EXTENDING EQUIPMENT LIFE: AVOIDING EXCESSIVE OVERHUNG LOAD

With improvements in technology, equipment maintenance is rapidly becoming a "science." Most maintenance personnel are familiar with using vibration sensors, temperature probes and the like.

However, one of the most misunderstood and ignored causes of downtime, broken equipment, and maintenance costs on drive equipment is excessive "overhung load." Overhung load is the force imposed on a shaft when a pinion, sprocket, or sheave is used as a power take-off. For example, a V-belt on a conveyor head-shaft delivers a load to the shaft from the belt that is "hung" on the shaft. The location of the load on the shaft is critical to preserving bearing, seal, gear and housing life.

To visualize overhung load, try this exercise. Imagine holding the end of a baseball bat in one hand with your arm extended out. Keeping the bat horizontal, slide a full book-bag on the opposite end. It is probably very difficult, if not impossible, for you to keep the bat horizontal. However, if you slide the book-bag six inches closer to your hand, the load on your wrist is reduced. As the hanging load gets closer, you will again be able to hold the bat horizontally.

The forces at work here are the same forces that impose loads on the drive shafts of rotating equipment. Namely, overhung load. Excessive overhung load is one of the most prevalent and overlooked causes of drive system rotating equipment failure.

Preventing Failure From Overhung Loads

If you're experiencing unpredictable or unusual equipment failures, excessive overhung load may be the hidden cause. The use of sprockets, gears, flat-belts, V-belts, timing- or toothed-belts on shafts applies an overhung load. Additionally, overhung load can be caused by coupling misalignment and the thermal expansion or contraction of the rotating equipment and the supporting housings. The following steps can help prevent failures from excessive overhung load.

- Calculate the actual overhung load and make sure the load is within the equipment manufacturer's allowable loads.
- Evaluate the operating conditions of the equipment to eliminate hidden overhung loads.
- Evaluate failures of shafts, bearings and couplings and determine a root cause. Give extra attention
- to repeated parts failure.

Excessive overhung load can cause a variety of equipment failures. In extreme cases, a drive's housing can even break (Photo 1). Drive shafts are usually the primary component to fail due to excessive overhung loads. However, keep in mind that excessive overhung load can damage all related components. For example, shaft bearings are especially susceptible to high overhung load. Bearings are designed for specific L10 life hours, and when additional load is applied, the bearing life is drastically shortened. For example, a 25 percent increase in load causes a 50 percent reduction in bearing life. Seals and other critical component parts requiring accurate alignment, such as gear teeth, are also subject to failure because of overhung loads.

Calculating Overhung Load

Clearly, excessive overhung load can cause serious equipment failures and lead to significant downtime. However, it is possible to calculate and anticipate excessive overhung loads. Most equipment is designed by manufacturers to accept certain levels of overhung load. It is excessive overhung load is that causes failures. Manufacturers' catalogs for gear drives or motors specify the acceptable amount of overhung load and how to calculate it.

I should mention here that the best time to calculate overhung load is when specifying and selecting your drive system equipment. Doing this prior to equipment selection will ensure that your equipment will be capable of handling the load it will receive. However, if the overhung load was not considered prior to equipment selection, and if system components are experiencing excessive overhung load symptoms, the calculations can be part of the trouble shooting process.

To calculate overhung load, gear drive manufacturers use the formula:

Overhung Load = 126,000 x HP x FC x LF/ P.D. x RPM

where:
HP = Horsepower
Fc = Load connection factor
Lf = Load location factor
P.D. = Pitch diameter of the sprocket, sheave or gear
RPM = Revolutions per minute of the shaft

The load connection factor, or FC, describes the type of sheave, sprocket, or pinion mounted on the shaft. A flat-belt has relatively high tension in order to transmit the load by friction. A V-belt has moderate tension in order to seat the V-belt and to transmit the load by friction. A timing-belt has some tension and a chain has very little tension since the load is transmitted by the teeth. A pinion or gear has a separating force related to the pressure angle of the tooth form.

Therefore, each connection is given a different factor to account for this additional load.

Flat-belt = 2.50 Pinion or gear = 1.25 V-belt = 1.50 Timing-belt = 1.30 Sprocket = 1.00

The load location factor (LF) is a function of the location of the center of the applied load on the drive shaft. The further out the load is located on the shaft, the greater the moment (force x length). Gear drive manufacturers use a location of one shaft diameter from the shaft seal as unity. Locating the overhung load closer to the seal retainer reduces the moment and decreases the load location factor.

Locating the overhung load at the end of the shaft increases the load location factor and results in an increased moment and an increased overhung load. Therefore, locating the overhung load close to the seal retainer will minimize the overhung load and could turn a potential failure into a successful operation.

Similarly, applying unnecessary excess tension to drive belts or chains can result in unexpected failures. To illustrate how to calculate overhung load, look at this simple conveyor application: A conveyor requiring 115 hp is driven by a gear drive with a low-speed shaft output speed of 68 rpm. A 15-inch pitch diameter, single chain sprocket is mounted on the drive's low-speed shaft with the center line of the load

5.5 inches from the seal cage. The low-speed shaft is 5.5 inches in diameter. Inserting these numbers in the above equation we have:

OHL = 126,000 x 115 x 1.0 x 1.0 = 14,206 pound overhung load 15 x 68

Check the gear drive catalog for the allowable overhung load and make sure your drive can accept the load. If the conveyor has a 15-inch chain sprocket, then the conveyor shaft and pillow block are also subjected to a 14,206 pound overhung load.

Other Causes of Excessive Overhung Loads

Overhung loads as calculated above are not the only cause of loading. Flexible couplings, while designed to allow for some misalignment with limited radial loads, do, in fact, generate loads when misaligned. Severe misalignment will result in overhung loads (Figure 1).

Similarly, gear couplings have friction between the coupling teeth causing loads and elastomer couplings have loads arising from the tension and compression of the rubber element. Alignment of a coupling to the manufacturer's specifications will maintain the loads at a low level. Another cause of high overhung loads that normally goes undetected is thermal expansion. Connected system components that have different heights from base to the centerline of the shaft and housings that have dramatically different operating temperatures are suspect. A difference of 20 inches between housing heights and 100°F in operating temperatures can cause a parallel misalignment of 0.013 inch between two connected shafts (Figure 2). If these values are known, the installation of the equipment can be aligned to account for this movement and the risk of failure from excessive overhung load can be reduced.

A good indication that a drive is experiencing excessive overhung load is when equipment that has been running successfully for a long time suddenly has repeated shaft or bearing failures. Installing a new motor, shaft or bearing without proper alignment leads to excessive misalignment overhung loads.

When to Expect Failure From Excessive Overhung Loads

Repeated failures of coupling elements, either rubber or steel, can be from overhung loads resulting from severe misalignment. This overhung load can lead to more catastrophic shaft or bearing failures.

Overhung load causes high stress at a point such as a keyway, notch or fretted surface. Contact seals can experience immediate leaking if overhung loads cause the shaft to put pressure on one side of the seal. The lack of contact 180 angular degrees away can cause a gap between the shaft and seal.

Gear teeth that show a carrot-shaped wear and pitting across the face width, can be a result of external loading or overhung load misalignment. Remember that all rotating equipment experiences some overhung load. The key is to keep the load within the specific design limits of the equipment. Careful evaluation and recognition of overhung load limits, especially in the specifying and selecting process, and staying within those limits, will lead to long service life of equipment.