Properties of Belt Drives

This section describes the general properties of V-belt and Toothbelt transmission systems, and provides a detailed explanation of **PRELOAD**, a necessary component of all types of belt drives.

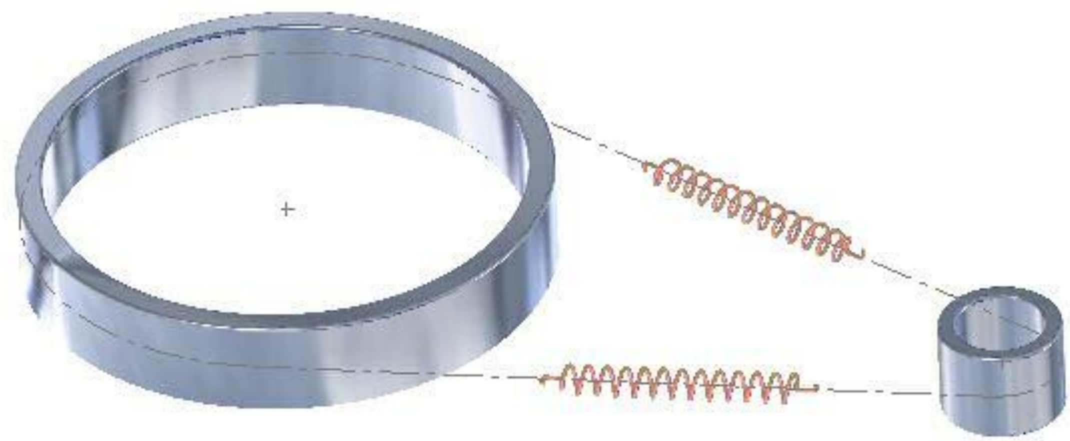
BELT DRIVE BASICS

In order for a belt drive to operate properly, the residual tension in the "loose" span (the non-driving span) of the belt can never be allowed to get near zero (unlike a chain drive, where the "loose" span can actually be loose.). That requirement is accomplished by establishing a static "preload" on the belt. The term "preload" means the establishment of a static tension value in all the spans of the belt.

For **V-belt** drives, preload maintains the contact force between the belt and the surface of the pulley grooves so that friction can transmit the power. For **toothbelt** drives, preload maintains the correct contact pattern between the belt teeth and sprocket grooves. The preload for V-belt drives is usually greater than that required for toothbelt drives.

Any belt will stretch when a load is applied to it, although the amount of stretch is usually very small. The amount of force to produce a specified stretch is known as the belt **modulus**.

The **static** preload in the system stretches each span (spring) of the belt equally, as illustrated in the picture below.



The amount of preload required in a belt drive depends on a number of factors, including:

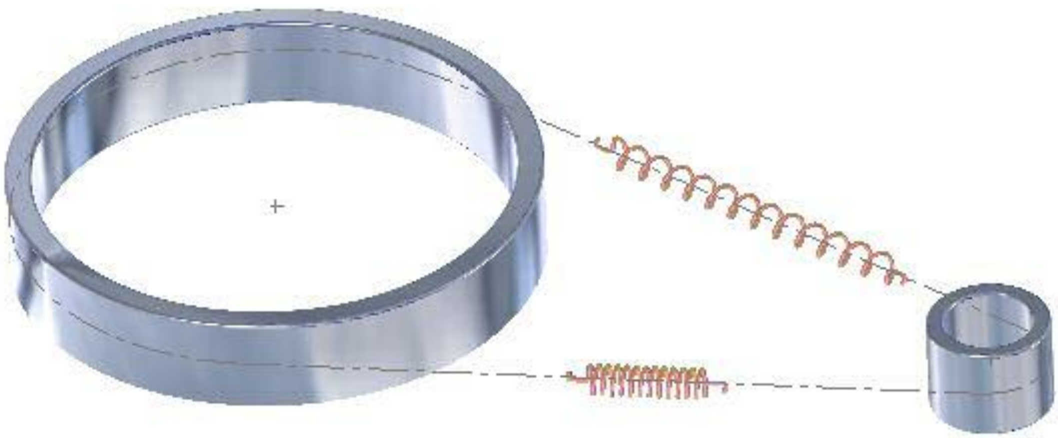
a. the maximum amount of torque which the drive must transmit;
b. the diameter of the driving sprocket (pulley);
c. the minimum arc of contact between the belt and sprockets ("wrap");
d. the properties of the belt.

Preload can be established by means of adjusting the centerline distance between shafts (shimming) or by using an idler which imposes a side load on the "loose" span.

Everyone is probably familiar with establishing preload on an automotive fan-belt system by wedging on the pivoting alternator and locking it in place with the slotted locator arm. You are also probably familiar with the result of not having enough preload in the drive: the belt will slip and squeal under high load. That happens frequently with power steering belts when you turn the steering wheel up against one of the stops.

When torque is applied to the driving sprocket (pulley) of a belt drive, one span of the belt gets tighter and stretches slightly in response to the additional load applied by the driving torque. At the same time, the load in the loose span reduces by the same amount, and the loose span shortens by the same amount the tight side stretched.

