Look to System Reliability When Selecting Bearing Protection

Fewer things to fail translate into fewer failures.

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Over the last 30 years, bearing protection has emerged as prime territory for increasing overall rotating equipment reliability. With metallurgy, tribology and bearing design having progressed to the point where further enhancements to bearings and lubrication will be incremental at best, the deceptively simple task of retaining lubricant in and contamination from the bearing housing remains the last zone for achieving significant gains in reliability.

Reliability defined

Though often used carelessly and inaccurately, the term "reliability" is really the mathematical probability that a device will "live" and perform for some time period. Quite simply, it's the odds that a device will work for a given interval. The practice of reliability is all about identifying and implementing the products, practices and procedures that put those odds more in your favor.

To understand how reliability is calculated, we first must look at the product life cycle.

Product life is customarily described by the classic saddle or "bathtub" curve (Fig. 1), which is broken into three distinct areas.

The first area describes the product's infant mortality or "bad actor" phase. That is, whenever a population of devices is applied, there will initially be a greater rate of failure. Improper installation, defective products or other non-normal errors will manifest themselves as premature failures. These are the failures that manufacturers traditionally hope will be discovered during shakedowns, burn-ins and test runs.

The second area of the product life-cycle curve, after all the bad actors have been eliminated, is an area where the failure rate as a function of time will be more or less constant. This may be described as the useful product life phase.

The third and last area is the wear-out phase. Here again we will see an increase in the failure rate as devices reach their maximum life expectancy.

Reliability is calculated only on the middle or constant-failure-rate area of the product life cycle. To obtain an accurate and comparable measure of reliability, we need to study products or devices before they wear out naturally–*and after the bad actors and damaged and defective devices have been shaken out of the population.*

