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Denver, Colorado USA

"Belt Drive Efficiencies"
PA NOTE

Gates continues to receive inquiries dealing with the V-belt drive system efficiency, and how this efficiency relates to energy savings.

Let's first define efficiency (in terms of percent) using the following relationship:

$$1)\ \ Efficiency = \frac{HP\ \ Output}{HP\ \ \ Input}\ x\ 100$$

or

$$2)\ \ Efficiency = \frac{Torque\ Out\ \ x\ \ RPM\ \ Out}{Torque\ In\ \ x\ \ RPM\ \ In}\ x\ 100$$

The first form is the classical definition, the second form is more useful. When discussing the source of energy losses in a belt drive system, it is easier to relate those losses in terms of torque and speed (RPM). For belts, torque losses are due to hysteresis losses incurred from bending stresses imposed as the belt goes around the sheave or pulley. There are also frictional losses at the belt and sheave/pulley interface, and some windage losses as the belt moves through the air. Speed losses are the result of slip and belt creep. These combined energy losses affecting belt efficiency will be released in the form of heat - the belt will run hotter on the drive.

Gates recognizes that drive maintenance can, perhaps more than any other single source, affect belt efficiency, thus energy losses. Misalignment, worn sheave grooves or pulleys and inadequate belt tension can account for a significant part of a belt drive system's inefficiency - as much as 10% reduction in efficiency.

Before addressing the impact of some of the above discussed factors, remember that belt drives are a very efficient transmitter of power. A properly designed and maintained belt drive can yield efficiencies ranging from 95 to 98 percent. Considering some of the added benefits of belts (quiet, clean, versatile, inexpensive, non-lubricated, and low maintenance), they often surpass many other forms of power transmission (gears, chain).

V-Belts vs. Synchronous Belt Efficiency

Many efficiency questions deal specifically with the relationship between V-belts and synchronous belts. Synchronous belts can offer a slight improvement in efficiency over the standard V-belts. Why? Only because they allow no slip (or creep) component (Equation #2) and they exhibit some reduced bending stresses on small diameter pulleys. Efficiency dollar savings, however, may be eliminated by higher initial drive costs for toothed pulleys and belts. Replacement costs would also be higher. Remember, synchronous belts require special drive considerations such as alignment tolerances, shock loads, etc. Let's review other misconceptions frequently encountered between synchronous and V-belt drive operation.

While synchronous belts offer positive engagement between belt teeth and pulley teeth, there exists a frictional component as belt enters and exits pulley. This friction, although minimal, can generate heat - hence energy losses. Same is true of V-belts.

Additionally, slack side tension on a synchronous belt drive is not zero. When transmitting a load, controlled laboratory testing has revealed that synchronous belts, like V-belts, tend to operate at approximately a 5 to 1 tension ratio. Consequently, operating tensions and resultant bearing loads are similar to those for V-belts operating under the same geometry and continuous load condition. For variable load operation, average bearing loads might be lower for a synchronous belt drive.

As with V-belts, synchronous belts require pre-tensioning and tension maintenance, although we would agree that the frequency of retensioning may be less. This is due to minimal belt seating in the pulley grooves, low growth tensile cords and closer manufacturing tolerances associated with synchronous belts. One other, but lesser discussed, consideration is the added reliability of multiple V-belt drives.

Field Measurement of Drive Efficiency

All belt drives exhibit very high efficiencies (when "properly designed" and "maintained"). Attempts to quantify efficiency ratings between different belt drive systems in order to determine energy savings, must be done with caution and an understanding of the parameters being measured. One of the most difficult problems is the method by which efficiency is quantified in the field. In addition to requiring accurate measuring equipment, care must be taken to minimize the affect of drive variables. These can include load, speeds, temperature of drive components (motor, DriveN unit), humidity, air density, wind velocity and others. Quantifying efficiencies is not easily done in a laboratory and is an even more arduous task when done under varying field conditions.

Accurate determination of input horsepower to the drive is possible to measure, particularly with electric motors, using laboratory quality equipment. Determining the horsepower out of the drive is not always a simple task. In a recent situation a change from V-belts to an HTD synchronous belt drive resulted in a 5% increase in efficiency on an air handling drive. However, unsubstantiated data led to questions. The reported energy savings were based on the fact that air volume (cfm) had increased by this same 5%. Since fan load varies to the cube of its speed (rpm), any change in speed ratio (pitch diameters) would have affected fan speed and loading. Additionally, variances in air density and wind velocity would alter motor electrical readings from test to test. Inertia differences (WR^2) between the two drive systems would also affect overall drive performance. Inadequate tension maintenance on the V-belt drive could have been allowing slip and hence affecting fan speed and load. In other words, the "5% increase in efficiency" was likely the result of variances in one or several drive parameters when the belt drive was changed over to synchronous belts, but was not necessarily a function of the change in belt types. It is possible that no efficiency improvement occurred - only a change in speed ratio.

The above example illustrates that measuring efficiency is quite complex, and results obtained can be misleading if not properly analyzed on a sound engineering basis.