

- Design with large pulleys with more teeth in mesh.
- Keep belts tight, and control tension closely.
- Design frame/shafting to be rigid under load.
- Use high quality machined pulleys to minimize radial runout and lateral wobble.

SECTION 10 BELT TENSIONING

10.1 What Is Proper Installation Tension

One of the benefits of small synchronous belt drives is lower belt pre-tensioning in comparison to comparable V-belt drives, but proper installation tension is still important in achieving the best possible drive performance. In general terms, belt pre-tensioning is needed for proper belt/pulley meshing to prevent belt ratcheting under peak loading, to compensate for initial belt tension decay, and to prestress the drive framework. The amount of installation tension that is actually needed is influenced by the type of application as well as the system design. Some general examples of this are as follows:

Motion Transfer Drives: Motion transfer drives, by definition, are required to carry extremely light torque loads. In these applications, belt installation tension is needed only to cause the belt to conform to and mesh properly with the pulleys. The amount of tension necessary for this is referred to as the minimum tension (T_{st}). Minimum tensions, on a per span basis, are included in **Table 19**, on page T-51. Some motion transfer drives carry very little torque, but have a need for accurate registration requirements. These systems may require additional static (or installation) tension in order to minimize registration error.

Normal Power Transmission Drives: Normal power transmission drives should be designed in accordance with published torque ratings and a reasonable service factor (between 1.5 and 2.0). In these applications, belt installation tension is needed to allow the belt to maintain a proper fit with the pulleys while under load, and to prevent belt ratcheting under peak loads. For these drives, proper installation tension can be determined using two different approaches. If torque loads are known and well defined, and an accurate tension value is desired, **Equation (10-1)** or **Equation (10-2)** should be used. If the torque loads are not as well defined, and a quick value is desired for use as a starting point, values from **Table 20** can be used. All static tension values are on a per span basis.

$$T_{st} = \frac{0.812 DQ}{d} + mS^2 \quad (\text{lb}) \quad (10-1)$$

(For drives with a Service Factor of 1.3 or greater)

$$T_{st} = \frac{1.05 DQ}{d} + mS^2 \quad (\text{lb}) \quad (10-2)$$

(For drives with a Service Factor less than 1.3)

where: T_{st} = Static tension per span (lbs)
 DQ = Driver design torque (lb·in)
 d = Driver pitch diameter (in)
 S = Belt speed/1000 (ft/min)
 where Belt speed = (Driver pitch diameter x Driver rpm)/3.82
 m = Mass factor from **Table 19**

Table 19 Belt Tensioning Force

Belt	Belt Width	<i>m</i>	<i>Y</i>	Minimum T_{st} (lbs) Per Span
2 mm GT2	4 mm	0.026	1.37	1.3
	6 mm	0.039	2.05	2.0
	9 mm	0.058	3.08	3.0
	12 mm	0.077	4.10	4.0
3 mm GT2	6 mm	0.077	3.22	2.2
	9 mm	0.120	4.83	3.3
	12 mm	0.150	6.45	4.4
	15 mm	0.190	8.06	5.5
5 mm GT2	9 mm	0.170	14.9	8.4
	15 mm	0.280	24.9	14.1
	20 mm	0.380	33.2	18.7
	25 mm	0.470	41.5	23.4
3 mm HTD	6 mm	0.068	3.81	2.5
	9 mm	0.102	5.71	4.3
	15 mm	0.170	9.52	7.8
5 mm HTD	9 mm	0.163	14.9	6.3
	15 mm	0.272	24.9	12.0
	25 mm	0.453	41.5	21.3
MXL	1/8"	0.003	1.40	1.0
	3/16"	0.004	2.11	1.7
	1/4"	0.005	2.81	2.3
XL	1/4"	0.010	3.30	3.2
	3/8"	0.015	4.94	5.1
T2.5	4 mm		0.3	0.2
	6 mm	*	0.55	0.45
	10 mm		1.05	0.92
T5	6 mm		7	2.25
	10 mm	*	17	5.62
	16 mm		27	8.99
T10	16 mm	*	73	24.73
	25 mm		133	44.96

NOTE: *Y* = constant used in Equations (10-4) and (10-5).

* Not available at press time.