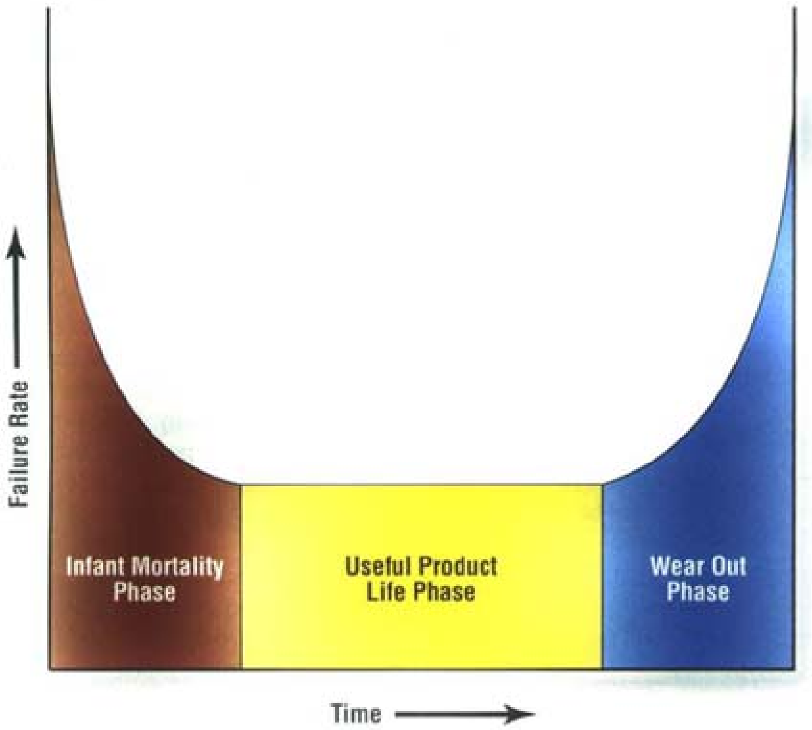

Fig. 1. **Classic saddle or "bathtub" curve is used to describe product life.**

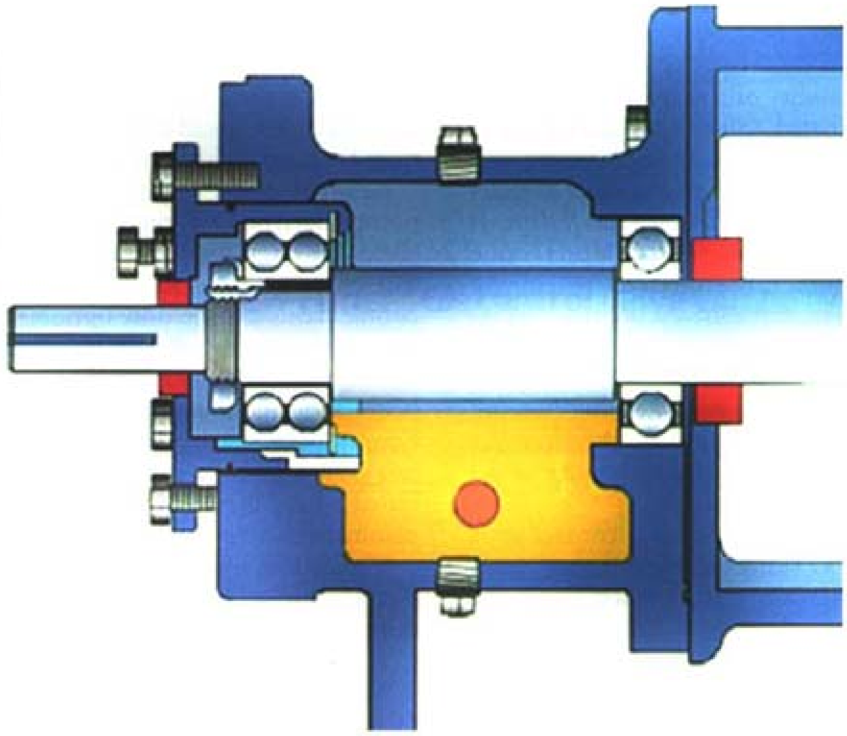

Fig. 2. In the pump bearing housing shown here, failure of either the radial or thrust bearing or radial or thrust seal will fail the system.

The formula for reliability as a function of time, Re(t), is:

$$Re\,(t) = e^{-\lambda(t)}$$

Where:

The failure rate λ is the total number of device failures divided by the cumulative amount of run time for all devices.

The value *(t)* is time for which we wish to know the probability of device survival.

The inverse of the failure rate, 1/λ, is the mean time between failures, or, the more commonly used MTBF.

Example:
A total of 670 failures were observed in a population of 3000 pumps over a period of 365 days. What is the probability of a pump lasting for 250 days?

The Failure rate λ is:

$$\lambda = \frac{670}{(3000)(365)} = 0.0006119$$

(Note: MTBF = 1/λ = 1/0.0006119 = 1634 pump-days.)

Reliability then is:

$$Re\,(t) = e^{-00061119(250)} = 0.858$$

This means there is an 86 percent chance that the pump in this population will survive 250 days. Keep in mind this also means there is a 14 percent chance that the pump will fail before that time. In other words, given a population of 3000 pumps, 420 pumps would be expected to fail prematurely.

System reliability

When the failure of any single device will result in failure of the total system, also called a *series system*, overall system reliability is calculated by multiplying the respective reliability of each individual component together. The failure of any individual component fails the entire system. This is analogous to a chain only being as strong as its weakest link. It's a simple and important concept, but one

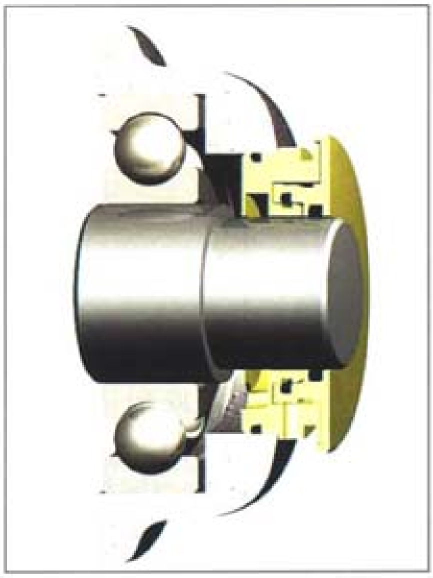

Fig.3. A typical bearing isolater *(courtesy Inpro/Seal Company)*

Fig. 4. Finite-life lip or face contact seals can be easily damaged during installation.

that all-to-often remains overlooked.

