Module
13
Belt drives

Lesson
2
Design of Flat Belt drives

Instructional Objectives:

At the end of this lesson, the students should be able to understand:

- Features of flat belt drives
- Flat belt materials
- Flat belt stresses and its specifications
- Types of design factors
- A sample design procedure.

13.2.1 Flat belt drives

Flat belts drives can be used for large amount of power transmission and there is no upper limit of distance between the two pulleys. Belt conveyer system is one such example. These drives are efficient at high speeds and they offer quite running. A typical flat belt drive with idler pulley is shown in Fig. 13.2.1. Idler pulleys are used to guide a flat belt in various manners, but do not contribute to power transmission. A view of the flat belt cross section is also shown in the figure.

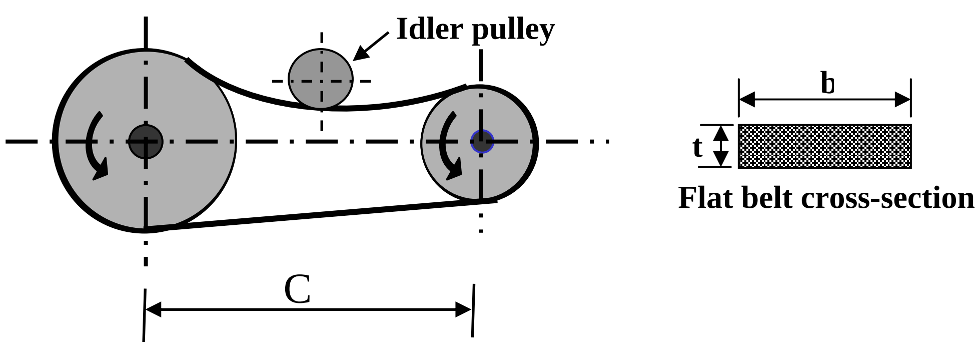

Fig.13.2.1 Belt drive with idler

The flat belts are marketed in the form of coils. Flat belts are available for a wide range of width, thickness, weight and material. Depending upon the requirement one has to cut the required belt length from the coil and join the ends together. The fixing of the joint must be done properly because the belt normally gets snapped from the improper joints. The best way is to use a cemented belt from the factory itself or with care one can join these belts with various types of clips that are available in the market.

13.2.2 Belt Material

Leather
Oak tanned or chrome tanned.

Rubber
Canvas or cotton duck impregnated with rubber. For greater tensile strength, the rubber belts are reinforced with steel cords or nylon cords.

Plastics
Thin plastic sheets with rubber layers

Fabric
Canvas or woven cotton ducks
The belt thickness can be built up with a number of layers. The number of layers is known as **ply.**

The belt material is chosen depending on the use and application. Leather oak tanned belts and rubber belts are the most commonly used but the plastic belts have a very good strength almost twice the strength of leather belt. Fabric belts are used for temporary or short period operations.

13.2.3 Typical Belt drive specifications

Belts are specified on the following parameters

Material

The decision of the material to be used depends on the type of service.

No. of ply and Thickness

Ply is the number of layers as indicated earlier. Therefore, the number of ply is decided depending upon the belt tensile strength required for a given power transmission.

Maximum belt stress per unit width

The belts are subjected to tensile load only. Therefore, the allowable tensile load depends on the allowable stress on the belt and its cross sectional area. It is customary to provide the belt stress value for a given belt thickness and per unit belt width. Hence, a designer has to select a belt thickness and then calculate the required belt width. Otherwise, one can calculate the belt cross sectional area and then adjust the belt thickness and the width from the standards.

The maximum belt stress is also dependent on the belt speed. Hence, the maximum belt stress (for a given belt thickness and per unit belt width) is provided either for different belt speeds or for a specified speed.

Density of Belt material

Density of Belt material is provided as, per unit length per unit cross section. Density of Belt material is required to calculate the centrifugal force on the belt.

Coefficient of friction of the belt material

Coefficient of friction for a pair of belt material and pulley material is provided in design data book.

13.2.4 Modification of Belt stress

When Maximum belt stress/ unit width is given for a specified speed, a speed correction factor ($\mathbf{C_{SPD}}$) is required to modify the belt stress when the drive is operating at a speed other than the specified one.
When angle of wrap is less than 180^0 :
The maximum stress values are given for an angle of wrap is 180^o for both the pulleys, ie, pulleys are of same diameter. Reduction of belt stress is to be considered for angle of wrap less than 180^o. The belt stress is to be reduced by 3% for each ten degree lesser angle of wrap or as specified in a handbook. For e.g., if the angle of wrap is 160^o , then the belt stress is to be reduced by 6%. This factor is given as $\mathbf{C_W}$.

13.2.5 Design considerations for flat belt drives

Transmission ratio of flat belt drives is normally limited to 1:5

Centre distance is dependent on the available space. In the case of flat belt drives there is not much limitation of centre distance. Generally the centre distance is taken as more than twice the sum of the pulley diameters. If the centre distance is too small then rapid flexing of the belt takes place and some amount of belt life will be lost.