Registration Drives: Registration drives are required to register, or position accurately. Higher belt installation tensions help in increasing belt tensile modulus as well as in increasing meshing interference, both reducing backlash. Tension values for these applications should be determined experimentally to confirm that desired performance characteristics have been achieved. As a beginning point, use values from **Table 20** multiplied by 1.5 to 2.0.

Table 20 Static Belt Tension, T_{st} (lbs) Per Span – General Values

Belt	4 mm	6 mm	9 mm	12 mm	15 mm	20 mm	25 mm
2 mm GT2	2	3	4	5	—	—	—
3 mm GT2	—	8	11	15	19	25	—
5 mm GT2	—	—	18	22	27	35	43
3 mm HTD	—	5	9	12	16	22	—
5 mm HTD	—	—	13	18	24	33	43
T2.5	0.34	0.67	1.37	—	—	—	—
T5	—	3	7	—	12	—	—
T10	—	—	—	—	28	—	41

Belt	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"
MXL	2	3	3	4	5	—	—
XL	2	3	4	5	6	8	9

Most synchronous belt applications often exhibit their own individual operating characteristics. The static installation tensions recommended in this section should serve as a general guideline in determining the level of tension required. The drive system should be thoroughly tested to confirm that it performs as intended.

10.2 Making Measurements

Belt installation tension is generally, measured in the following ways:

Force/Deflection: Belt span tension can be measured by deflecting a belt span 1/64" per inch (0.4 mm per 25 mm) of span length at midspan, with a known force (see **Figure 20**). This method is generally convenient, but not always very accurate, due to difficulty in measuring small deflections and forces common in small synchronous drives. The force/deflection method is most effective on larger drives with long span lengths. The static (or installation) tension (T_{st}) can either be calculated from **Equation (10-1)** or **Equation (10-2)**, or selected from **Table 19** or **Table 20**. The deflection forces can be calculated from **Equation (10-4)** and **Equation (10-5)**. The span length can either be calculated from **Equation (10-3)**, or measured. If the calculated static tension is less than the minimum T_{st} values in **Table 19**, use the minimum values.

$$t = \sqrt{CD^2 - \left(\frac{PD - pd}{2}\right)^2}$$

where: t = Span length (in)
 CD = Drive center distance (in)
 PD = Large pitch diameter (in)
 pd = Small pitch diameter (in)

$$\text{Deflection force, Min.} = \frac{T_{st} + \left(\frac{t}{L}\right) Y}{16} \quad (\text{lbs})$$

$$\text{Deflection force, Max.} = \frac{1.1 T_{st} + \left(\frac{t}{L}\right) Y}{16} \quad (\text{lbs})$$

where: T_{st} = Static tension (lbs)
 t = Span length (in)
 L = Belt pitch length (in)
 Y = Constant, from **Table 19**

Shaft Separation: Belt installation tension can be applied directly by exerting a force against either the driver or driven shaft in a simple 2-point drive system (see **Figure 21**). The resulting belt tension will be as accurate as the force applied to driver or driven shaft. This method is considerably easier to perform than the force/deflection method and, in some cases, more accurate.

In order to calculate the required shaft separation force, the proper static tension (on a per span basis) should first be determined as previously discussed. This tension value will be present in both belt spans as tension is applied. The angle of the spans with respect to the movable shaft should then be determined. The belt spans should be considered to be vectors (force with direction), and be summed into a single tension vector force (see **Figure 22**). Refer to **SECTION 14 BELT**

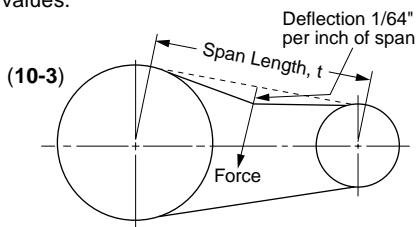


Fig. 20 Force/Deflection Method

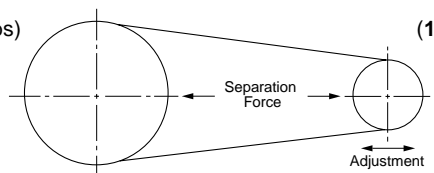


Fig. 21 Shaft Separation Method

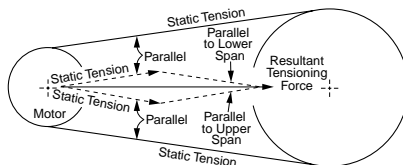


Fig. 22 Single Tension Vector Force

PULL AND BEARING LOADS for further instructions on summing vectors.

