

## How Subsurface Fatigue Leads to Bearing Failure

Andy Page  
Principal  
GP Allied

The health of bearings is integral to the overall health of machines and to the overall health of a plant. Bearings could be seen as the “sacrificial lambs” of a rotating machine. For many machines, their relationship to bearings is much like that of batteries to a remote control. As long as they are replaced before they fail and/or cause damage to other parts, the machine should enjoy a decent lifespan. Of course bearings are not the only things that wear, fatigue, and fail, but they represent the lion’s share of the primary causes of failures to many rotating machines.

However, many common misconceptions—especially incorrect assumptions about how long a bearing should last and what constitutes “appropriate” wear—result in bearings wearing out too quickly (or, conversely, being replaced when they should not be). For example, some maintenance personnel follow a preset schedule under which bearings are replaced every 1 or 2 years, or they believe that bearings that only last 1-2 years have “done their job.”

There are much better ways to determine when a bearing needs to be replaced, though, and one of the most reliable methods lies in identifying the presence of subsurface fatigue.

Through understanding the factors that contribute to and accelerate this process, plant personnel will gain a more realistic expectation of bearing health and lifecycles and will be well prepared to move from reactive maintenance to condition-based maintenance and thus greater reliability.

### **The Role of Lubrication**

To understand how subsurface fatigue leads to bearing faults, we must first understand the role of lubrication. Is the correct lubricant or grease being used? Is it being stored correctly? Is the lubricant free of contamination? If the answer to any of these questions is “no,” then the bearing is going to find itself in trouble.

When the right type and amount of lubricant are being used, then the roller never touches the race. However, if the wrong type or amount is used, it will result in bearing damage. Here’s how.

Lubricants and greases are not compressible, but an increase in pressure does result in a change to one of the physical properties of the lubricant...its viscosity. So for any lubricant, as pressure goes up, viscosity goes up: not just a little, but *exponentially*. When the pressure reaches 200,000 psi, the lubricant actually becomes harder than the metal in the bearing. As the lubrication molecule enters the load zone, pressure builds on it. Since it resists compression, an oil wedge forms.

As the oil wedge passes through the load zone, the face of the race, which is under the roller and beneath the oil wedge, is compressed. As the wedge travels past this location, the face of the race decompresses.

The force beneath the ball or roller can be displayed via the Hertzian stress model. (Graphic 1,2) The force directly beneath the roller is the highest, while the force to the left and right of the roller is less intense. As a result, each roller carries with it a "stress cone" as it rotates around the inner race and inside the outer race, specifically as it traverses through the load zone.

As the rollers continue through the load zone, they carry that stress concentration with them, and the cycle of compression and release continues until the material reaches its fatigue-load limits. Imagine repeatedly bending a coat hanger or "unbreakable" comb. Eventually, the compression/release cycle will begin to compromise the integrity of the material, and it will break.

Looking at the calculations below, consider how many times this cycle of compression and release happens in one day.

- Take a 1,775 rpm shaft running at around 29.6 rotation cycles per second.
- For example, for a given bearing, in one rotation of the inner race, 8.193 balls or rollers will pass a single spot.

Therefore, in a 24-hour period, that location in the load zone is compressed and relieved 21 million times, and over the course of a year, it is compressed and relieved 7.6 *billion* times.

Now, consider that bearings should last 8 to 12 years, and multiply 7.6 billion times 8 (a low estimate for bearing life), and the number of compression/relief cycles is astronomical in scale. Eventually, the bearing reaches its fatigue load limit. The first manifestation of this gradual decay is called *subsurface fatigue*.

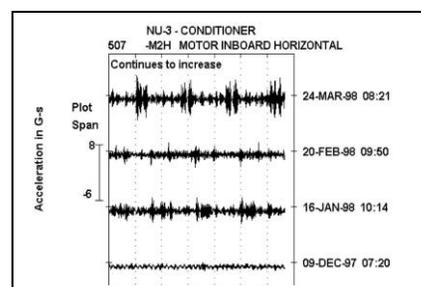
### The First Sign of Trouble

Subsurface fatigue is exactly what it sounds like: small cracks, generally around 5-6 microns deep, which can be seen with the naked eye once the bearing is removed, disassembled, and cleaned. The evidence of this subsurface fatigue is the discoloration seen in the outer and inner track. Subsurface fatigue is the first sign that a bearing is on its way to fatigue failure.

