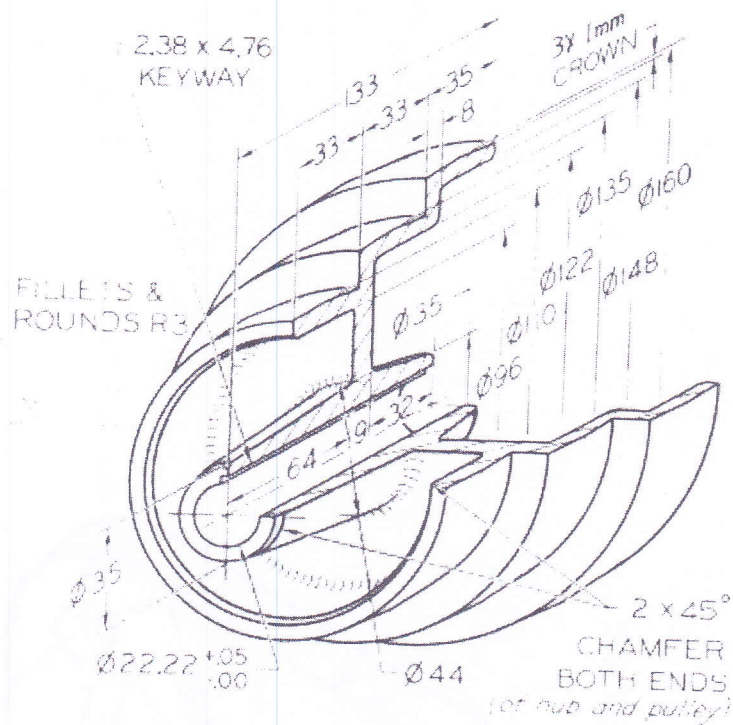
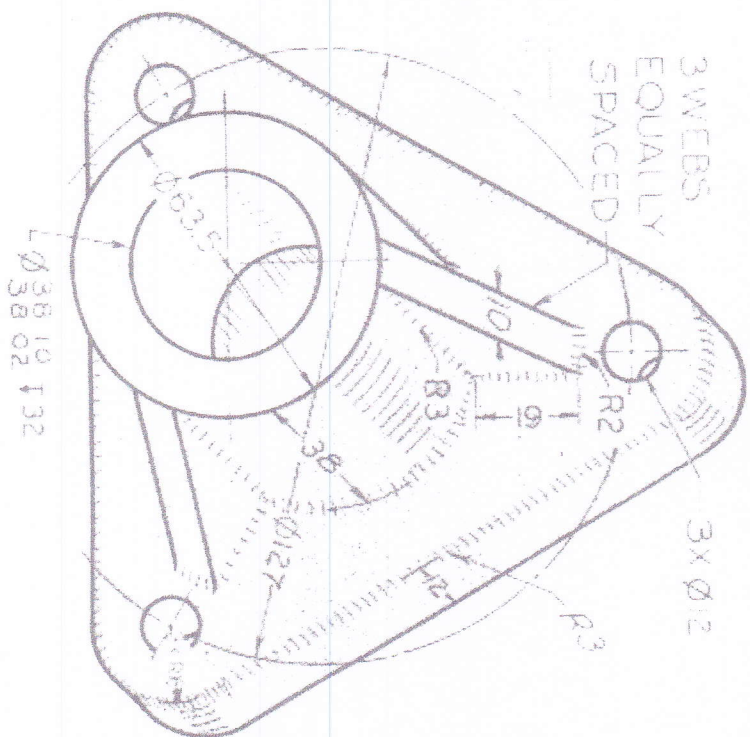


