The Science of Radial Shaft Seals

SKF Product Investigation Center Troubleshoots Critical Rotating Equipment Applications with Analysis, Research and Testing Procedures

Matthew Jaster, Senior Editor

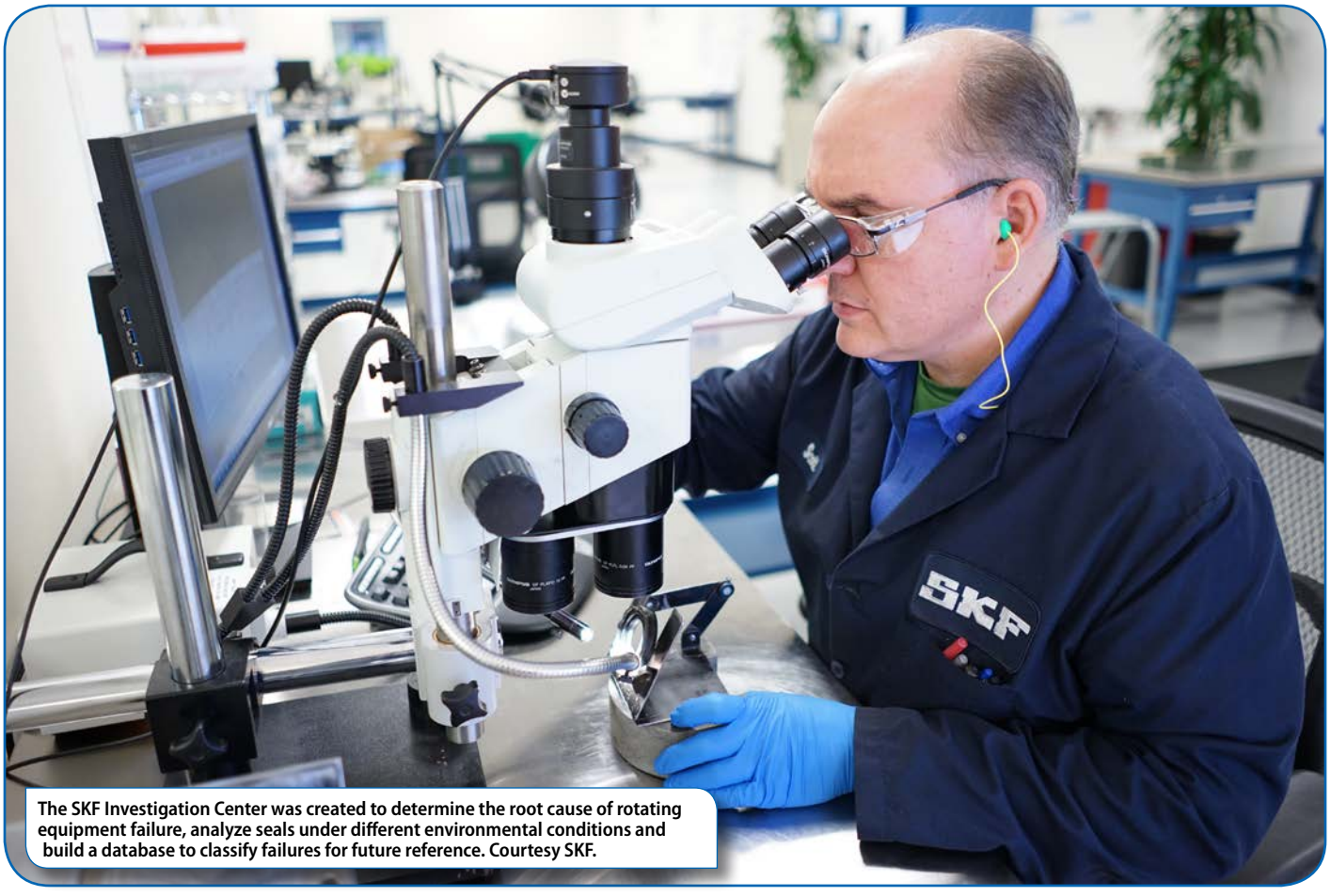
It's hardly a stretch of the imagination to walk into the SKF Product Investigation Center (42 miles northwest of Chicago) and think about a crime lab. Though the employees here have titles like material development engineer, investigation administrator or application engineer, they're all detectives in the grand scheme of things. Instead of solving crimes, they're tasked with determining why seals fail. They take this data and share it throughout SKF in order to make their products safer and more efficient. It's also a pivotal step in developing new seal technologies.

Bryan Uncapher, seal business development at SKF, says that most rotating equipment will work until bearing failure, which is greatly related to seal performance. "If it is a grease application, external contamination can enter the bearing and cause corrosion or wear, which will lead to system failure or stoppage. If oil is the main lubrication, the oil will eventually leak out, which causes metal to metal contact, which also leads to bearing failure. This can result in a great amount of repair and loss performance expense for the operator," he said.

