Baldor•Dodge Product: Shaft Loading Due to Synchronous Belt Drives

C.O. Engineering - Bearings and PT Components
December 9, 2015

As new, higher capacity synchronous belts are introduced, there is often a misconception that these belts result in higher loading on the shafts to which these drives are attached. And yet, the opposite can be true. This paper will look at the shaft loads produced by synchronous belt drives and compare expected shaft loading due to the new, high capacity Baldor•Dodge HT500 belt versus the existing HT200 belt.

When people talk about shaft loading due to synchronous belt drives, they are usually referring to either belt pull, overhung load, or static shaft load. Belt pull is the dynamic loading due to the HP being transmitted. Consider the formula for belt pull shown below.

$$Belt\ Pull\ [lbs.] = \frac{126{,}000\ X\ HP\ X\ f}{RPM\ X\ PD}$$

Where: HP = Motor horsepower being transmitted.
f = Drive factor based on the type of belt drive.
RPM = RPM of the smaller sprocket.
PD = Pitch diameter of the smaller sprocket.

The drive factor is a constant based on the type of belt drive and is related to the amount of static tension required, by that type of belt drive, to transmit torque. The value of drive factor varies from 1.0 for chain drives to 2.5 for old style, flat belt drives. For all synchronous belt drives, the drive factor is a constant; 1.3. By examining the formula for belt pull, it should be noted that the specific belt rating does not play any role in the magnitude of belt pull. Size for size, an HT200 belt drive would result in the exact same belt pull as an HT500 belt drive. However, because HT500 belts offer significantly higher HP ratings than HT200 belts, it is often possible to reduce the diameter of driver sprockets, which could result in higher belt pull.

Overhung load differs from belt pull in that it takes into account placement of the drive as it relates to the location of supporting bearings. High capacity belt drives, like the HT500, can allow the use of thinner belts. By using a thinner belt, the drive may be located closer to the supporting bearings, resulting in lower overhung load and longer bearing life.

Static shaft load refers to the load on each shaft of a belt drive while the drive is at rest and is a result of the tension imposed on the belt during installation. Refer to the equation for static shaft load below.

$$Static\ Shaft\ Load\ [lbs.] = 2\ X\ Tst\ X\ \sin(\emptyset/2)$$

Where: Tst = Static tension in the belt in pounds.
$\emptyset$ = Arc of contact on the small sprocket.

Looking at the equation above, we find that static shaft load is a function of the static, or installation, tension in the belt due to installation and the angle of contact the belt makes with the smaller sprocket. The (2) in the equation is due to the fact that there are two sides of the belt pulling on each sprocket. Sprocket size for sprocket size, the only variable that could differ between belts of different ratings would be the static tension in the belt. For synchronous belt drives, static tension is calculated using the equation below.

$$Minimum\ Installation\ Tension\ [lbs.] = \frac{20\ X\ HP}{V} + mV^2$$

Where: HP = Motor horsepower being transmitted.
V = Belt speed [feet per minute] / 1000.
m = Belt mass factor.

Again, comparing drives with equal sprocket diameters, belt speed would be the same. Obviously motor horsepower does not change, so let us look at the belt mass factor. The belt mass factor relates to the mass of the belt per unit length. In simple terms the installation tension in a synchronous belt drive is related to the required torque to be transmitted and tension required to keep the belt engaged with the sprocket due to centrifugal forces. Table 1 below shows the belt mass constant for various HT200 and HT500 belts.

HT200			HT500		
Belt Pitch	**Belt Width**	**m**	**Belt Pitch**	**Belt Width**	**m**
8M	20	0.58	8M	12	0.33
	30	0.88		21	0.57
	50	1.46		36	0.97
	85	2.45		62	1.68
14M	40	1.78	14M	20	0.92
	55	2.44		37	1.69
	85	3.77		68	3.11
	115	5.11		90	4.12
	170	7.55		125	5.72

Table 1 – Belt Mass Constant

Trying to compare values for HT200 versus HT500 is somewhat difficult using the table above due to the fact that, for a given belt pitch, belt width offerings vary between the two. However, if we understand that these values are the related to the mass of the belt per unit length, it makes sense that belts of differing width would have a different mass constants. Dividing the mass constant by the belt width gives us a mass per unit width and length and offers a direct comparison. Table 2 shows the results of this calculation.

HT200			HT500		
Belt Pitch	**Belt Width**	**m/Belt Width**	**Belt Pitch**	**Belt Width**	**m/Belt Width**
8M	20	0.03	8M	12	0.03
	30	0.03		21	0.03
	50	0.03		36	0.03
	85	0.03		62	0.03
14M	40	0.044	14M	20	0.046
	55	0.044		37	0.046
	85	0.044		68	0.046
	115	0.044		90	0.046
	170	0.044		125	0.046

Table 2 – Modified Belt Mass Constant

Now comparing HT200 versus HT500 is easy. As you can see, the belt mass constant is virtually identical between the two belt types. Minimum Installation tension, and therefore static shaft load would therefore be nearly identical on drives of the same size. Again, however, because HT500 belts have a much higher HP rating, you can often handle the same amount of HP with a thinner belt, resulting in a minimum installation tension.

So if belt pull, overhung load, and static shaft load associated with high capacity belts can often be similar or less than lower capacity belts, what is different? The answer to that is primarily stiffness. New high capacity synchronous belts have extremely stiff tensile members. Higher stiffness means belts are typically thinner for a given application. These new tensile members are also extremely lightweight. Thinner, lighter belts generally means that, for a given level of tension, the required installation tension frequency is considerably higher on high capacity belts like the HT500, but it has no effect of shaft loading.

Synchronous belt ratings continue to increase due to advances in materials and manufacturing technology. However, that doesn’t mean your shafting has to get larger. Higher capacity belts can allow for reductions in sprocket diameter and/or belt width. Both of these things can result in lower cost. However, care should be taken when converting an existing synchronous drive. In those situations it may be better to think thinner rather than smaller.

For questions about the new Baldor•Dodge HT500 synchronous belt drives, or any of our other industrial power transmission products, visit www.baldor.com or contact one of our application engineers by phone at 864-284-5700 or by email at brgpttechsupport@baldor.abb.com.