HOW BELT DRIVES IMPACT OVERHUNG LOAD
HOW TO IMPROVE WORKER SAFETY AND REDUCE MAINTENANCE

Introduction

Today's belt drive systems are capable of transmitting enormous power in a compact space. What impact does this load-carrying capacity have on the shafts and bearings of speed reducers attached to belt drives? The answer lies in understanding Overhung Load (OHL).

Let's say you replace a chain drive attached to the output shaft of a speed reducer with a synchronous belt drive. All goes well. But then the bearings overheat and fail. What could be the problem?

The cause might be excessive overhung load. Overhung load is a force exerted perpendicular to a shaft beyond the outermost bearing. When that force exceeds the maximum rated capacity for the equipment, shafts and bearings become overloaded and wear out at a higher than normal rate.

Manufacturers of speed reducers publish OHL ratings for each of their products. When designing or retrofitting a belt drive attached to a speed reducer, it falls upon designers to keep within these published OHL limits. Doing so can extend bearing and shaft life considerably.

But how do you know whether your drive design has exceeded the maximum OHL value? Following are some practical guidelines to help you make that determination.

Understanding Overhung Load
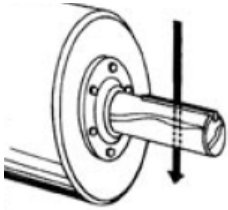
**Figure 1:** Overhung Load

To visualize OHL in simple terms, extend your arm horizontally and imagine a bucket of water draped over your wrist by the handle. You strain to keep your arm in a horizontal position. Now slide the bucket handle up your arm to a point near your shoulder. Keeping your arm horizontal is much easier.

You can liken your arm to the output shaft of a speed reducer, your shoulder to the outermost bearing, and the bucket handle to the pulley or sprocket of a belt drive attached to the shaft. The perpendicular force pulling down on your arm is akin to overhung load (see Figure 1). When the load is excessive, your arm and shoulder eventually give out. The same happens to overloaded shafts and bearings on speed reducers.

CHAIN OR BELT: WHICH GENERATES MORE OHL?
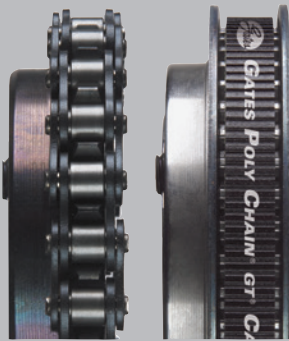
A Gates Poly Chain GT Carbon synchronous belt drive can operate in the same space as roller chain in most applications.

A common misconception is that belt drives always generate more OHL than chain drives because belts need to be wider/larger to match chain's load carrying capacity. This is not the case. Gates Poly Chain® GT® Carbon® synchronous belt drives have a load carrying capacity equivalent to roller chain drives in sizes #35 to #180 and higher, in belt widths as narrow or narrower than chain. Additionally, their sprocket hub widths (length thru bore) are generally equivalent to roller chain. Overall, these belt drives can maintain OHL at the same level as chain.

Overhung load aside, synchronous belt drives offer the designer a number of advantages over roller chain. Belts require no lubrication, and once installed and properly tensioned, a synchronous belt drive never needs retensioning for the life of the drive. Synchronous belt drives can also operate at higher speeds than chain, and deliver a longer life. Compared to a standard roller chain drive, a Poly Chain GT Carbon synchronous belt will last up to 3x longer than chain, and the drive sprockets up to 10x longer. Minimal maintenance and longer life make synchronous belt drives competitive in overall cost to roller chain drives over the life of the drive.

Understanding Overhung Load

Figure 2: Torque

Speed reducers are designed to carry a certain amount of overhung load. Different manufacturers use different formulas to calculate maximum OHL ratings (expressed in pounds or the metric equivalent) for each of their products. No single standard formula exists due to variances in speed reducer shaft sizes, materials of construction, types of bearings, distance between bearings, and other criteria. All the formulas, however, are based on the principle of torque. Torque is defined as a rotational force (pull) around a point, applied at a radius from that point (see Figure 2).

The magnitude of torque generated is directly related to the radius about which it acts. Or, expressed in terms of a belt drive, pull is a function of the sprocket radius and the torque load.
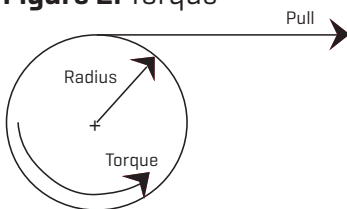
Speed reducer output shafts connected to driven equipment by belt or chain drives experience both torsional (twisting) and radial (bending) loads (see Figure 3). Torsional shaft loads result from the transmitted torque, and affect the level of stress in the output shaft. Radial shaft loads result from the pull exerted by the belt or chain, affecting not only the level of stress in the output shaft, but also the load on the bearings.

Generally speaking, increasing output torque capacity reduces radial load capacity, and thereby the overhung load rating. The same is true in reverse. These combined effects go into the calculations that speed reducer manufacturers use to determine allowable OHL ratings for their individual products.

