Impact of **imperfections** on bearing performance

Phil Burge discusses research into the measurement of microstructure and pre-existing imperfections of bearing materials and how these measurements are aiding the development of predictive modelling tools to study the effects of metallurgical imperfections on the long term performance of bearings

Modern machinery is expected to work at or near its design limits, which places a considerable burden of responsibility on manufacturers of critical components such as bearings, to ensure that their materials of construction are resilient against such phenomena as rolling contact fatigue and white edge cracking, and are thus able to perform reliably in the long term under highly stressed conditions. Research on these fatigue mechanisms is thus fundamental to advancing bearing technology for challenging applications, and to better understand the effects of microstructure and pre-existing metallurgical imperfections on bearing performance.

Premature bearing failure is rare these days – some estimates put this at around 0.5% of all bearings in service – but modern bearings do sometimes fail prematurely due to rolling contact fatigue (RCF) and white etching cracking. Gaining an understanding of the failure mechanisms involved is fundamental to the continuous improvement in bearing metallurgy and, ultimately, the long term performance of bearings in high power density applications.

RCF is rare; indeed, the final achieved life of a rolling bearing is usually in excess of its calculated rating life. There are instances, however, where in specific applications a bearing may fail prematurely, usually as the result of failure of the weakest link in its construction. Apart from the effects of poor lubrication of the bearing's rolling surfaces (the culprit for nearly a third of all bearing failures in service), premature failure due to RCF is likely to be the result of imperfections in the subsurface material, non-metallic inclusions, for example, which are an inevitable consequence of steel production.

The stress concentration near an inclusion can cause local plasticity of the steel, inducing a localised tensile residual stress, which, together with other components of the local stress near the inclusion, may cause crack initiation and eventually crack propagation.

SKF has developed a modelling technique using the finite element method (FEM) to study the behaviour of

Predictive maintenance

Jan-Hendrik Bruns look as how implementing Industry 4.0 technologies can be an enabler for predictive maintenance

The British manufacturing industry is facing uncertainty. This has led to companies investigating ways of increasing profitability, productivity and efficiency. Coupled with this, evolving technology and changing consumer demands are putting manufacturers under pressure to increase output capacity and minimise downtime, while maintaining product quality.

The rise of industry 4.0 technologies can help solve the problem of increased equipment downtime and sub-par productivity. Companies can benefit from total cost of ownership (TCO) savings that the rise of the smart, connected factory can bring, which allows for manufacturers to take pre-emptive maintenance action.

Shell Lubricants has found that in the UK, only half (53%) of manufacturers have taken full advantage of new technologies available, potentially due to the lack of understanding and awareness. Let's examine three key technologies to be aware of.

Sensor-based technologies can self-test, validate, adapt, identify and understand the environment they are in, while managing a wide range of conditions. 68% of UK manufacturers are opting for real-time, on-site lubrication health monitoring by using these technologies, instead of waiting for the analysis to take place in laboratories.

Using these technologies means that lubricants are now replaced or replenished based on their 'true condition' as sensors provide real-time readings, including friction, wear and tear and lubricant condition, so manufacturers are now able to plan for predictive maintenance. Upon detecting contamination or early stage lubricant degradation, sensors can alert maintenance staff of the need to intervene before the problem worsens, thereby helping to avoid costly unplanned breakdowns.

Big Data-Based Technologies: With the adoption of sensor technologies comes an increase in data that covers all stages in the life of a product or an asset. If used effectively, 'big data' can allow manufacturers to amass TCO savings. Shell Lubricants has found that in the UK, one in three (31%) manufacturers lack understanding around how to introduce big data-based technologies.

Big data is another way technology can facilitate a proactive approach to preventative maintenance. Real-time telemetry that details various aspects of the production process allows for manufacturing companies to predict when machines will fail with extreme accuracy.

Shell LubeAnalyst, for example, processes and compiles huge quantities of data which can then be used to generate accurate reports that help monitor stationary or mobile equipment's oil over time.

Cloud-based technologies: The introduction of cloud-based technology into manufacturing means that companies can store large amounts of data in the cloud. As such, anyone on the supply chain is privy to information, in real time, spurring manufacturers to become more agile and efficient, and encouraging them to quickly adapt to changing demands.