Clearly then, the tension in the tight (driving) span becomes *greater* than the preload, and conversely, the tension in the loose span becomes *less* than the preload. This behavior is illustrated in the picture below.



When a belt drive is operating and transmitting power, the amount of force being transmitted from the driving sprocket (pulley) to the driven sprocket (pulley) is the **difference** between the tension in the " tight" (driving) span of the belt and the tension in the "loose" (following) span of the belt.

NOTE that the sum of the tight and loose strand tensions is always the same, which means that ***the bearing loads and shaft bending load caused by a belt drive will be essentially constant, regardless of the torque being transmitted.*** (Only the angle of application changes with applied torque).

The value of the tension in the tight (driving) span is the sum of two values: (a) the "driving tension" plus (b) the existing "loose-side" tension, as shown above. The "driving tension" is the tension in the tight span produced by the torque applied to the driving sprocket (pulley), and has the value:

Driving Tension = applied drive torque / drive sprocket pitch radius

For example, a torque of 2760 lb-in (230 lb-ft) applied to a sprocket of 2.155 pitch radius (4.311 pitch diameter) produces a **driving tension of 1281 pounds** (2760 / 2.155). If a smaller diameter driving sprocket is used, say 1.705 pitch radius (3.409 pitch diameter) then the **driving tension increases to 1620 pounds** (2760 / 1.705).

The amount of preload which a belt drive requires is specified by a value known as "tension ratio" **(TR)**, which is expressed as:

TR = Tight-Side Tension / Loose-Side Tension

Knowing that Tight-Side Tension is the sum of the Driving Tension plus the Loose-Side Tension, that equation can be rewritten as:

TR = (drive tension + loose-side tension) / loose-side tension

or (by means of some high-school algebra)

TR = 1 + (drive tension / loose-side tension)

Rearranging that equation produces the more useful form:

Loose-side tension = Drive-tension / (**TR** - 1)

The value of the preload can be **measured** by applying a **side force** to one span and measuring the force required to deflect the belt a specified amount. **Note** that the side-load force you apply at midspan is **NOT** the preload. The force required to produce the specified deflection just a rough measure of the belt preload.

The force and deflection values used to measure preload are a function of the "springiness" of the belt and the length of the span, and can be calculated from data provided by belt manufacturers.

V-BELT DRIVES

The transmission of force from a pulley to a V-belt (and the inverse) depends on friction between the belt and the pulley. The friction force between the belt and the pulley depends on three factors:

a. the normal force between the belt and the pulley (that is, the force which is *perpendicular to the side surface* of the groove),

b. the coefficient of friction between the belt and the pulley, and

c. the arc of contact between the belt and the pulley.

You already know (explained in **Force and Friction**) that the frictional force between two objects is the product of the *coefficient of friction* and the *normal* force. The coefficient of friction is independent of the shape of the belt, but the normal force between the belt and sides of the pulley sheave depends on:

a. the included angle between the sheave sides, and
b. the tension on the belt.

Because of the wedging action between the belt and the pulley, the normal force is a significant multiple of the belt tension.

In order for the system to transmit the required torque, the belt(s) must be wedged into the groove(s) tightly enough to transmit the applied force.

In order to achieve the necessary wedging, it is necessary to apply a static preload to the drive system. The required preload is calculated from three factors:

a. the maximum torque to be transmitted by the drive,
b. the minimum arc of contact, and
c. the pitchline velocity of the belt(s) (to account for the effect of centrifugal force, which reduces the wedging effect).

Belt manufacturers recommend that the tension ratio for a system with 180° of contact on each sheave should be no tighter than 5:1 (when a new belt has been installed) and no looser than 8:1 (after the belt has run-in).

If the arc of contact on any load-transmitting pulley in the system is less than 180°, then the required tension ratio decreases, which means more preload.

TOOTH-BELT DRIVES

Preload in a toothed-belt system is required in order to keep the teeth from attempting to climb up the sides of the grooves in the sprockets, and, in extreme cases, from jumping ("ratcheting") under the most severe loading conditions.

In a static (non-moving) toothed-belt drive, the tension force in each span of the belt is equal, and is determined by the required preload. The required preload is determined by four factors:

a. the number of teeth engaged on the driving sprocket,
b. the pitch diameter of the driving sprocket,
c. the maximum torque to be transmitted by the drive, and
d. the recommended tension ratio.

If the preload of a toothbelt is *slightly* less than required, the teeth will try to climb the sides of the grooves at high torque loadings, which leads to (a) rapid wear of the belt, and (b) very high shaft bending loads (**higher than if the preload were correct**).

Belt manufacturers recommend that the *tension ratio* for a system with more than a defined minimum number of teeth in contact on the smallest sprocket should be in the range of 8:1 to 10:1 (after the belt has run-in).

Source:

http://www.epi-eng.com/mechanical_engineering_basics/belt_drive_properties.htm