When identifying a shaft center location, each X-Y coordinate is specified with a measurement in the "X" as well as the "Y" direction. This requires a horizontal and vertical measurement for each shaft center in order to establish a complete coordinate. Either English or Metric units of measurement may be used.

A complete coordinate is specified as follows:

$$(X, Y) \quad \textbf{(13-1)}$$

where: X = measurement along X-axis (horizontal)
Y = measurement along Y-axis (vertical)

In specifying X and Y coordinates for each shaft center, the origin (zero point) must first be chosen as a reference. The driver shaft most often serves this purpose, but any shaft center can be used. Measurements for all remaining shaft centers must be taken from this origin or reference point. The origin is specified as (0, 0).

An example layout of a 5-point drive system is illustrated in **Figure 28**. Here, each of the five shaft centers are located and identified on the X-Y coordinate grid.

When specifying parameters for the movable or adjustable shaft (for belt installation and tensioning), the following approaches are generally used:

Fixed Location: Specify the nominal shaft location coordinate with a movement direction.

Slotted Location: Specify a location coordinate for the beginning of the slot, and a location coordinate for the end of the slot along its path of linear movement.

Pivoted Location: Specify the initial shaft location coordinate along with a pivot point location coordinate and the pivot radius.

Performing belt length and idler movement/positioning calculations by hand can be quite difficult and time consuming. With a complete geometrical drive description, we can make the drive design and layout process quite simple for you.

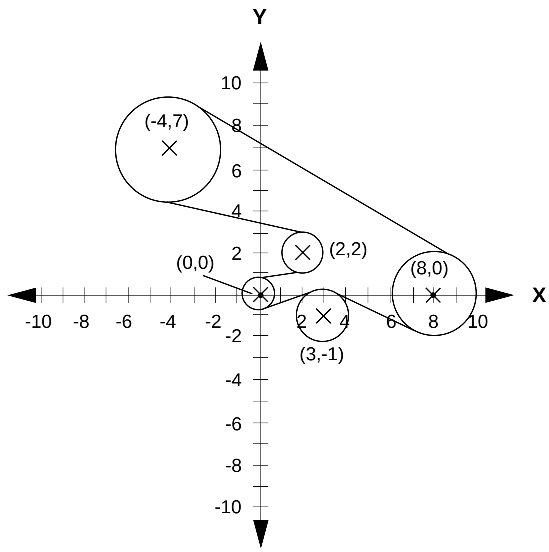

Fig. 28 Example of 5-Point Drive System

SECTION 14 BELT PULL AND BEARING LOADS

Synchronous belt drives are capable of exerting lower shaft loads than V-belt drives in some circumstances. If pre-tensioned according to SDP/SI recommendations for a fully loaded steady state condition, synchronous and V-belt drives will generate comparable shaft loads. If the actual torque loads are reduced and the level of pre-tension remains the same, they will continue to exert comparable shaft loads. In some cases, synchronous belts can be pre-tensioned for less than full loads, under nonsteady state conditions, with reasonable results. Reduced pre-tensioning in synchronous belts can be warranted in a system that operates with uniform loads most of the time, but generates peak loads on an intermittent basis. While V-belt drives require pre-tensioning based upon peak loads to prevent slippage, synchronous drive pre-tensioning can be based upon lower average loads rather than intermittent peak loads, as long as the belt does not ratchet under the peak loads. When the higher peak loads are carried by the synchronous drive, the belt will self-generate tension as needed to carry the load. The process of self-tensioning results in the belt teeth riding out of the pulley grooves as the belt enters the driven pulley on the slack side, resulting in increased belt tooth and pulley wear. As long as peak loads occur intermittently and belts do not ratchet, reduced installation tension will result in reduced average belt pull without serious detrimental effects. Synchronous belts generally require less pretension than V-belts for the same load. They do not require additional installation tension for belt wrap less than 180 degrees on loaded pulleys as V-belt drives do. In most cases, these factors contribute to lower static and dynamic shaft loads in synchronous belt drives.

Designers often wish to calculate how much force a belt drive will exert on the shafting/bearings/framework in order to properly design their system. It is difficult to make accurate belt pull calculations because factors such as torque load variation, installation tension and pulley runout all have a significant influence. Estimations, however, can be made as follows:

14.1 Motion Transfer Drives

Motion transfer drives, by definition, do not carry a significant torque load. As a result, the belt pull is dependent only on the installation tension. Because installation tensions are provided on a per span basis, the total belt pull can be calculated by vector addition.

