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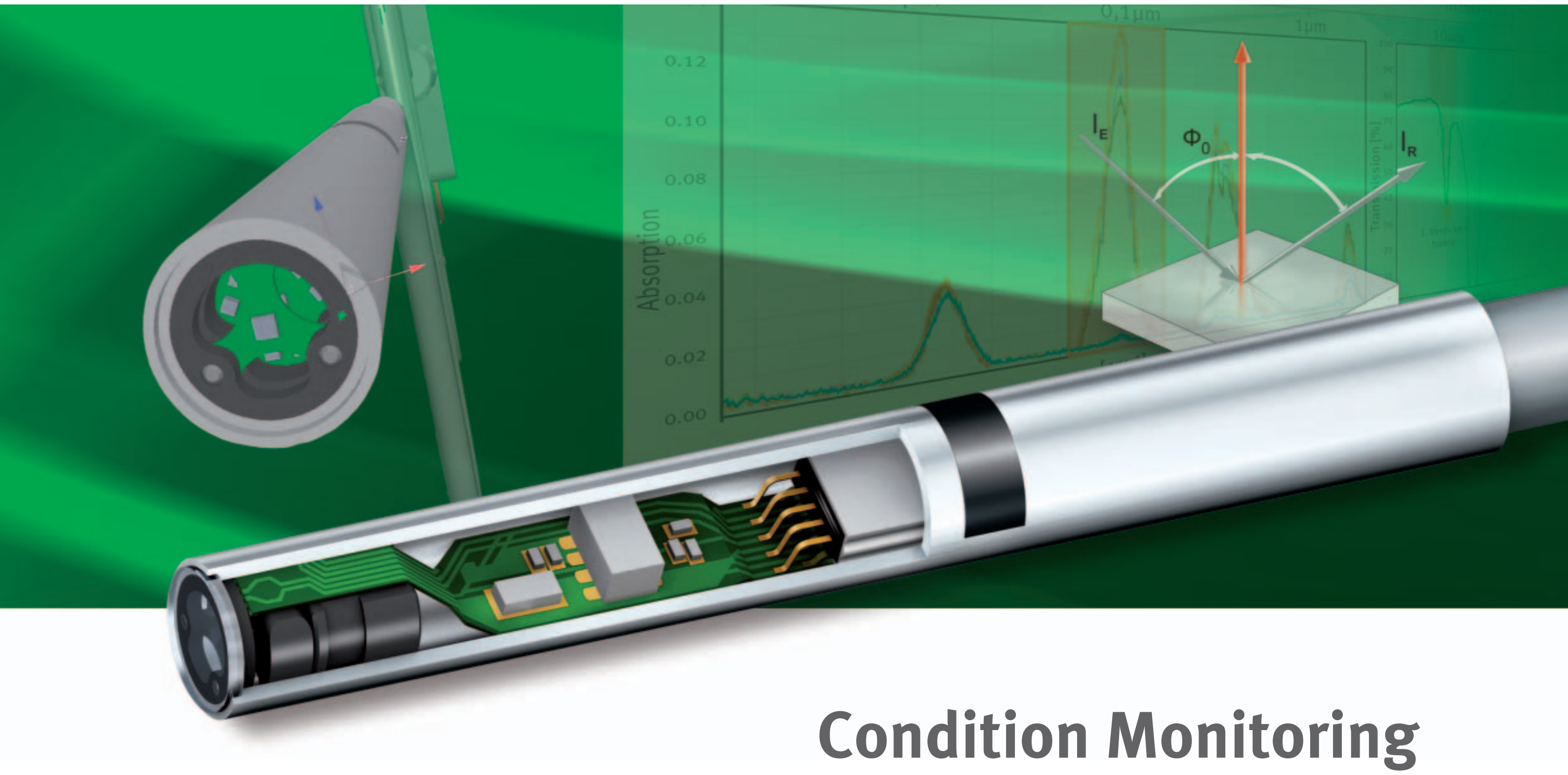

