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ME Assignment on Belts

1. A 60-hp four-cylinder internal combustion engine is used to drive a brick making machine under a schedule of two shifts per day. The drive consists of two 26-in sheaves spaced about 12 ft apart, with a sheave speed of 400 rev/min. Select a V-flat belt arrangement. Find the factor of safety, and estimate the life in passes and hours.

Given: $H_{nom} := 60\ hp$ $\quad D := 26\ in$ $\quad d := D$ $\quad C := 12\ ft$ $\quad N := 400\ \dfrac{rev}{min}$

Required: "Select a V−belt arrangement" $\quad n_d = ?$ $\quad Life = ?$

From table 17-15, since the drive is an IC engine, assume the source of power is medium shock with normal torque characteristic. And to be conservative, take the higher value of $K_S := 1.4$ for a service factor.

Since the two sheaves are equal in size, the inside circumference is easily calculated...

$$L := 2 \cdot C + 2 \cdot \frac{\pi \cdot D}{2} \xrightarrow{explicit, ALL} 2 \cdot 12\ ft + 2 \cdot \frac{\pi \cdot 26\ in}{2} = 369.681\ in$$

From table 17-10, the closest nominal belt length to this value is $L := 360\ in$ under section D.

Then using table 17-11, convert inside circumference to pitch length. For section D belts, we add 3.3"

$L_p := L + 3.3\ in = 363.3\ in$ $\quad \theta_d := \pi$ $\quad \theta_D := \pi$ $\quad$ *(Because the pulleys are equal in size.)

From Table 17-13, for $\theta_d = 180\ deg$, $K_1 := 1$ and from table 17-14, for D360, $K_2 := 1.10$

From table 17-12, by *linear* interpolation, we get $H_{tab} := 16.94\ hp$

$H_a := K_1 \cdot K_2 \cdot H_{tab} \rightarrow 18.634 \cdot hp$ $\quad$ This is the allowable power per belt...

$$H_d := H_{nom} \cdot K_S \cdot n_d \xrightarrow{substitute, n_d = 1} 84.0 \cdot hp$$

Then, the required number of belts is...

$$N_b := \frac{H_d}{H_a} \xrightarrow{explicit, ALL} \frac{84.0 \cdot hp}{18.634 \cdot hp} = 4.508 \qquad N_b := \text{ceil}(4.508) = 5$$

We round up to 5 because any number below 5 will result in power-per-belt more than the allowable value...

$$\Delta F_a := \frac{H_a}{N \cdot \frac{d}{2}} = 225.849\ lbf \qquad T_a := \Delta F_a \cdot \frac{d}{2} = \left(2.936 \cdot 10^3\right)\ lbf \cdot in \qquad \text{....*per belt}$$

$$V := \frac{d}{2} \cdot N = \left(2.723 \cdot 10^3\right)\ \frac{ft}{min}$$

$$F_c = K_c \cdot \left(\frac{V}{1000}\right)^2$$ Equation 17-21 where from table 17-21 we find that $K_c := 3.498$ and $K_b := 5680$

$$F_c := \left(K_c \cdot \left(\frac{V \cdot \frac{min}{ft}}{1000}\right)^2\right) lbf = 25.931\ lbf$$ per belt Assume $f := 0.5$

$$F_i := \frac{T_a}{d}\left(\frac{\exp(f \cdot \theta_d) + 1}{\exp(f \cdot \theta_d) - 1}\right) \xrightarrow{float, 4} 172.2 \cdot lbf$$ ...Equation 17-9

$$F_1 := F_c + F_i \cdot \left(\frac{2\ \exp(f \cdot \theta_d)}{\exp(f \cdot \theta_d) + 1}\right) = 311.059\ lbf$$

Finally we get... $$n_{fs} := \frac{H_a \cdot N_b}{H_d} = 1.109$$

To find the Life, since d=D, T_1=T_2...

$$T_1 := \left(F_1 \cdot lbf^{-1} + \frac{K_b}{d \cdot in^{-1}}\right) lbf = 529.521\ lbf \qquad T_2 := T_1$$

$$N_p := \left(\left(\frac{K}{T_1 \cdot lbf^{-1}}\right)^{-b} + \left(\frac{K}{T_2 \cdot lbf^{-1}}\right)^{-b}\right)^{-1} \xrightarrow[b = 11.105, float, 5]{substitute, K = 4208} 0.49615 \cdot 10^{10} = 4.962 \cdot 10^9$$

$$t := \left(\frac{N_p \cdot (L_p \cdot in^{-1})}{720 \cdot \left(V \cdot \frac{min}{ft}\right)}\right) hr = (9.195 \cdot 10^5)\ hr \qquad t > (9.195 \cdot 10^5)\ hr$$

Since N_p is greater that 10^9, Shigley recommends that, "*If Np >10^9, report that Np =10^9 and t > NpLp/(720V) without placing confidence in numerical values beyond the validity interval.*"

2. Explain the advantages of using V-flat belts over VV-belts.

V-flat belts are commonly used for applications where the 'drum' or the larger sheave is relatively big. Then, because there is sufficient contact length, we don't need the v-groove to increase friction. This means we can avoid the disadvantages of VV-belts like too much friction

and heat which result in increased wear while also maintaining efficiency of power transmission.

3. A flat-belt drive is to consist of two 4-ft-diameter cast-iron pulleys spaced 16 ft apart. Select a belt type to transmit 60 hp at a pulley speed of 380 rev/min. Use a service factor of 1.1 and a design factor of 1.0.