14.2 Power Transmission Drives

Torque load and installation tension both influence the belt pull in power transmission drives. The level of installation tension influences the dynamic tension ratio of the belt spans. The tension ratio is defined as the tight side (or load carrying) tension T_T divided by the slack side (or nonload carrying) tension T_S. Synchronous belt drives are generally pre-tensioned to operate dynamically at a 5:1 tension ratio in order to provide the best possible performance. After running for a short time, this ratio is known to increase somewhat as the belt runs in and seats with the pulleys, reducing tension. **Equations** (**14-1**) and (**14-2**) can be used to calculate the estimated T_T and T_S tensions assuming a 5:1 tension ratio. T_T and T_S tensions can then be summed into a single vector force and direction.

$$T_T = \frac{2.5\ (Q)}{Pd}\ \text{(lb)} \qquad \textbf{(14-1)}$$

$$T_S = \frac{0.5\ (Q)}{Pd}\ \text{(lb)} \qquad \textbf{(14-2)}$$

where: T_T = Tight side tension (lbs)
T_S = Slack side tension (lbs)
Q = Torque Load (lb•in)
Pd = Pitch diameter (in)

If both direction and magnitude of belt pull are required, the vector sum of T_T and T_S can be found by graphical vector addition as shown in **Figure 29**. T_T and T_S vectors are drawn parallel to the tight and slack sides at a convenient scale. The magnitude and direction of the resultant vector, or belt pull, can then be measured graphically. The same

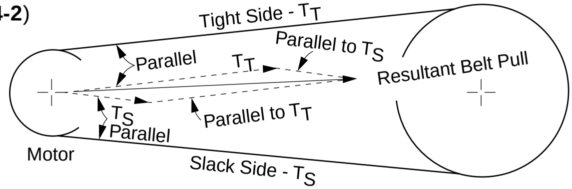

Fig. 29 Belt Pull Vector Diagram

procedures can be used for finding belt pull on the driven shaft. This method can also be used for drives using three or more pulleys or idlers.

For two pulley drives, belt pull on the driver and driven shafts is equal but opposite in direction. For drives using idlers, both magnitude and direction may be different. If only the magnitude of the belt pull is needed in a two pulley drive, use the following procedure:

1. Add T_T and T_S
2. Using the value of $(D - d)/C$ for the drive, find the vector sum correction factor using **Figure 30**. Or, use the known arc of contact on the small pulley, where: D = large diameter
   d = small diameter
   C = center distance
3. Multiply the sum of T_T and T_S by the vector sum correction factor to find the vector sum, or belt pull.

For drives using idlers, either use the graphical method or contact our Application Engineering Department for assistance.

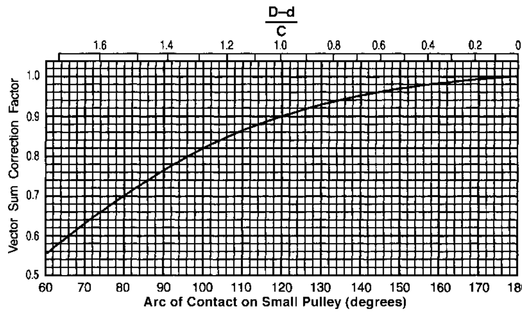

Fig. 30 Vector Sum Correction Factor

14.3 Registration Drives

Synchronous belt drives used for purposes of accurate registration or synchronization generally require the use of higher than normal installation tensions (see section on Belt Tensioning). These drives will operate with higher belt pulls than normal power transmission drives. Belt pull values for these types of applications should be verified experimentally, but can be estimated by adding the installation tension in each belt span vectorially.

14.4 Bearing Load Calculations

In order to find actual bearing loads, it is necessary to know the weights of machine components and the value of all other forces contributing to the load. However, sometimes it helps to know the bearing load contributed by the belt drive alone. The resulting bearing load due to belt pull can be calculated if both bearing spacing with respect to the pulley center and the belt pull are known. For approximate bearing load calculations, machine designers use belt pull and ignore pulley weight forces. If more accurate bearing load calculations are needed, or if the pulley is unusually heavy, the actual shaft load (including pulley weight) should be used.

A. Overhung Pulleys (See **Figure 31**)

$$\text{Load at B} = \frac{\text{Shaft Load} \times (a + b)}{a} \qquad \textbf{(14-3)}$$

$$\text{Load at A} = \frac{\text{Shaft Load} \times b}{a} \qquad \textbf{(14-4)}$$

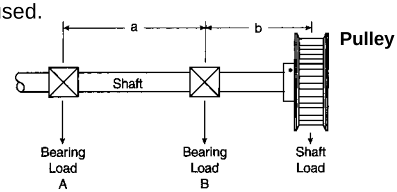

Fig. 31 Overhung Pulley

B. Pulley Between Bearings (See **Figure 32**)

$$\text{Load at D} = \frac{\text{Shaft Load} \times c}{(c + d)} \qquad \textbf{(14-5)}$$

$$\text{Load at C} = \frac{\text{Shaft Load} \times d}{(c + d)} \qquad \textbf{(14-6)}$$

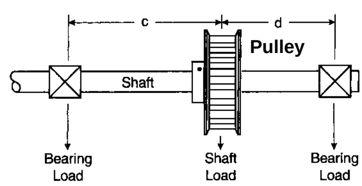

Fig. 32 Pulley Between Bearings