Figure 7-52

Step-Cone Pulley. Draw necessary views, with full section (Layout B-4 or A3-4 adjusted).*



$$\Rightarrow f' = \frac{1}{\theta} \ln \left[\frac{F_1 a - F_c}{F_2 - F_c} \right]$$

$$\Rightarrow f = \frac{1}{\theta} \ln \left[\frac{F_1 a}{F_2} \right] \quad \Rightarrow F_1 a = [S_f - \tau_b] t b$$

$$\Rightarrow S_f = \frac{S_y}{3} \quad \Rightarrow S_f = 97702 \text{ Np}^{-0.407}$$

$$\Rightarrow b_{\min} = \frac{1}{a_0 - a_2} \left[\frac{H_d}{v} \cdot \frac{\exp(\theta t)}{\exp(\theta t) - 1} \right]$$

$$\Rightarrow a_0 = F_a C_p C_v$$

$$\Rightarrow a_2 = \frac{\gamma_t}{g} v^2$$

$\Rightarrow F_c = 0$ for rotal always no centrifugal
Back to page 895:

$$\Rightarrow \tau_b = \frac{F_t}{(1 - v^2) D}$$

$$\Rightarrow \tau_1 = \frac{F_1}{b x t} \quad \Rightarrow \tau_2 = \frac{F_2}{b x t}$$

$$\Rightarrow F_1 > F_2 \quad \Rightarrow \tau_1 > \tau_2$$

$$\Rightarrow \text{max allowable stress} = \tau_b + \tau_1 \text{ \& } \tau_b + \tau_2$$

$\Rightarrow$ To design, it is helpful to write the formulae

of width b and then work back to avoid unnecessary

$$\Rightarrow b_{\min} = \frac{\Delta F}{q} = \frac{\exp(f\theta)}{\exp(f\theta) - 1} \quad b > b_{\min}$$

$\Rightarrow$ V-belt :

$$\Rightarrow H_{\text{nom}} = \frac{H_d}{H_a}$$

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Thursday

- 17-14 page 927:

$$\begin{aligned}\Rightarrow H_{\text{nom}} &= 1 \text{ KW} \quad \Rightarrow N_1 = 1750 \text{ rpm} \quad \Rightarrow C = 380 \text{ mm} \\ \Rightarrow N_2 &= \frac{1750}{2} \left(\frac{N_1}{2} \right) \quad \Rightarrow D = 2d \quad \Rightarrow K_s = 1.2 \\ \Rightarrow n_d &= 1.05 \quad \Rightarrow N_p = 10^6 \text{ cycles} \quad \Rightarrow f = 0.35 \\ &\Rightarrow \text{Mat: stainless steel}\end{aligned}$$

$$\Rightarrow f = \frac{1}{\Theta} \ln \left[\frac{(F_i)_a}{F_2} \right]$$

$$\Rightarrow \Theta_d = \pi - 2 \sin^{-1} \left[\frac{D-d}{2C} \right] = \pi - 2 \sin^{-1} \left[\frac{2d-d}{2C} \right]$$

$$\Rightarrow \Theta_d = \pi - 2 \sin^{-1} \left[\frac{d}{2C} \right] = \pi - 2 \sin^{-1} \left[\frac{150}{2 \times 380} \right] = 2.74 \text{ rad}$$

$$\Rightarrow (F_i)_a = \left[S_f - \frac{E t}{(1-\mu^2) D} \right] b x t$$

$$\begin{aligned}\Rightarrow S_f &= 97702 \times N_p^{-0.407} = 97702 \times 10^6^{-0.407} \\ &= 353.1 \text{ MPa}\end{aligned}$$

from table 17-8 page 897

$$\Rightarrow E = 193 \text{ GPa} \quad \Rightarrow \mu = 0.285 \quad \Rightarrow S_y = 1206 \text{ MPa}$$

from table 17-7 page 896

$$\Rightarrow t = 0.25 \text{ mm} \quad \Rightarrow d = 150 \text{ mm} \quad \Rightarrow D = 2 \times 150 = 300 \text{ mm}$$

$$\begin{aligned}\Rightarrow (F_i)_a &= \left[353.1 - \frac{193 \times 10^3 \times 0.25}{(1 - 0.285^2) \times 300} \right] \times b \times 0.25 \\ &= 44.51 b \text{ N assuming } b \text{ in mm}\end{aligned}$$

$$\Rightarrow (F_1)_a - F_2 = \frac{2T}{D}$$

$$\Rightarrow T = \frac{H_d \times 60}{2\pi N} = \frac{H_{nom} \times K_s \times n_d \times 60}{2\pi N}$$