The investigation center was created to determine the root cause of rotating equipment failure, analyze how the seal reacts under certain environmental conditions and build a database (or backlog) to classify typical failures for future reference. Here, in a maze of testing stations, analytical labs and manufacturing work cells, the former Chicago Rawhide headquarters (see sidebar) has the look and feel of a highly-technical research center where seal failure is literally put under the microscope.

The Investigation Process

Seals have a crucial impact on system performance. They need to provide a minimum amount of friction and wear while maintaining maximum protection from external environmental contamination and retain bearing lubrication under a variety of unique and hazardous conditions. When they fail,



The SKF Investigation Center was created to determine the root cause of rotating equipment failure, analyze seals under different environmental conditions and build a database to classify failures for future reference. Courtesy SKF.

machines, operators and components are all at risk.

The SKF Product Investigation Center has a very thorough (and organized) procedure to examine each seal case.

"The advantage of our new product investigation system is that it offers a systematic approach to define the root cause of failure and identify possible solutions. It ensures that our application engineers can collect the critical field data and work according to a scientific process with our analytical, chemical and validation labs to identity the causes of failure and offer the right solution for our customers," said Bouchra Le Hir, global product testing & investigation manager at SKF.

So, what exactly happens when a customer sends a seal into the investigation center? First, it's the job of application engineers like Mark Haughey to examine the seals, collect all the pertinent information (any damage analysis, application history, etc.), conduct initial inspections and report key findings.

This includes examining the packaging materials the seal was shipped in as well as checking for any contaminations. The engineers will also look to see if the damage was simply a case where the operator dropped the seal on the floor prior to installation (which happens more than you think).

Most of this initial research is considered a Level 0 investigation.

A Level 1 investigation includes taking photos of the seal (courtesy of a light box assembly created by Philip Sajor), and an initial comprehensive bearing seal inspection. Dave Zimmerman, investigation manager, is one of the first in the building to provide this detailed inspection.

Zimmerman begins with a small pile of plastic bags at his workstation. These bags hold various seals from industries like automotive, off-highway equipment, steel mills, rail, and mining applications (to name a few). Each seal tells a different story and provides Zimmerman with clues as to why the seal failed in the first place. There are several different causes of seal failure including manufacturing defects, assembly errors, compatibility with the lubrication or working fluid, and/or system design flaws.

Seal failure can sometimes be determined by simply taking the seal out of the plastic bag and examining it with the naked eye. Other cases might need a combination of microscopes, photographic images, hand tools and 38 years of bearing seal experience to help solve the mystery. Zimmerman has all four.

A seal customer may submit a performance claim (citing the seal product itself as the cause of failure) on many seals that come across Zimmerman's desk even though it shows obvious signs that it was damaged by the installer.

Zimmerman said one of the most common modes of failure is improper installation, where the seal case is hit with a metal socket which changes contact forces, backward installation, misalignment, and cut lips. What is very interesting is that operation errors are one of the easiest methods to detect if samples are provided.

If that's still not enough, the seal moves to Sajor and the SKF measurement team in a temperature-controlled room for a variety of evaluations. Then it is moved to the next levels of inspection (Level 2: the analytical lab with Albrecht Becker) and (Level 3: Terry Kirschbaum, test lab validation).

Once you get into Level 2 and Level 3, the seal is put through a series of intense chemical and environmental tests for further analysis. It truly is a team-based process where the slightest errors or miscommunication could hinder the outcome.

"We're in constant contact with everyone involved in a particular investigation," Kirschbaum said. "You have to have all the information in front of you in order to succeed and this information needs to be as accurate as possible. Communication is so important, it might be as simple as making sure metric and inch conversions are consistent."

These investigations come with a laundry list of challenges, according to Uncapher, though meeting these challenges is part of what makes the investigative work so interesting.

"Sometimes determining the mode

of seal failure is difficult when limited information is supplied, as it is critical to know the hours of operation, application temperature from oil and environment (min & max), operating speed, age of product installed being able to distinguish between damage from seal removal versus application issues and manufacturing defects," he said. "Also, when working with rubber seals it can be difficult to differentiate from manufacturing defects (process contamination and mishandling) versus application impact."

The key is having the right amount of experience and the right equipment to do the job.

"SKF meets these various challenges with equipment for visual inspection (microscopes), CMM dimensional measuring, and chemical analysis tools (FT-IR Fourier transform infrared spectroscopy and X-ray fluorescence), thermal analysis (thermal gravimetric analysis, and DSC Differential scanning calorimetry) and physical analysis tools (hardness, tension, compression, wear and fatigue testers)," Le Hir said.