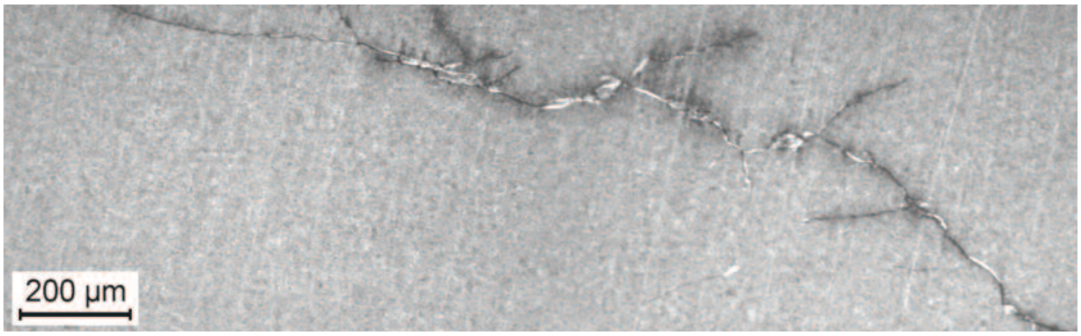
By storing information in the cloud, manufacturing companies need not worry about the loss of vital information should they face a disaster, such as an industrial fire. As such, a shorter period of time would be needed to get the factory up and running again.

Used correctly, cloud-based technology has enormous potential to help enhance manufacturing production and performance. Weaving in big data, companies can glean actionable insights through predictive analytics, such as ensuring lubrication quality and improvements or preventive maintenance, giving them an edge over competitors.

Technology to help optimise operations

To help customers navigate upcoming challenges and capitalise on new opportunities, Shell Lubricants is constantly working to create solutions that embrace new technologies to help raise equipment efficiency and uptime, and help to reduce energy consumption and operating expenses.

An example of this solution is Shell LubeChat, an AI-powered chatbot tool for B2B lubricants customers in the UK. Shell LubeChat is designed to provide users with easy,



subsurface inclusions under surface loading. The method considers different types of inclusion and their bonding to the surrounding steel crystalline structure. This FE simulation also takes account of the elastic-plastic behaviour of bearing steels to account for the localised plasticity in the vicinity of the inclusion.

Modelling shows that under a specified contact pressure, initiation of a crack from an inclusion depends primarily on the local stress near the inclusion. It is governed by the type rather than the size of the inclusion, the stress raising factor being independent of the inclusion size. Moreover, a crack initiated from an inclusion doesn't always go on to develop a spall and in some cases the crack may be permanently arrested.

White edge cracks

A bearing subject to RCF often reveals signs of an extensive subsurface crack network within its steel microstructure known as white etching cracks (WECs). Affected areas consist of ultra-fine, nano-crystalline, carbide-free ferrite, or ferrite with a very fine distribution of carbide particles that appear white when viewed under a microscope. Over time, WECs will propagate towards the bearing surfaces, and may typically result in raceway spalling.

Considered a symptom of fatigue failure rather than the root cause, WECs occur due to a number of factors, principal among which is RCF. Another cause of WECs is accelerated fatigue (premature spalling) resulting from higher stress and lower material strength. Bearings are subject to higher stresses as a result of transient high loadings or temperature effects. Examples include structural stress in the bulk material of the bearing caused by factors such as misalignment, and increased stress on the raceways due to tribological factors, including reduced lubricant film thicknesses.

The material strength of a bearing may also be negatively influenced by environmental factors that are suspected to generate hydrogen, including water contamination, corrosion and electrical stray currents. In these cases, even moderate loading conditions can lead to premature bearing failure.

White etching is a universal phenomenon, found in all types of industry, all types of bearing and all types of heat treatment. WECs occur at the end of the failure chain and are a natural consequence of crack networks in prematurely failed bearings. The key to identifying the root causes for bearing premature failure is not only to study WECs, but rather to discover the relevant weakening effects (the higher stresses or lower material strength mentioned above) that lead to accelerated fatigue.

Each premature bearing failure is unique and the reasons for premature spalling can be very different. A single root cause does not exist, and each failure case needs to be reviewed in the light of the corresponding operating conditions. Higher stress or lower material strength have been identified as principal weakening drivers and within these broad categories, general recommendations can help to identify a likely cause of premature failure.

However, for a truly accurate diagnosis, this general advice should be underpinned either with a deep knowledge of the mechanisms of bearing failure, or by seeking help from an acknowledged expert with the tools and research background to support their diagnostic capabilities.

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real-time access to product support, technical services and lubricants data, help improve efficiency and solve commonplace challenges like quickly finding information about effective equipment lubrication.

Shell LubeChat can be used across a wide range of businesses and sectors, including general manufacturing, construction, agriculture, power and fleet. Designed to help optimize efficiency for our customers and distributors, Shell LubeChat, alongside the entire suite of Shell Lubricants services, can help solve day-to-day challenges like quickly finding information about effective equipment lubrication.

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