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BEARING LIFE IN VIBRATORY EQUIPMENT

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When you look at all of the equipment in a plant from the haul truck that dumps material into the primary feeder hopper to the finishing screen and conveyors that separate your final products, you might start to notice that they all have one critical component in common. Bearings are used in almost every piece of equipment across a plant and at some point, either that piece of equipment will need to be replaced or the bearings needed to make the equipment function will need to be replaced. Either way, this can be really costly or time consuming. Having a better understanding about the concepts behind proper bearing selection can help provide a better understanding on how to make your equipment last longer.

Out of all the equipment in your facility, the piece of equipment that is the harshest on your bearings are your vibratory screens and feeders. In addition to being in a harsh environment, there are a significant amount of changes that can be made to a screen during its life that can drastically affect its bearing life. When your equipment is designed, the theoretical life is calculated on your bearings. Each equipment manufacturer has their own set of policies and standards to determine what an acceptable bearing life is. Screens and feeders are typically designed around the application needs and the best corresponding bearing life available. This is why many manufacturers have different size vibrating units that utilize different bearings. For each application, the screen will weigh different, it will run at a different speed and the number of counterweights needed will vary.

Manufacturers will design your screen to a given bearing life, but what does that mean exactly? When talking about bearing life, one of the more typical terms it is referred to as its L10 life. This is defined by the American Bearing Manufacturers Association (ABMA) as the period of time that 90% of identical bearings will not develop metal fatigue. This metal fatigue is the point of failure for the metal used to construct the bearing and can be noted by the small cracks that will form in the metal.

Essentially, in a perfect environment, the L10 life reflects the minimum life expectancy of the bearing. Keep in mind, this is not a guarantee from either the equipment or bearing manufacturer. While this isn't a guarantee, this

should be an estimate you can rely on. So if your machine was designed with a 30,000 hour L10 and you run 10 hours a day for 5 days a week, you should expect your machine to run for 11½ years without needing its bearings replaced.

While L10 life reflects the minimum life of the bearing, another term that gets thrown around in order to quantify the bearings life, often referred to as the L50 or average life. The L50 life is defined as the amount of time that 50% of identical bearings will not develop metal fatigue. The L50 life is simply 5 times the calculated L10 life. While this is not the proper method according to the ABMA to calculate how long before a bearing will develop metal fatigue, it can be useful to help gauge, as the name implies, how long a bearing should last on average.

The actual equation for calculating L10 life is shown in figure 1. This equation will provide the bearing life in millions of revolutions, where the upper case variable C represents the basic dynamic load rating and the upper case variable P represents the equivalent dynamic bearing load. Both variables are typically given in the English units of a pound. The lower case variable P is the exponent for the life equation, which is either 3 for ball bearings or 10/3 for roller bearings.

$$L_{10} = ({}^{C}/_{P})^{p}$$

Figure 1: Bearing Life Calculation
(In Millions of Revolutions)

Calculating the L10 life in millions of revolutions might not be very practical. After all, it doesn't correlate to any measurable period of time. Simply by multiplying by a conversion factor as shown in figure 2, where n is the speed of the bearing in revolutions per minute, the L10 bearing life will be calculated in hours.

$$L_{10} = \left(\frac{16,666}{n}\right) * \ (C/_P)^p$$

Figure 2: Bearing Life Calculation
(In Hours of Operation)

In order to actually calculate the bearing life, you will need to know the dynamic load rating of the bearings in your machine as well as the radial load being exerted on your bearings. The dynamic load rating is a constant value given by the bearing manufacturer and will vary based on the outside diameter, bore and thickness of your bearing.

While the equipment manufacturer may or may not be willing to provide this information, most bearing manufacturers stamp their company name and part number on the side of the bearing. In the event this is unable to be found, using the bearing dimensions will allow a bearing to be selected in any manufacturers catalog. Since these values are public knowledge, bearing manufacturers have an incentive to be within an acceptable range of each other so there bearing could be used as a suitable replacement. In the case of vibratory equipment, most bearing manufacturers have specific bearings designed for shaker duty operation.