The Benefits of Seal Investigation

The obvious benefit of product investigation is for SKF to develop a positive working relationship with its customer base. By providing quick, efficient solutions for their manufacturing challenges, they will continue to utilize SKF products and services in the future.

"We're working first and foremost for our customers," said Uncapher. "But there is plenty of research and analysis conducted here that benefits us internally as well."

Often, a customer will make upgrades to their machines including new additives to their lubrication, more horsepower, faster speeds and higher pressures and temperatures. "There are many cases where the customer fails to check with the seal manufacturer. Having the ability to understand the cause of failure and product limitations allows us to develop new seal configurations in the future," Uncapher said.

And this is why the work conducted here is so vital, according to Le Hir. "Each case involves a learning curve. We're taking this field research and applying it to future products that will make them better. It's an educational opportunity for our staff as well as our customers."

For example, Zimmerman discussed earlier that one of the most common modes of failure is improper installation. As a result, SKF has developed a line of installation tools for its Scot Seal Products to increase the robustness of the supporting structure and allow for easier installation in latter generations.

SKF is also currently working on the project to collect all typical failures and classify them, and at the same time develop a user-friendly mobile application. "This will be beneficial for our customers for understanding our investigations and visualizing the scenarios of failures," Uncapher said.

Working to Improve

One of the challenges mentioned regarding seal investigation was the lack of information available on the entire mechanical system. In many circumstances, the application engineer is working with very a limited amount of data and in most cases just the seal itself which begs a different question: Would it benefit the investigation center to look at the entire system and not just the seals?

Uncapher said that SKF would need a much larger receiving and tear down area as a bearing and seal might be part of large and heavy system. "We are able to measure and inspect up to 2.5 tons in Elgin and have other facilities in SKF which can accept much large items, but normally this is prohibited given the transportation costs and asset value. Additionally, we are able to perform level 0 & 1 inspections for bearings."

He continues, "Very often customers do not have spare housing and shafts and must reassemble new bearings and seals and continue production. This is why we rely on our field support team of application engineers and industrial specialists to collect the critical field data."

The plan in Elgin is to further implement computer simulation and modeling for seals. The investigation center and test lab allow for validation of existing models and creation of new modeling formulas. "We are planning to add a microscope with advanced features and also a Scanning Electron Microscope (SEM) to go in-depth in the investigations and analysis," Le Hir said. "Currently, we're using an SEM located in another SKF facility."

Without doubt, the success of the investigation team in Elgin will rest on the capable shoulders of the women and men behind the scenes, testing products, analyzing materials and providing data that can be used to make seal products and technologies better and more reliable in the future.

"It is very difficult to find experts in this field since it is not something that can solely come from education, but it is more of combination of higher education and years of experience," Le Hir added. "The more experts we have with investigation experience, the closer we get to the root cause of failures and can implement the corrective action." **PTE**

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Each case involves a learning curve at the SKF Investigation Center where data can be applied to future seal design. Courtesy SKF.

SKF Seals

A MANUFACTURING HISTORY

During the Great Chicago Fire (1871) every establishment working with leather in the city of Chicago was destroyed. In the next few years, Chicago moved very rapidly to "Rise up Again" from the disaster.

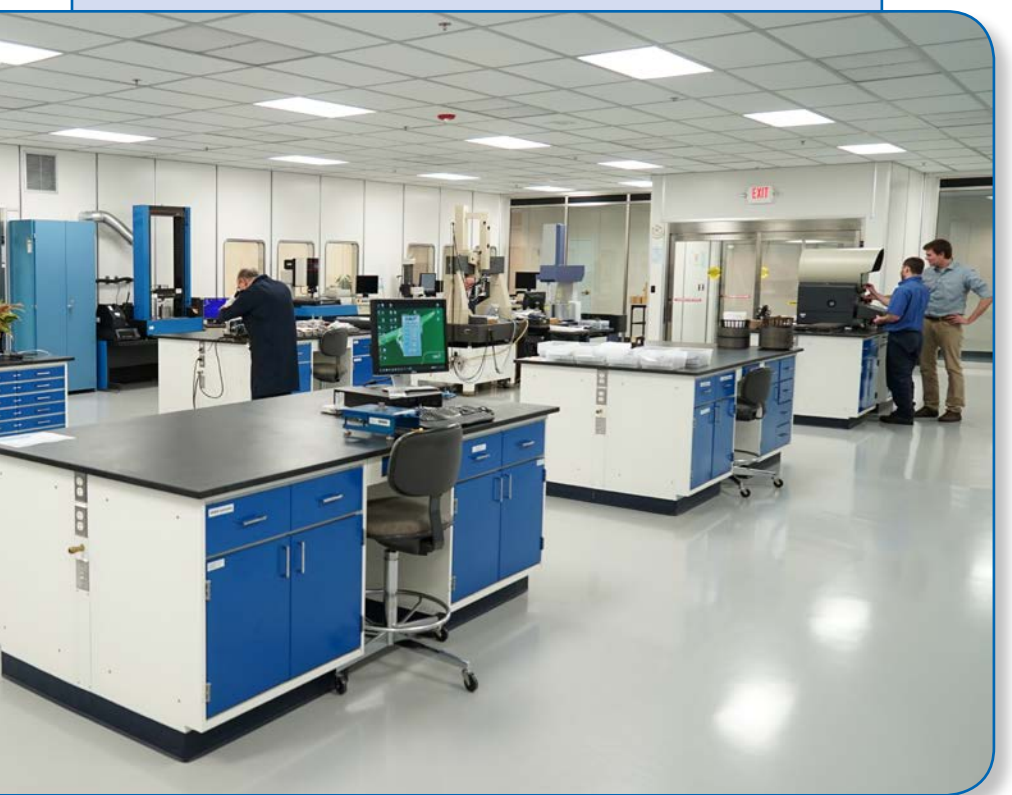
Seven years after the Chicago Fire, in 1878, three men, William H. Preble (secretary), August C. Krueger (leather processor) and Andrew Spurling (president) met in a loft near Monroe and Clark in Chicago, hired 25 employees and began the manufacture and sale of rawhide products under the name of Chicago Rawhide Manufacturing Company.