While OHL calculations are generally based on the actual torque delivered by the speed reducer output shaft, some manufacturers use horsepower and shaft speed, some use shaft torque directly, and others use motor horsepower corrected for speed reducer efficiency.

Whatever the method of calculation, belt or chain sprocket diameter is a critical element in all the various formulas, because it has a direct relationship to OHL. Given the same belt width, doubling the sprocket diameter cuts the OHL in half; while conversely, reducing the sprocket diameter by half doubles the OHL.

Additional Factors

While torque load and sprocket diameter are the major determinants of OHL for a belt drive, three additional factors, or constants (K), are often used to account for specific belt drive conditions unique to each application. They include:

› Application Service Factor (KSF)
› Load Connection Factor (KLCF)
› Load Location Factor (KLLF)

The Application Service Factor (KSF) is a value assigned to various types of driven equipment. Higher factors denote harsher duty cycles and heavier shock loads. These values are typically based on American Gear Manufacturers Association (AGMA) data. **Do not confuse application service factors with the service factors used in the synchronous belt drive design process, which are generally higher.** The Load Connection Factor (KLCF) takes into account the shaft load exerted by various types of drive systems, based on their operating tension ratios. Higher tension ratios result in lower overhung load values, and vice versa. As described in Table 1, a synchronous belt drive operates at a higher tension ratio (8:1) than a V-belt drive (5:1), so it is assigned a lower KLCF factor.

Table 1: AGMA Load Connection Factors with Corresponding Tension Ratios

TYPE OF DRIVE	K AGMA LOAD CONNECTION FACTORS	TOTAL SKUS
Roller Chain	1.00	-
Gear	1.25	-
Synchronous Belt	1.30	8:1
V-Belt	1.50	5:1
V-Ribbed Belt	1.70	4:1
Flat Belt	2.20	2.5:1

The Load Location Factor (KLLF) accounts for the location of the overhung load on the speed reducer output shaft. Varying locations on the shaft will affect shaft bending stresses and bearing loads. For example, a sprocket whose center is located one shaft diameter from the outermost bearing will have a different load location factor than one placed at the midpoint of the shaft (see Figure 4).

While torque load and sheave/sprocket radius are the primary components in calculating OHL for a belt drive, factoring the constants described above into the calculation can double or triple the calculated overhung load for a given application.

Figure 4: Various Locations of Shaft Load on a Speed Reducer Shaft

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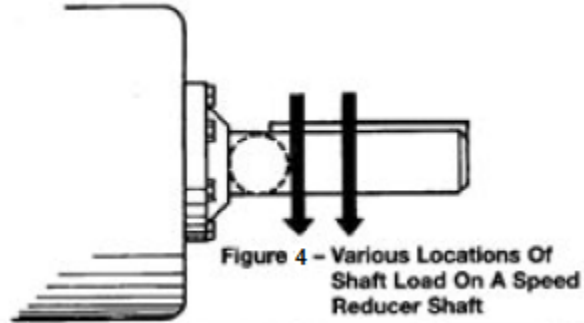
SHAFT AND BEARING LOAD

SHAFT LOAD

Shaft load is a commonly used industry term that describes the load on a shaft exerted by the tension, or pull, of a belt or chain, combined with the weight of the sheave or sprocket that's attached to the shaft. Depending on the orientation of the drive, the sheave/sprocket weight could be adding or subtracting from the force of the tension being applied.
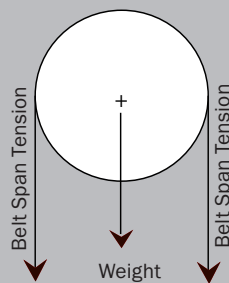
Adding to Belt Span Pull
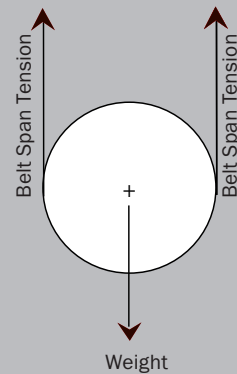
Subtracting from Belt Span Pull

BEARING LOAD

Bearing load is another commonly used term. Weight and tension applied to the shaft exerts a force on the supporting bearings. The amount of this force depends on where the bearings are located on the shaft in relation to the center of the sheave or sprocket, where the pulling force is being applied.

Why Not Use "Belt Pull" Instead of OHL?

Belt pull represents the magnitude of pull (force) that belt drives exert on shafts while transmitting input loads. However, while the primary determinants of both belt pull and OHL are torque and sprocket/sheave radius, belt pull values also include belt span tension ratios and the vector angles resulting from the drive geometry.

By taking into account the tight- and slack-side span tensions (tension ratio) of the belt drive and the arc of contact (or "wrap") between the belt and sprocket, belt pull calculations may return a value that is more conservative than OHL. More importantly, though, OHL must be calculated strictly according to the manufacturer's formula in order to produce a result comparable to the manufacturer's recommended maximum OHL value for a particular product. This ensures that speed reducers are applied within manufacturer's recommendations.