Idler Force: Belt installation tension can also be applied by exerting a force against an idler pulley within the system that is used to take up belt slack (see **Figure 23**). This force can be applied manually, or with a spring. Either way, the idler should be locked down after the appropriate tension has been applied.

Calculating the required force will involve a vector analysis as described previously in the shaft separation section.

Sonic Tension Meter: The Sonic Tension Meter (**Figure 24**) is an electronic device that measures the natural frequency of a free stationary belt span and instantly computes the static belt tension based upon the belt span length, belt width, and belt type. This provides accurate and repeatable tension measurements while using a nonintrusive procedure (the measurement process itself doesn't change the belt span tension). A measurement is made simply by plucking the belt while holding the sensor close to the vibrating belt span.

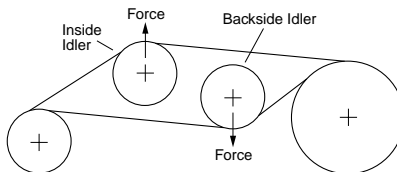


Fig. 23 Idler Forces



Fig. 24 Sonic Tension Meter

The unit is about the size of a portable phone (8-1/8" long x 3-3/4" wide x 1-3/8" thick or 206mm long x 95mm wide x 35mm thick) so it can be easily handled. The sensor is about 1/2" (13mm) in diameter for use in cramped spaces, and the unit is either battery operated for portability or AC operated for production use. The unit measures virtually all types of light power and precision belts. A gain adjustment allows measurements to be made in environments with high noise levels. Data can also be collected through an IBM Compatible RS-232 serial port, if desired. For additional details, see the product section of this handbook.

SECTION 11 DRIVE ALIGNMENT

11.1 Angular And Parallel

Drive misalignment is one of the most common sources of drive performance problems. Misaligned drives can exhibit symptoms such as high belt tracking forces, uneven belt tooth wear, high noise levels, and tensile cord failure. The two primary types of drive misalignment are angular and parallel. Discussion about each of these types are as follows:

Angular: Angular misalignment results when the drive shafts are not parallel (see **Figure 25**). As a result, the belt tensile cords are not loaded evenly, resulting in uneven tooth/land pressure and wear. The edge cords on the high tension side are often overloaded which may cause an edge cord failure that propagates across the entire belt width. Angular misalignment often results in high belt-tracking forces as well which cause accelerated belt

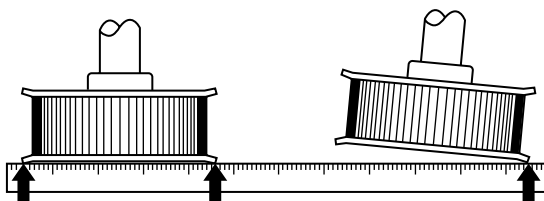


Fig. 25 Angular Misalignment

edge wear, sometimes leading to flange failure or belts tracking off of the pulleys.

Parallel: Parallel misalignment results from pulleys being mounted out of line from each other (see **Figure 26**). Parallel misalignment is generally more of a concern with V-type belts than with synchronous belts because V-type belts run in grooves and are unable to free float on the pulleys. Synchronous belts

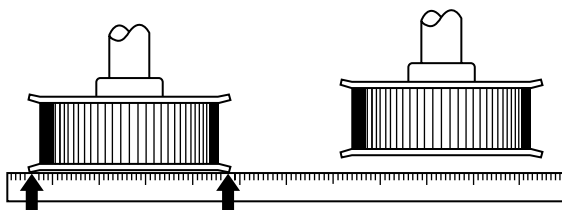


Fig. 26 Parallel Misalignment

will generally free float on the pulleys and essentially self-align themselves as they run. This self-aligning can occur as long as the pulleys have sufficient groove face width beyond the width of the belts. If not, the belts can become trapped between opposite pulley flanges causing serious performance problems. Parallel misalignment is not generally a significant concern with synchronous drives as long as the belts do not become trapped or pinched between opposite flanges. For recommendations on groove face width, see **Table 37**, on page T-68.