$$\Rightarrow T = \frac{1 \times 10^3 \times 1.2 \times 1.05 \times 60}{2\pi \times 1750} = 6.87 \text{ Nm}$$

$$\Rightarrow F_2 = 44.51 b - \frac{2 \times 6.87 \times 10^3}{300}$$

$$= 44.51 b - 45.8$$

$$\Rightarrow \frac{(F_1)_a}{F_2} = e^{f' \theta}$$

$$\Rightarrow \frac{44.51 b}{44.51 b - 45.8} = e^{0.35 \times 2.78} \Rightarrow b \geq 1.65 \text{ mm}_{\min}$$

$\Rightarrow$ to reduce the value of b will increase $b > b_{\min}$ we assume $b = 2 \text{ mm}$

$$\begin{aligned} \Rightarrow f' &= \frac{1}{\theta} \ln \left[\frac{(F_1)_a}{F_2} \right] \\ &= \frac{1}{2.78} \ln \left[\frac{44.51 \times 2}{44.51 \times 2 - 45.8} \right] \end{aligned}$$

$$\Rightarrow f' = 0.26 < 0.35 \quad \checkmark$$

Home work 17-15

- 17-18 page 928:

⇒ 2 B2125 V Belt ⇒ $d = 135 \text{ mm}$ ⇒ $N_1 = 1200 \text{ rpm}$

⇒ $D = 400 \text{ mm}$ ⇒ $K_s = 1.25$ ⇒ $H_{nom} = ?$ ⇒ $C = ?$

$$\Rightarrow H_{nom} = \frac{H_d}{K_s \times n_d} \quad \Rightarrow H_d = H_a = K_1 K_2 H_{tab}$$

⇒ K_1 from table 17-13 page 902

⇒ K_2 from table 17-14 page 902

⇒ H_{tab} from table 17-12 page 901

$$\Rightarrow V = \frac{\pi d N}{60} = \frac{\pi \times 135 \times 10^{-3} \times 1200}{60} = 8.48 \text{ m/s}$$

⇒ $B = 135$ for $5 \text{ m/s} = 1.19 \text{ kW}$

for $10 \text{ m/s} = 1.95 \text{ kW}$

⇒ when $V = 8.48 \text{ m/s}$ ⇒ $H_{tab} = 1.72 \text{ kW}$

$$\Rightarrow C = 0.25 \left[\left(L_p - \frac{\pi}{2} (D+d) \right) + \sqrt{\left[L_p - \frac{\pi}{2} (D+d) \right]^2 - 2(D-d)^2} \right]$$

⇒ $L_p = \text{pitch length}$ B 2125

⇒ $B = \text{Type of Belt}$ 2125 = Circumference (length)

⇒ $L_p = \text{Circumference} + \text{Constant from table 17-11}$

$$= 2125 + 45 = 2170 \text{ mm}$$

$$\Rightarrow C = 651 \text{ mm}$$

$$\text{for } K_1 \Rightarrow \frac{D-d}{C} = \frac{400-135}{651} = 0.4$$

$$\therefore K_1 = 0.94$$

$$\text{for } K_2 \Rightarrow B2125 \approx B 2.125 \text{ mm} \Rightarrow K_2 = 1$$

$$\Rightarrow H_d = H_a = K_1 K_2 H_{cab} = 0.94 \times 1 \times 1.72 \\ = 1.626 \text{ kW}$$

$$\text{Since we have two belt } H_a = 2 \times 1.626 = 3.2524 \text{ kW}$$

$$\Rightarrow H_{nom} = \frac{H_a}{K_s \times n_d} = \frac{3.2524}{1.25 \times 1} = 2.6 \text{ kW}$$