Depending on the driving and driven shaft speeds, pulley diameters are to be calculated and selected from available standard sizes.

Belt speed is recommended to be within 15-25 m/s.

A belt drive is designed based on the design power, which is the modified required power. The modification factor is called the service factor. The service factor depends on hours of running, type of shock load expected and nature of duty.

Hence,

Design Power (P_{dcs}) = service factor (C_{sev})* Required Power (**P**) (13.2.1)

C_{sev} = 1.1 to 1.8 for light to heavy shock.

From the basic equations for belt drive, it can be shown that,

$$P_{des} = bt\left(\sigma' - \rho v^2\right)\left(1 - \frac{1}{e^{\mu\alpha}}\right)v$$

(13.2.2)

where, $\sigma' = \sigma_{max} \times C_{SPD} \times C_W$

Finally, the calculated belt length is normally kept 1% short to account for correct initial tension.

Sample Problem

Design a flat belt drive for the following data:

Drive: AC motor, operating speed is 1440 rpm and operates for over 10 hours. The equipment driven is a compressor, which runs at 900 rpm and the required power transmission is 20 kW.

Solution

Let us consider the belt speed to be 20 m/s, which is within the recommended range.

The given speed ratio = 1440/900 =1.6

Let the belt material be leather, which is quite common.

Now,

$$20 = \frac{\pi \times d_s \times 1440}{60 \times 1000}$$
$$\therefore d_S = 265.3\,\text{mm}$$
$$\therefore d_L = 1.6 \times 265.3 = 424.5\text{mm}$$

From the standard sizes available, d_S=280 mm and d_L= 450 mm.

Recalculated speed ratio.

$$\frac{d_L}{d_S} = \frac{450}{280} = 1.607 \approx 1.61$$

Therefore, the choice of both the pulley diameters is acceptable.

$$\text{Center distance, } C > 2(d_L + d_L)$$
$$\therefore\ C > 1460\text{mm}$$
$$\text{Hence, let } C \approx 1500\text{ mm (it is assumed that space is available)}$$

Considering an open belt drive, the belt length,

$$L_o = \frac{\pi}{2}\left(d_L + d_S\right) + 2C + \frac{1}{4C}\left(d_L - d_S\right)^2$$
$$= \frac{\pi}{2}\left(450 + 280\right) + 3000 + \frac{1}{6000}\left(450 - 280\right)^2 \approx 4151\text{ mm}$$

As a guideline, to take into consideration the initial tension, the belt length is shortened by 1%. Hence, the required belt length,

L_O = 4110 mm.

Determination of angle of wrap

$$\beta = \sin^{-1}\left(\frac{d_L - d_s}{2C}\right) = 3.25^0$$
$$\alpha_L = 180 + 2\beta = 186.5^0 = 3.26\text{ rad}$$
$$\alpha_S = 180 - 2\beta = 173.5^0 = 3.03\text{ rad}$$

For the leather belt, the co-efficient of friction, μ may be taken as 0.4.

In this design, both the pulley materials are assumed to be the same, hence, angle of wrap for the smaller pulley being lower, smaller pulley governs the design and the angle of wrap is 3.03 radian.

$$\text{Design power, } P_{des} = \text{service factor } (C_{sev}) \times \text{required power } (P)$$
$$= 1.3 \times 20 \text{ kW} = 26 \text{ kW}$$

The value 1.3 is selected from design data book for the given service condition.

For the design stress in the belt, $\sigma' = \sigma_{max} \times C_{SPD} \times C_W$

However, design stress, σ', for leather belt may be considered as 2 MPa. Similarly, density of leather belt is 1000 kg/m^3.

$$P_{des} = bt\left(\sigma' - \rho v^2\right)\left(1 - \frac{1}{e^{\mu\alpha}}\right)v$$
$$26 \times 10^3 = bt(2 - \frac{10^3 \times 20^2}{10^6})(1 - \frac{1}{3.36}) \times 20$$
$$bt = 1156.78 \text{ mm}^2$$

Let us choose standard belt thickness, t =6.5 mm
Therefore standard belt width, b = 180mm

A leather belt of 6.5 mm thickness, 180 mm width and 4110 mm length will satisfy the design conditions.

Questions and answers

Q1. Name some of the common flat belt materials.

A1. Leather, rubber, plastics and fabrics are some of the common flat belt materials.

Q2. What is the correction factors used to modify belt maximum stress?

A2. Correction factor for speed and angle of wrap are used to modify the belt maximum stress. This correction is required because stress value is given for a specified drive speed and angle of wrap of 180^0. Therefore, when a drive has different speed than the specified and angle of wrap is also different from 180^0 , then above mentioned corrections are required.

Q3. What is the recommended center distance and belt speed for a flat belt drive?

A3. The recommendations are; the center distance should be greater than twice the sum of pulley diameters and the belt speed range should be within 15-25 m/s.

References

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