Over time, these microscopic cracks will eventually begin to connect, resulting in "advanced" subsurface fatigue.

While this wear and tear still cannot be seen or felt, the energy given off by the fatigue is ultra-high frequency, so ultrasound instrumentation picks it up very well. Vibration analysis also is helpful in identifying this phenomenon, as can be seen in this analysis, which shows the fatigue becoming more advanced over a period of three months.

As subsurface fatigue progresses, the microscopic cracks eventually connect, and wide, thin chunks of metal start popping out of the race. At this point, the damage becomes palpable and audible. This is called *spalling*.



Once spalling occurs, it accelerates very quickly. The contact area becomes much larger, and the pressure becomes more volatile. As a result, it is difficult for the lubricant wedge to maintain its shape, and surfaces can no longer remain separate. The spalling then accelerates quite quickly.

Anything that affects the radial and axial load of the drive train accelerates this process, including the following:

- Imbalance
- Misalignment
- Over-tightened V belts
- Broken bolts
- Loose bolts
- Broken welds
- Overloading machines
- Over-speeding machines
- Shock loading machines

Seeing all the trouble that subsurface fatigue causes, it's easy to see the business case for implementing a plan to detect and prevent it. Ultrasound, oil analysis, vibration analysis, infrared, and motor circuit analysis are all helpful in this endeavor. No one inspection method can detect everything, but in concert, the technologies are very effective at finding the early warning signs of bearing failure.

## **Conclusion**

Bearings are not meant to last forever, and subsurface fatigue and other failure mechanisms are inevitable. However, by using the proper mix of technologies to detect such failure mechanisms—and, more important—understanding how important it is to catch defects early, plants can enjoy a more reliable and predictable maintenance schedule and avoid costly premature bearing replacement.

For more information, resources, and solutions regarding subsurface fatigue and other ways bearings fail, visit [www.uesystems.com](http://www.uesystems.com) and [www.gpallied.com](http://www.gpallied.com).

## **[SIDEBAR]**

### **So, How Long Should Bearings Last**

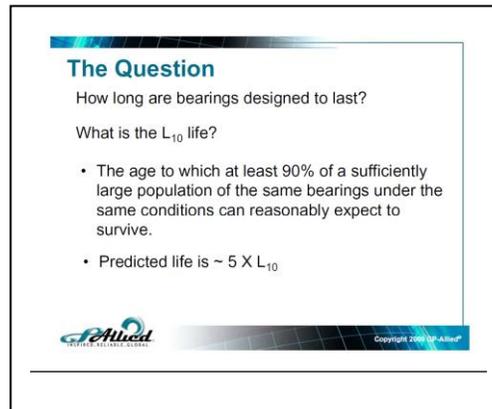
As was stated at the beginning of this article, bearings are sometimes replaced when they are still perfectly functional. This is partly because many maintenance personnel do not understand how long a bearing should reasonably be expected to last, presenting a formidable barrier to reliability and optimization. Were you to ask a roomful of professionals, “How long do bearings last?” you would get a wide variety of answers, ranging from a couple of years to indefinitely.

When properly maintained, most bearings should last approximately 8 to 12 years. Bearing lifespans are represented through a concept called the  $L_{10}$  life.

The  $L_{10}$  life is the age to which approximately 90 percent of bearings of a sufficiently large population under similar conditions will survive. The “10” in  $L_{10}$  refers to the 10 percent of bearings that will not reach the  $L_{10}$  life.

The life of a bearing should be approximately 5 times the calculated  $L_{10}$  life (again, as a solid rule of thumb, usually around 8 to 12 years). Check your manufacturer’s specifications for further information and to get a better idea of how long your bearings should reasonably last.

[END SIDEBAR]



**The Question**

How long are bearings designed to last?

What is the  $L_{10}$  life?

- The age to which at least 90% of a sufficiently large population of the same bearings under the same conditions can reasonably expect to survive.
- Predicted life is  $\sim 5 \times L_{10}$

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Contact:

UE Systems, Inc.  
14 Hayes Street  
Elmsford, NY 10523  
PH: 800-223-1325, Int: +914-592-1220  
E: [info@uesystems.com](mailto:info@uesystems.com)  
W: <http://www.uesystems.com>