What is important about the dynamic load rating is that this is a constant value determined by the bearing selected. No matter what changes are made to the machine, this value will not change. So when there is an opportunity to comparing and selecting bearings used in your machine, it is important to take this into consideration.

The other variable needed to calculate the bearing life is the equivalent radial load on the bearing. There are a number of different ways this can be calculated, but as shown in figure 3, this can be simplified in terms of the variables on a screen.

The upper case variable S refers to the static moment of the vibrating unit and the upper case variable R refers to the speed of the bearing. Both variables are divided by a constant which is multiplied by the lower case variable b, which represents the number of bearings.

$$P = \left(\frac{S * \ R^2}{35200 * b}\right)$$

Figure 3: Equivalent Dynamic Bearing Load Calculation
(In Pound Force)

The static moment is the centripetal force exerted by a spinning mass at a given distance. It can be easily visualized by thinking about tying a string to an empty water bottle and spinning it around similar to a windmill. When the water bottle is empty, there isn't a lot of force pulling against the string. Now if you were to fill the bottle with water and repeat this process, you will notice a significant increase in force as you spin the bottle around. Your screen operates in the same manner. The more counterweights you add to your vibrator, the more force output the vibrator will generate. This force can be seen by taking the throw or stroke of your machine, but the actual value of the static moment can only be provided by your equipment manufacturer.

Without knowing the exact static moment applied on your bearings, calculating the radial load will be very difficult. What is possibly more important than the actual relationship between the static moment, speed and number of bearings used in your machine? Since the static moment and speed are in the numerator, an increase or decrease in either variable will directly increase or decrease the radial load. The opposite is true for the number of bearings since it is in the denominator. An increase in bearings will decrease the radial load by the same factor. When plugging the radial load into the bearing life equation, you will notice that since it is in the denominator just like the number of bearings, an increase in the radial load will correlate to a decrease in bearing life. So that means that increasing your static moment or speed will decrease your bearing life while decreasing your static moment or speed will increase your bearing life.

Aside from the relationship between the variables, it is also important to understand that increasing the bearing speed or the number of bearings have some hidden ramifications. Since the bearing speed is squared, the change to the bearing life will happen twice as fast. Additionally, when converting the L10 bearing life from millions of revolutions to hours, the conversion factor includes the speed of the bearing in the denominator which will inversely affect your bearing life. Say you want to change your screen or feeder speed by 10%, which roughly equates to a standard sheave change. This would increase the vibrating unit bearing speed from at 825 RPM to 900 RPM. Running through the L10 bearing life calculation will show that a 10% increase in bearing speed will result in a 50% decrease in bearing life.

Typically, when you want to increase your bearing life and can't increase you're bearing capacity any more, the easiest option might be to increase the number of bearings. Since increasing the number of bearings usually happens in multiples of 2, it's easy to see that upgrading from a single shaft machine to a double shaft machine will increase your bearing life by a factor of 10. Increasing from a single shaft machine to a triple shaft machine would in turn increase your bearing life by a factor of 40. While on paper this looks like the perfect solution to make your bearings last forever, the reality is that when you increase the number of bearings in your machine, your static moment increases by a similar factor. The increase in bearings means that there are a significant amount of components that need to be added to your machine, increase its overall weight which will require more static moment to achieve the throw your application needs. So while increasing the number of bearings in your machine will increase the bearing life, it might not be as dramatic of an increase as you might think. The same concept applies to your screen when adding features such as liners. While they will help increase the overall life you're your machine, the added weights will pay a toll on your bearing life as it will increase the overall weight of your machine, requiring more static moment operate.

While understanding the bearing life calculation and how changes you make can positively or negatively affect it is beneficial, it is also important to understand that a very small percentage of bearings fail because they have reached their life expectancy. A significant amount of bearings will fail due to improper lubrication, contamination or other causes. Setting up a proper maintenance schedule per your equipment manufacturer's recommendations is the best way to ensure your bearings reach their full life expectancy. Routinely inspect your machine, adding grease or changing oil when necessary. If your bearings are oil lubricated, work with a local and reputable oil analysis lab in order to help determine the condition of the bearings and oil.

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