Allowable Misalignment: In order to maximize performance and reliability, synchronous drives should be aligned closely. This is not, however, always a simple task in a production environment. The maximum allowable misalignment, angular and parallel combined, is $1/4^\circ$.

11.2 Practical Tips

Angular misalignment is not always easy to measure or quantify. It is sometimes helpful to use the observed tracking characteristics of a belt, to make a judgment as to the system's relative alignment. Neutral tracking "S" and "Z" synchronous belts generally tend to track "down hill" or to a state of lower tension or shorter center distance when angularly misaligned. This may not always hold true since neutral tracking belts naturally tend to ride lightly against either one flange or the other due to numerous factors discussed in the section on belt tracking. This tendency will generally hold true with belts that track hard against a flange. In those cases, the shafts will require adjustment to correct the problem.

Parallel misalignment is not often found to be a problem in synchronous belt drives. If clearance is always observable between the belt and all flanges on one side, then parallel misalignment should not be a concern.

SECTION 12 INSTALLATION AND TAKE-UP

12.1 Installation Allowance

When designing a drive system for a manufactured product, allowance for belt installation must be built into the system. While specific installation allowances could be published, as they are for larger industrial belt drives, small synchronous drive applications are generally quite diverse, making it nearly impossible to arrive at values that apply in all cases. When space is at a premium, the necessary installation allowance should be determined experimentally using actual production parts for the best possible results.

12.2 Belt Installation

During the belt installation process, it is very important that the belt be fully seated in the pulley grooves before applying final tension. Serpentine drives with multiple pulleys and drives with large pulleys are particularly vulnerable to belt tensioning problems resulting from the belt teeth

being only partially engaged in the pulleys during installation. In order to prevent these problems, the belt installation tension should be evenly distributed to all belt spans by rotating the system by hand. After confirming that belt teeth are properly engaged in the pulley grooves, belt tension should be rechecked and verified. Failure to do this may result in an undertensioned condition with the potential for belt ratcheting.

12.3 Belt Take-up

Synchronous belt drives generally require little if any retensioning when used in accordance with proper design procedures. A small amount of belt tension decay can be expected within the first several hours of operation. After this time, the belt tension should remain relatively stable.

12.4 Fixed Center Drives

Designers sometimes attempt to design synchronous belt drive systems without any means of belt adjustment or take-up. This type of system is called a Fixed Center Drive. While this approach is often viewed as being economical, and is simple for assemblers, it often results in troublesome reliability and performance problems in the long run.

The primary pitfall in a fixed center design approach is failure to consider the effects of system tolerance accumulation. Belts and pulleys are manufactured with industry accepted production tolerances. There are limits to the accuracy that the center distance can be maintained on a production basis as well. The potential effects of this tolerance accumulation is as follows:

Low Tension:

Long Belt with Small Pulleys on a Short Center Distance

High Tension:

Short Belt with Large Pulleys on a Long Center Distance

Belt tension in these two cases can vary by a factor of 3 or more with a standard fiberglass tensile cord. This potential variation is great enough to overload bearings and shafting, as well as the belts themselves. The probability of these extremes occurring is a matter of statistics, but however remote the chances may seem, they will occur in a production setting. In power transmission drives, the appearance of either extreme is very likely to impact drive system performance in a negative manner.

The most detrimental aspect of fixed center drives is generally the potentially high tension condition. This condition can be avoided by adjusting the design center distance. A common approach in these designs is to reduce the center distance from the exact calculated value by some small fraction. This results in a drive system that is inherently loose, but one that has much less probability of yielding excessively high shaft loads. **NOTE:** This approach should not be used for power transmission drives since the potentially loose operating conditions could result in accelerated wear and belt ratcheting, even under nominal loading.

There are times when fixed center drive designs can't be avoided. In these cases, the following recommendations will maximize the probability of success.

1. Do not use a fixed center design for power transmission drives. Consider using a fixed center design only for lightly loaded or motion transfer applications.
2. Do not use a fixed center design for drives requiring high motion quality or registration precision.
3. When considering a fixed center design, the center distance must be held as accurately as possible, typically within 0.002" – 0.003" (0.05 mm – 0.08 mm). This accuracy often requires the use of stamped steel framework. Molding processes do not generally have