Static belt pull calculations also include static belt tension, which is added to counteract the centrifugal forces of the belt. As a belt rotates rapidly, centrifugal forces throw it outward, neutralizing part of the installation tension. When the drive is stopped, the belt pull (force) is higher because these centrifugal forces are not present. Static belt pull values are generally higher for V-belt drives than for synchronous belt drives.

Belt pull values are typically provided by belt manufacturers. They can be calculated from formulas published in belt drive design manuals, or they can be found in printouts generated by belt drive design software.

The key consideration is that belt pull values and OHL values are calculated differently, and should not be used interchangeably, since the calculations can return significantly different magnitudes.

What's It All Mean?

Keeping overhung load within design limits extends equipment service life. Does that mean designers should calculate OHL values every time they design a belt drive? Not necessarily.

Calculating OHL for a belt drive design for each speed reducer product is a tiresome chore. First, the designer must determine what formula the speed reducer manufacturer used to obtain the maximum allowable OHL. Using that formula, the designer must then calculate how much OHL the belt drive design produces. If it exceeds the manufacturer's limit, the drive must be redesigned to bring the OHL value within the limit, or shaft and bearing overload will result.

Is there an easier way? There is. As a rule of thumb, calculating OHL is critical only when the belt drive pulley or sprocket is smaller than the pulley or sprocket it r eplaces (assuming the original design was sized correctly). If the previous drive did not yield shaft or bearing related problems, then the diameter is probably acceptable.

Designers may be tempted to use smaller, narrower sprockets and belts to reduce cost, eliminate weight, and create a more compact drive. This is a worthwhile objective, and easily achievable given the load carrying capacity of today's synchronous belts. The danger is placing too great an overhung load on the speed reducer's shaft.

By keeping sprockets the same size or larger when converting a drive, designers can generally stay within the allowable OHL limits. By increasing the sprocket diameter 10 percent, shaft and bearing life can be extended even further. And remember, increasing sprocket diameter by 10 percent also doubles belt life.

Remember that key design factors influencing overhung load in a belt drive system include:

› Sprocket diameter
› Belt width
› Sprocket position on the shaft

In greatly simplified terms, one can reduce overhung load by using narrower belts and larger diameter sprockets mounted as close as possible to the outermost bearing on the shaft.

Regarding this last point, sprocket hardware can make a difference. Gates Poly Chain® synchronous belt drives include a unique, left-justified sprocket hub design. Sprocket rims are always flush with the left (bearing) side of the sprocket hubs, rather than centered over the hubs as are most other designs. This configuration allows the sprocket to be mounted closer to the outermost bearing, thereby reducing overhung load.

When it is not possible to use a synchronous drive, Gates Predator® V-Belts are a smart alternative. Predator V-Belts combine limited stretch with extraordinary strength and durability in order to handle pulsating or heavy shock loads. They are designed to resist debris, slip under extreme shock loads, and reduce heat for longer life.

In 2015, Gates introduced Poly Chain ADV™, which is the strongest synchronous belt on the planet. For drives requiring the narrowest widths*, Poly Chain ADV is the solution.

Newer synchronous belt technology drives greater power in dramatically skinnier widths compared to older profiles.

| 8.91x | 6.70x | 2.81x | 1.14x | 1x |
| TIMING | HTD | PowerGrip GT3 | Poly Chain GT Carbon | Poly Chain ADV |
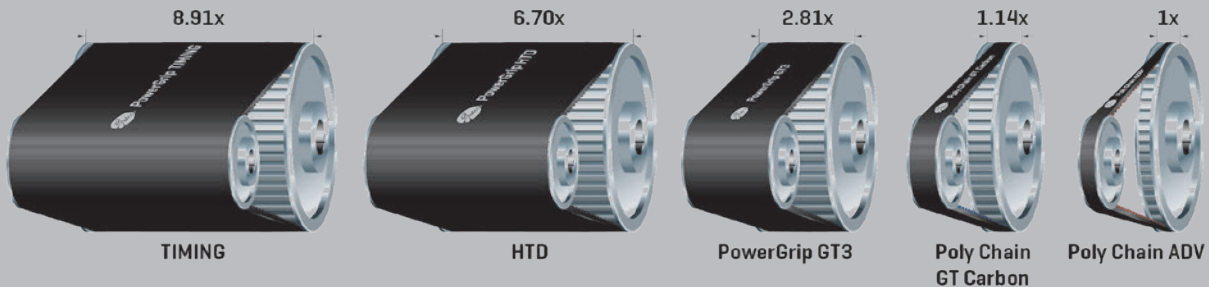
*If your design cannot be converted to a synchronous belt drive system, Predator® V-Belts are a high capacity alternative that can similarly reduce drive width.

Visit www.gates.com/drivedesign for tools and resources to help you with belt drive designs. You can find belt pull calculations in Gates Design Flex® Pro™ and Design Flex® Mobile™ drive design software.

WITH OVER 100 YEARS OF EXPERIENCE, GATES PRODUCTS ARE TRUSTED BY PROFESSIONAL TECHNICIANS AROUND THE WORLD.