12/3/2013
Wednesday

- 17-19 page 928:

$$\Rightarrow H_{nom} = 45 \text{ kW}$$

$$\Rightarrow d = D = 650 \text{ mm}$$

$$\Rightarrow N = 4000 \text{ rpm}$$

$$\Rightarrow C = 3.6 \text{ m}$$

$$\Rightarrow L_p = 2C + \pi \frac{(D+d)}{2} + \frac{(D-d)^2}{4C}$$

$$\begin{aligned} \Rightarrow L_p &= 2 \times 3.6 \times 10^3 + \pi \frac{(650+650)}{2} + 0 \\ &= 9242 \text{ mm} \end{aligned}$$

$$\Rightarrow L_p = NL + CF \quad \text{from table 17-10 page 899}$$

$\therefore L_p = 9242$ so we have C, D, E and chose E

$$CF = 112 \quad \therefore NL = 9242 - 112 = 9130$$

We selected E9000 because is nearest

checking for value of C; $L_p = 9000 + 112 = 9112$

$$\Rightarrow C = 0.25 \left[\left(9112 - \frac{\pi}{2} (650+650) \right) + \sqrt{\left[9112 - \frac{\pi}{2} (650+650) \right]^2 + 0} \right] = 3.53$$

So the select for Belt is E9000

$$\Rightarrow \eta_d = \frac{H_d N_b}{H_{nom} K_s} \quad \text{assume } K_s = 1.2$$

$$\Rightarrow H_d = K_1 K_2 H_{tab}$$

$$\Rightarrow V = \frac{\pi d N}{60} = \frac{\pi \times 650 \times 10^{-3} \times 400}{60} = 13.61 \text{ m/s}$$

$\Rightarrow$ from 17-12 page 901:

$$\Rightarrow E = 650 \quad \text{for } 15 \text{ m/s} = 22.60 \text{ kW}$$

$$\text{for } 10 \text{ m/s} = 17.01 \text{ kW}$$

$$\Rightarrow \text{When } V = 13.61 \text{ m/s} \Rightarrow H_{tab} = 21.04 \text{ kW}$$

$$\Rightarrow K_1 \text{ from table 17-13 page 902: } K_1 = 1$$

$$\Rightarrow K_2 = 1.05 \quad \text{from Belt E; } 8.25-9.75 \\ \text{and length} = 9.112 \text{ m}$$

$$\Rightarrow H_d = 1 \times 1.05 \times 21.04 = 22.1 \text{ kW}$$

$$\Rightarrow N_b \geq \frac{H_d}{H_a} = \frac{H_{nom}}{H_d} = \frac{45 \times 1.2}{22.1} = 2.44 \approx 3$$

$$\Rightarrow \eta_d = \frac{H_d \times N_b}{H_{nom} \times K_s} = \frac{22.1 \times 3}{45 \times 1.2} = 1.22$$

$$\Rightarrow T_1 = F_1 + \frac{K_b}{d} \quad \Rightarrow T_2 = F_1 + \frac{K_b}{D}$$

$$\because D = d \quad \text{so } T_1 = T_2$$

$\Rightarrow$ from table 17-16 page 903:

$$\Rightarrow K_b = 10850 \quad \Rightarrow K_c = 5.041$$

$$\Rightarrow F_1 = F_c + \Delta F \frac{\exp(f\theta)}{\exp(f\theta) - 1}$$

from equation 17-21 page 901:

$$\Rightarrow F_c = K_c \left[\frac{v}{2.4} \right]^2 = 5.041 \left[\frac{13.61}{2.4} \right]^2 = 162.11 \text{ N}$$

$$\Rightarrow \Delta F = \frac{\frac{H_d}{N_b}}{\frac{\pi n d}{60}} = \frac{\frac{H_d}{N_b}}{v}$$

$$\Rightarrow H_d = H_{nom} \times \eta_d \times K_s = 45 \times 1.2 \times 1.2 = 64.8 \text{ kW}$$

$$\Rightarrow \theta = 3.14 \text{ rad}$$

$$\Rightarrow f = 0.5123 \text{ V-belt}$$

$$\Rightarrow \Delta F = \frac{64.8}{13.61} = 1.587 \text{ kW} = 1.587 \times 10^3$$

$$\Rightarrow F_1 = 162.11 + \frac{1.587 \exp(0.5123 \times 3.14)}{\exp(0.5123 \times 3.14) - 1}$$

=