The main purpose of the company filed in the incorporation papers in 1879 was the "purchase and curing of hides, the manufacture and sale of rawhide leather, belting, lacing, ropes and all other articles of merchandise and utilities where rawhide leather can be used."

In 1882, William H. Emory, a banker, proposed to build for the original owners a building to manufacturer these products on Ohio Street in Chicago. By this time, the company was making rawhide fly nets for horses, rawhide ropes, rawhide shoe laces, leather belting and buggy whips.

Leather belting around steam engines and pulleys (in the late 1880s) was now driving the U.S. Industrial Revolution. In 1891, Emory was elected president of Chicago Rawhide and the company was the only manufacturer of rawhide belting in the world.

- In 1893 at the Chicago World Columbian Fair in Machinery Hall more than 200 exhibitors used Chicago Rawhide Belting and the company won an award.
- In 1897, Chicago Rawhide started a new product with the introduction of leather gears. In 1907, the Elston Avenue plant in Chicago was built. In 1918, 70 percent of the products made by Chicago Rawhide were for the U.S. war efforts.



- As early as 1914, Chicago Rawhide was selling leather products to the Ford Motor Company for the Model T.
- In 1928, the company patented the first Perfect Oil Seal made of leather.
- By 1938, 93 percent of the automobile equipment built was equipped with the Chicago Rawhide Perfect Oil Seal. During World War II, Chicago Rawhide was ordered by the U.S. Government to license other companies to make oil seals to ensure enough products were available for the war efforts. Chicago Rawhide had to share their trade secrets on seal manufacturing and design with the competitors.
- In 1949, Chicago Rawhide purchased the Majestic Radio and Television plant in Elgin, Illinois. This would later become its worldwide headquarters.
- In 1955, Chicago Rawhide began selling its products to the replacement markets. This included distributors, garages, repair shops and truck fleet operations.
- In 1964, the last of the Emory family to run the company died in Canada.
- In 1979, the original family and owners sold Chicago Rawhide to the IFNT Company. Also in the 1970's, SKF acquired the seals company Eurofigat S.p.A of Italy manufacturing seals for roller bearings, shock absorber seals and oil seals.
- In April of 1990, SKF acquired Chicago Rawhide. This was the largest SKF acquisition since the 1960s for SKF.
- In 1994, SKF Chicago Rawhide acquired Goetze Elastomere in Germany.
- Between 1995 and 2005, SKF started seals manufacturing units in India and China.
- In 2004, SKF formed a global seals business unit with operations in Europe, Asia, and North America.
- In 2006, SKF acquired Macrotech Polyseal Inc. in Salt Lake City, Utah and Economos, Austria GmbH which provide seals for the hydraulic and fluid handling markets.
- In 2007 SKF launched HMS5 and HMSA10 for metric gearbox seals.
- In 2012, SKF launched the next generation of SKF Speedi-Sleeves, which offered 30% less shaft wear then previous versions.
- In 2013, SKF acquired Blohm + Voss Industries, which specialized in marine solutions including Sterntube and bulkhead seals. Additionally, SKF purchased Kaydon Corporation, which included their Kaydon Ring & Seals.
- In 2017, SKF opened a new product investigation center to support customer field returns and product performance inquiries in Elgin, Il. **PTE**

Chicago Rawhide in Elgin, Illinois is now SKF Sealing Solutions.

SKF acquired Chicago Rawhide in April 1990.