For example, in the pump bearing housing shown in Fig. 2, the failure of either the radial or thrust bearing or radial or thrust seal will fail the system. *(There are other components to consider as well, but to simplify this example we will use only four.)*

The total reliability then is defined as:

$$\text{Re}\ (system) = \text{Re}_{(Thrust\ Seal)}\ x\ \text{Re}_{(Thrust\ Bearing)}$$
$$x\ \text{Re}_{(Radial\ Bearing)}\ x\ \text{Re}_{(Readidal\ Seal)}$$

If each individual component had a reliability of 0.95, the total system reliability then is reduced to:

$$\text{Re}\ (system) = 0.95 \text{ x } 0.95 \text{ x } 0.95 \text{ x } 0.95$$
$$= 0.81$$

No matter what is done to increase the reliability of individual components, in a system all the respective reliabilities are multiplied together. The key to system reliability then is not just to increase component reliability, but also to reduce the total number of multipliers in the reliability calculation.

The fewer reliability numbers we have to multiply together, the greater our overall system reliability. This is where selecting the right type of bearing protection will pay huge dividends. Non-contact, non-wearing bearing isolators have an infinite design life, or a reliability value Re = 1.0. If we eliminate finite-life contact-type seals from the foregoing example, the system reliability becomes:

$$\text{Re}\ (system) = 0.95 \text{ x } 0.95 \text{ x } 1.0 \text{ x } 1.0$$
$$= 0.90$$

Contact seals cannot have an Re value of 1.0 since they have a 100 percent failure rate over time.

Increasing system reliability

Experience in a wide range of industrial settings over several decades has demonstrated that installing bearing isolators (Fig. 3) on a population of rotating equipment will greatly increase system reliability.

The ability of the bearing isolator to retain lubricant and expel contaminants is certainly important, but the mere fact that components with a life expectancy have been replaced by components with *no life- expectancy limitation* cannot be discounted.

There are fewer failures when bearing isolators are used, not only because they are doing a better job of protecting the bearings, but also because the probability of a seal failure has been eliminated. *(Since a seal failure necessarily causes bearing failure, many system failures are misdiagnosed as bearing failures when a seal failure is causal.)* A bearing isolator's value becomes more obvious when you recall from the life-cycle curve that we are only considering the useful life phase when calculating reliability. Non-contact, non-wearing bearing isolators also eliminate the wear-out and infant mortality phases of all finite-life products.

Finite-life lip or face contact seals (Fig. 4) easily can be damaged upon installation and, consequently, be dealt a shortened life expectancy. Unfortunately, damage or manufacturing defects also may not be readily apparent from visual observation during system assembly. A finite -life contact seal may have little life left after installation, which will place that device in the precarious infant mortality phase of the life-cycle curve.

Cold hard facts

Anything with a life expectancy can easily have that life shortened. There is much you can do to shorten the life of any device or component. Conversely, there is little you can do to make any device or component last beyond its life expectancy.

The best you can hope for is to try and keep the product out of the infant mortality life-cycle phase. All contact seals will fail. *When* is simply a matter of time and probability.

Failure analysis seminars are usually quite popular. (Interestingly, failure analysis manuals are often larger than application guides.) Yet, while failure analysis is important, the lessons learned will only help increase the reliability multipliers, not eliminate them, and perhaps reduce the number of devices falling into the infant mortality phase. To eliminate the probability of a seal failure, and thus a system failure, you would need to eliminate finite-life contact seals from the equation.

Granted, given a system's design, non-contact, non-wearing bearing isolators may not be a viable option. There are instances where finite-life contact seals are the only option. In those cases, living with an increased number of reliability multipliers, and hence a lowered system reliability, becomes a necessity. In most cases, however, contact seals and their associated reliability multipliers should be eliminated wherever possible.

The bottom line is really quite simple: Want fewer failures? Install fewer things that fail.

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