DRIVE RATIO CONSIDERATIONS

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Considering a linear drive, the ball screw lead and drive ratio must be selected to match the rated speed of the motor to the maximum feed rate requirements of the machine axis. In selecting a ratio to use, it should be noted that the available machine thrust is directly related to the ratio used (motor speed being downspeed to the ball screw). Also, the reflected inertia to the motor is reduced by the square of the ratio.

The predominant reflected load inertia will be derived from the components closest to the motor shaft. When belt ratios are used it should be noted that the pulley inertias increase as the fourth power of their diameters. Thus, their reflected inertias to the motor may be excessive if large-diameter pulleys are used. A compromise can be made using a double pulley arrangement with two ratios in series.

For cases where the motor is directly connected to a ball screw, it should be noted that the benefit of increasing the machine slide thrust and reducing the reflected load inertia will not be realized without a ratio. Additionally, the drive resolution and stiffness will be reduced. Drive stiffness is an important consideration in selecting a drive ratio. There are two reasons why an industrial servo drive should have high drive stiffness. First, the servo drive should have sufficient static and dynamic stiffness to be insensitive to load disturbances during motion. In addition, the servo drive must remain stationary or clamped when not in motion. The static stiffness of the servo drive is the equivalent spring constant of the drive. The servo drive stiffness increases as the square of the ratio. The drive ratio also reduces the reflected inertia to the drive motor by the square of the ratio, which is directly related to servo stability. Thus the drive ratio is a very significant factor in sizing a servo drive to an industrial machine.

There are a number of ways a drive ratio can be obtained. First, the use of spur gears has definite disadvantages since it is very difficult to eliminate backlash or lost motion, which has a direct relation to servo position loop stability. Wound-up gear boxes have been used but they are very expensive. However, there are commercial gear boxes available (such as planetary gear boxes) that offer minimum backlash. These gear boxes have very high stiffness but the dynamic stiffness must also be considered since the gear box resonances are often inside the servo position loop and can affect stability. Timing belts and pulleys offer a cheap solution to eliminating backlash. Dynamically they don't display any resonances below approximately 200 Hz. However, as stated previously, the reflected inertia of a pulley is proportional to the fourth power of its diameter. The smaller pulley, with minimal inertia, is usually at the motor and the larger driven pulley is connected to the machine drive lead screw. The larger pulley inertia reflected to the servo motor limits the practical ratio to about 3.

Worm and wheel gear boxes can also be used, and are quite often used with rotary servo drives. The have the advantage of providing larger ratios in a small volume. They can wear and introduce backlash but modern commercial worm/wheel gear boxes have adjustments to eliminate the backlash. These worm/wheel gear boxes have a wide range of efficiencies with the higher ratios having lower efficiencies. These efficiencies must be taken into consideration during the drive sizing. The majority of industrial servo applications using worm/wheel gearing are of this type where the losses are frictional.

As industrial servo drives are applied to machines, there are two general categories. There is a class of applications where the machine positions from one position to another, often referred to as a transfer servo. These servo drives usually have one load to consider which is the frictional loss. The other class of industrial servo has some friction along with other loads doing some work as they position. These loads can result from such things as grinding, forming, drilling, milling, etc. Cutter vibration is one form of load disturbance. The worst-case situation can occur with an interrupted turning cut on a lathe where the loads are severe intermittent tansient steps in loading. Just about all modern industrial servos have an internal torque (current loop) regulator, which minimizes these load disturbances. However, these load disturbances must be sensed by the servo motor and drive. Therefore, it is important that torque disturbances be reflected back to the servomotor through the gearing to maintain the required stiffness. This is not a problem with spur gear boxes or belt/pulley ratios, but worm/wheel gear boxes have a wide range of efficiencies in back-driving the worm/wheel gear box. In commercial worm/wheel gearboxes the back-driving efficiencies can range from a high of about 95% at high speed using small ratios, down to about 70% in the servo positioning speeds. For higher ratios (the usual case with rotary drive positioning servos) the back-driving efficiencies at high speed range from about 40% down to 0% in the servo positioning range. Typical worm/wheel gear box efficiencies vs motor speed and ratio are shown in figure 44. For very low efficiencies a worm/wheel gear box can greatly diminish the servo drive stiffness. Fortunately, most industrial servo applications are not subject to back-driving load disturbances. Some machine tool applications definitely require that load disturbances be sensed by the servo torque loop to maintain the required stiffness.