Given: $H_{nom} := 60\ hp \qquad N := 380\ rpm \qquad D := 4\ ft \qquad d := D$

$C := 16\ ft \qquad K_S := 1.1 \qquad n_d := 1$

Required: "Belt type"

$$V := \frac{d}{2} \cdot N = \left(4.775 \cdot 10^{3}\right) \frac{ft}{min}$$

Assume belt material to be Polyamide A-3, so from table 17-2, we have...

$f := 0.8$ $\quad F_a := 100 \frac{lbf}{in}$ (per unit width) $\quad t := 0.13\ in$ $\quad \gamma := 0.042 \frac{lbf}{in^3}$

From table 17-4, pulley correction factor C_p for flat belts...

Since $d = 48\ in$ which is over 31.5", $C_p := 1.0$ $C_v := 1$

$$F_1 := b \cdot F_a \cdot C_p \cdot C_v \rightarrow \frac{100.0 \cdot b \cdot lbf}{in} \qquad w := 12\ \gamma \cdot b \cdot t \rightarrow \frac{0.06552 \cdot b \cdot lbf}{in^2}$$

$$F_c := \left(\frac{w \cdot \frac{in^2}{lbf}}{g \cdot \frac{s^2}{ft}} \left(\frac{V \cdot \frac{min}{ft}}{60} \right)^2 \right) \xrightarrow{float, 6} \frac{415.01 \cdot b \cdot ft}{g \cdot s^2} \qquad F_c := 12.67 \cdot b \cdot \frac{lbf}{in} \rightarrow \frac{12.67 \cdot b \cdot lbf}{in}$$

$$T := \frac{H_{nom} \cdot K_S \cdot n_d}{N} = \left(1.095 \cdot 10^{4}\right) lbf \cdot in$$

$$T = \left(F_1 - F_2\right) \left(\frac{d}{2}\right) \xrightarrow[explicit]{solve, F_2} \frac{F_1 \cdot d - 2 \cdot T}{d}$$

$$F_2 := \frac{F_1 \cdot d - 2 \cdot T}{d} \xrightarrow{float, 4, simplify} -1.0 \cdot \frac{5473.0 \cdot in \cdot lbf}{ft} + \frac{100.0 \cdot b \cdot lbf}{in}$$

$$F_i := \frac{F_1 + F_2}{2} - F_c \xrightarrow[collect, b]{simplify} b \cdot \frac{87.33 \cdot lbf}{in} - \frac{2736.5 \cdot in \cdot lbf}{ft}$$

$$\exp(f \cdot \phi) = \frac{F_1 - F_c}{F_2 - F_c} \xrightarrow[float, 4]{substitute, \phi = \pi} 12.35 = \frac{-0.01596 \cdot b \cdot ft}{in^2 - 0.01596 \cdot b \cdot ft} \xrightarrow[float, 4]{solve, b} \frac{68.18 \cdot in^2}{ft} = 5.682\ in$$

If we choose a standard width like $b := 6\ in$

$$F_1 := b \cdot F_a \cdot C_p \cdot C_v = 600\ lbf \qquad w := 12\ \gamma \cdot b \cdot t = 0.393 \frac{lbf}{in}$$

$$F_c := 12.67 \cdot b \cdot \frac{lbf}{in} \rightarrow 76.02 \cdot lbf \qquad F_2 := \frac{F_1 \cdot d - 2 \cdot T}{d} = 143.895\ lbf$$

$$\exp(f' \cdot \phi) = \frac{F_1 - F_c}{F_2 - F_c} \xrightarrow[float, 4]{substitute, \phi = \pi} e^{3.142 \cdot f'} = 7.72 \xrightarrow[float, 4]{solve, f'} 0.6505$$

Since f'(0.65) is less than f (0.80), the design is okay. So the selected belt-type will be a polyamide A-3 flat belt with t=0.13" and b=6"

4. What is the effect of groove angles on V-belt drives?

The groove angle of a V-belt drive affects its performance by influencing the wedging action, power transmission, and belt wear. A smaller groove angle increases the wedging action, enhancing torque transmission but also generating more friction and heat, leading to higher belt wear. Conversely, a larger groove angle reduces the wedging action, making it easier for the belt to move in and out of the groove, which decreases friction and heat but may compromise torque transmission.

5. What are flat metal belts? What are their application areas? How is their drive analyzed?

Flat metal belts are power transmission belts made from metal, typically stainless steel. They are designed for high-speed, high-torque applications and are known for their durability, precision, and ability to operate in extreme conditions. These belts have a flat, smooth surface and are often used in applications where cleanliness and resistance to chemicals, heat, and abrasion are critical.

Application Areas

Flat metal belts are used in a variety of industries and applications, including:

- Food Processing: For conveying food products in a hygienic manner.
- Pharmaceuticals: In cleanroom environments where contamination must be minimized.
- Automotive: For precision manufacturing processes.
- Electronics: In the production of electronic components.
- Textiles: For high-speed textile machinery.
- Packaging: For high-speed packaging lines.
- Printing: In printing presses for precise and consistent operation.

Drive Analysis

The analysis of flat metal belt drives involves several key factors:
Tensioning: Proper tensioning is crucial to ensure the belt operates efficiently and does not slip. This can be achieved through pre-tensioning or using a tension pulley.
Power Transmission: The power transmitted by the belt is calculated based on the tension difference between the tight and slack sides of the belt and the belt speed.
Belt Speed: The speed of the belt is determined by the rotational speed of the pulleys and their diameters.
Belt Length: The length of the belt is calculated based on the center distance between the pulleys and their diameters.
Friction: The friction between the belt and the pulleys affects the efficiency of power transmission. Proper material selection and surface treatment can enhance friction and reduce slippage.
Load Distribution: The load distribution across the belt must be uniform to prevent uneven wear and tear.

For a detailed analysis, engineers often use analytical models that consider the elastic behavior of the belt, residual strains, and inertia effects