



TECHNICAL APPLICATIONS BULLETIN

Motor bearings in Tri-Stack® systems

Direct drive vs. belt drive and their affect on bearing life

The method of powering your exhaust fan is critical to the reliability and longevity of your exhaust system. Basically there are only two drive-train methods used for fans and blowers: direct drive and belt drive. A direct drive system couples the fan impeller directly to the motor shaft via a keyed shaft and/or through bolt. A belt drive system connects the motor to the fan impeller through belts, sheaves, and an impeller shaft. In belt drive systems the impeller shaft is retained by two bearing assemblies, commonly referred to as "pillow block" bearings (Figure 1).

How do these two different drive methods affect system reliability? Since a fan must have a motor to operate, when motors need replacement you are faced with system down time, labor effort, and added costs. In general motor bearings in belt drive fans have life expectancies of **less than half** of their counterparts in direct drive motor/fan configurations. To

applications. What does L₁₀ mean? As it relates to motor bearings, L₁₀ means that in any group of motors, 10 percent will experience a bearing failure within the defined timeframe¹ due to fatigue failure. The main reason for this substantial difference is simply the excessive radial loads on the motor bearings in the V-belt configuration due to belt tension. This tension exerts a lateral force on the motor shaft with resultant unequal radial loading on the motor bearings. On the other hand, without enough belt tension the motor could not efficiently transfer power to the fan impeller.

Five points of failure

Both belt drive and direct drive systems share the motor as a common point of failure. There's a big difference between them from this point on: belt drive systems present five additional points of failure not found in direct drive systems. These include the sheaves, belts, impeller shaft, and inboard/outboard impeller shaft bearings (Figure 2). Obviously the more parts that move, the more parts that will ultimately fail. The pillow block bearings that support the impeller shaft are rated on the same statistical methods as motor bearings; that is, the L₁₀ life expectancy. Remember, too, that these ratings are theoretical and based on statistics. To arrive at this theoretical data many assumptions have been made including proper lubrication, perfect alignment, a clean operating environment, and non-extreme temperatures. Tri-Stack systems have been marketed for a number of years with L₁₀ bearing life of 100,000 hours for our fan motors.

Vibration levels affect bearing life

Actual installations usually vary widely from ideal assumed conditions that were used to establish theoretical values. Also, keep in mind that bearing life expectancy does not in-

clude factors such as motor vibration and excessive thrust loads. Vibration is an overall indicator of design and build quality. Belt drive centrifugal fans with high vibration levels—typically between 1.5 to 3 mils peak-to-peak—are prone to premature bearing failure. The reason is simple: L₁₀ life expectancy assumes little or no vibration when establishing bearing ratings. Unfortunately, "industry standard" vibration levels for typical centrifugal fans are 2-3 mils peak-to-peak depending on motor speed. This high level of vibration is translated directly into the pillow block bearings that hold the impeller shaft and into the motor bearings which are already under uneven radial load due to belt tension.

Of course that is not the only consideration. System effect and aerodynamic turbulence can also cause excessively high axial thrust. This axial force is parallel to the impeller shaft of a belt drive centrifugal fan, which is more likely to suffer from aerodynamic turbulence caused by severe changes in airflow direction required in centrifugal fan inlet housings. This excessive force is directed onto the impeller shaft bearings which are typically not rated for this type of axial thrust loading. The result is excessively high vibration—and ultimately premature impeller shaft bearing failure.



Pillow block bearing failure

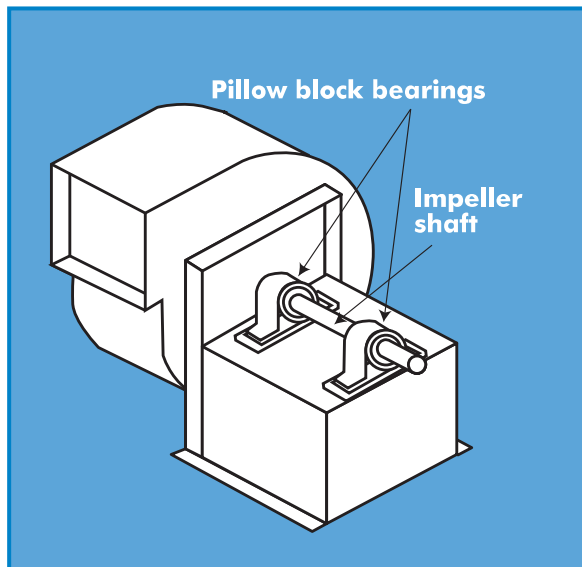


Figure 1

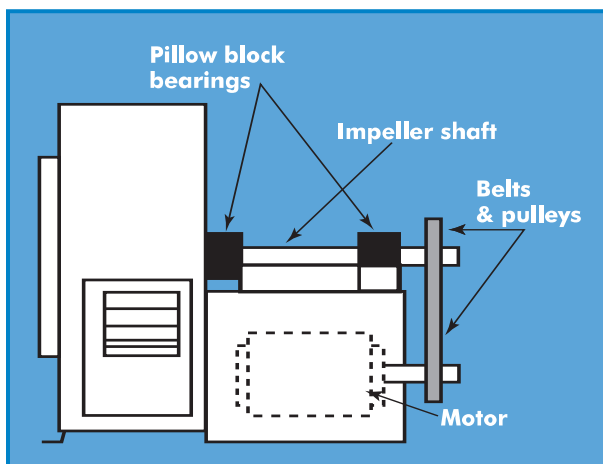


Figure 2

put it another way, you will have to service and/or replace a belt drive motor **more than twice as often** as the same fan with the impeller directly mounted to the motor—over and above recommended routine maintenance procedures. Here's a typical example:

According to most major motor manufacturers, motors on V-belt applications have an L₁₀ life of 40,000 hours compared to an L₁₀ life of 100,000 hours on direct connected

Many belt drive fan manufacturers recommend **against** specifying bearings with L₁₀ 200,000 hour life because they cost more. Instead, they suggest that it would be more cost-effective (and practical) to spend the additional money on maintenance! Where's the logic? Another problem with "over specifying" bearings is the potential for skidding; this condition results from insufficient radial loading allowing the rollers to skid within the race, also ultimately leading to premature bearing failure.

Lubrication considerations

Bearing lubrication (to prevent metal-to-metal contact) is also critical for life extension. This could mean too much, too little, improper lubricants, or some combination.

Metal-to-metal contact of bearing components usually leads to excessive heat built up within the bearing and thus premature failure. Over-extended service intervals typically result in under-lubrication. Finally, pinching of the outer race of a pillow block bearing can occur when the bearing is mounted to a bent or scored impeller shaft. This will result in uneven loading of the bearing in two places as the bearing components travel through the pinched areas.

Consider some of the maintenance headaches associated with these issues. Changing pillow block bearings and impeller shafts on belt drive centrifugal fans requires complete impeller removal (or at least support

of the impeller by removing the fan casing). In any event, maintenance workers are likely to be exposed to the contaminated air stream, thus putting them at risk. This doesn't even account for system down time and added costs.

As you see there are many pitfalls associated with the operation and maintenance of bearings on belt drive equipment. Particularly when used for laboratory workstation fume hood exhaust—where system reliability and worker safety is paramount—belt drive fans just don't make sense. Direct drive fans with low vibration levels offer superior reliability by eliminating the extra set of impeller shaft bearings. Because Tri-Stack fans are direct drive they are not subject to the high radial loads that belt drive systems place on their motor bearings. Tri-Stack systems avoid any potential system effect entering the inlet plenum and fan. Thus the maximum allowable vibration level of a Tri-Stack fan is 0.5 mils peak-to-peak at the motor operating speed. In reality, Tri-Stack fans are delivered to users with dynamic vibration levels significantly lower than 0.5 mils peak-to-peak.

Unlike many other components and systems, fan motor bearings take a particularly tough beating. In fact, according to engineers at SKF USA, Inc., "fan related bearing problems represent a significant portion of failures." There are four main reasons for this, including 1.) high speed; 2.) low radial loads; 3.) high thrust loads, especially in relation to low

radial loads; and, 4.) air flow over the bearings (which may be contaminated).

SKF (**EVOLUTION**—the business and technology magazine; www.skf.com) says that these four characteristics can "interrelate with one another in varying ways." This can result in a bearing application that is prone to failure. Problems can occur quickly and without warning before the machine can be shut down or appropriate action taken.

The issue of vibration as it affects bearing life was discussed previously. According to SKF technical literature, bearings are "universal exciters of vibration." This means that the entire rotating and support system must be considered when analyzing vibrations and not just the bearings. For this reason, you will not likely find centrifugal fan manufacturers stating that fan motor bearing life will meet requirements of L₁₀ or greater; in fact, most centrifugal fan manufacturers state their motor bearing life at about half that of Tri-Stack fan motors.

Operating conditions and fan configurations

Operating conditions of roof exhaust fans—centrifugal and mixed flow impeller types—also influence bearing life. In many cases these fans are subject to high moisture, dirty, and high temperature environments. Under these conditions fan motor bearings require more frequent lubrication. In addition, belt drives themselves have a negative affect on bearing life. For example, a specific combination of pulleys and their mountings can make a substantial difference between a bearing performing for its entire useful life or failing prematurely. *Again, not an issue with direct drive Tri-Stack systems.*

Much literature and documentation is available on the critical subject of bearing lubrication and its affect on bearing life. There are many factors associated with lubrication specifically, such as bearing configuration, how it is used, where it is used, etc.; chances are, an entire volume can be written on this subject alone. To sum up, if you want long term system reliability, minimal maintenance headaches, and worker protection from possible harmful fumes, direct drive fans clearly are a sensible solution.

1. The American Bearing Manufacturers Association (ABMA) defines basic rating life (L₁₀) as the bearing life "associated with a 90% reliability when operating under conventional conditions."

Calculated L₁₀ Bearing Life Direct Drive vs. Belt Drive Fans

Direct Drive:

Motor bearings:

L₁₀ 400,000 Hrs = 45.66 years*

Belt Drive:

Motor bearings (radial load):

L₁₀ 40,000 HRS = 4.57 years or

10 times more frequent chance of motor change-out

Pillow blocks (pair):

L₁₀ 40,000 HRS = 4.57 years or

10 times more frequent bearing and shaft change-out

Overall:

A belt drive fan has a 20 times greater chance of motor or bearing change-out

* Based on actual historical data provided by independent motor manufacturer.



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