Condition Monitoring of Greases in Rolling Bearings

Demand-controlled relubrication by grease analysis during operation

SCHAEFFLER GROUP
INDUSTRIAL

Condition monitoring of greases in rolling bearings

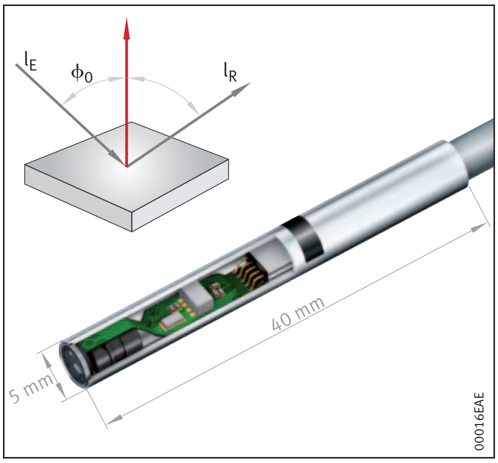

Figure 1: Basic design and function of the grease sensor

Approximately 95% of all rolling bearings are lubricated with grease. The grease forms a lubricant film on the contact surfaces that is sufficiently capable of supporting loads and is thus intended to prevent premature fatigue of the bearing. Reliable information about the condition of the grease in the rolling bearing is therefore of major significance. Around three quarters of all rolling bearing failures thus occur in conjunction with the lubricant, for example, due to insufficient lubrication, lubricant contamination or ageing of the lubricant. Up until now, it has not been possible to analyse greases in rolling bearings during operation. It is for this reason that greases are usually replaced long before the end of their operating life as part of preventive maintenance in order to prevent damage to the rolling bearings and therefore prevent expensive downtime and failure of machinery and plant. Alternatively, an incorrect concept of safety leads to overgreasing, which can have a negative effect on the function and operating life of the bearing. The Schaeffler Group, working in partnership with Freudenberg Dichtungs- und Schwingungstechnik GmbH & Co. KG and the lubricants expert Klüber Lubrication München KG, has developed a grease sensor that can be used to analyse the condition of the grease in the rolling bearing during ongoing operation, *Figure 1*. As a result, grease changes can be made in future on the basis of actual requirements.

Disadvantages of previous methods

Many bearing failures can be attributed to old grease. It is now possible by means of condition monitoring, such as monitoring of structure-borne sound spectra, to detect defects in machines at an early stage. This, in turn, enables maintenance measures to be precisely scheduled, thereby preventing secondary damage to bearings and transmission components. The disadvantage of this method is that damage must already be present in the machine in order for a signal to be detected. As a result, at least one component must be replaced during the next maintenance operation. The advance warning time until actual failure of the machine will vary depending on the signal recorded, *Figure 2*.

With the aid of the newly developed grease sensor and the associated electronic evaluation system, it is now possible to detect changes in the condition of the grease long before any damage to the rolling bearing occurs. This means that replacement of the grease can be precisely planned, whereby the user can decide at which point in the condition of the grease (from 100 per cent for as-new to a theoretical 0 per cent for unusable) relubrication or a grease change should be carried out.

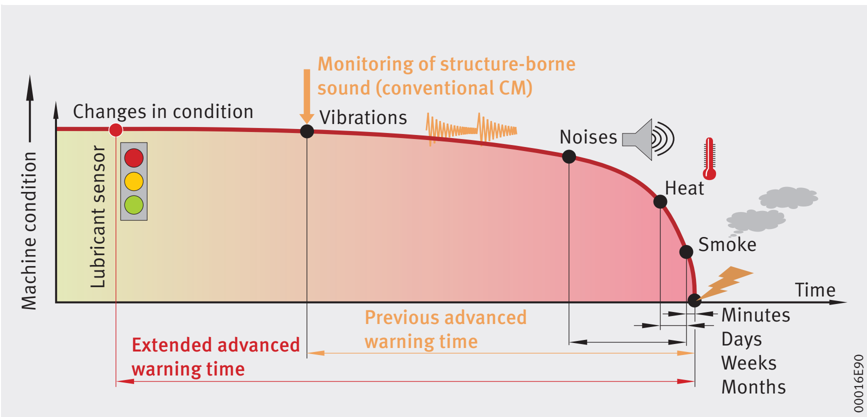

Figure 2: The grease sensor and electronic evaluation system enable changes in the condition of the grease to be detected long before damage occurs to the rolling bearing

With the new grease sensor, relubrication is changed from time-based to demand-based.

From time-based to demand-based relubrication

In plant that is difficult to access, such as offshore wind turbines or assembly lines, the failure of a rolling bearing can incur secondary costs far in excess of the value of the rolling bearing itself.

If increased attention is paid to tribological influences, it is possible to achieve considerable savings through:

- reductions in downtime that can be attributed to operational disruption
- reductions in lubricant costs
- reductions in the costs expended on maintenance and replacement parts
- reductions in plant costs due to higher levels of utilisation and efficiency.

Optimum lubrication of rolling bearings is a science in itself, since greases are highly complex mixtures that should be optimally matched to the specific application conditions. In general, greases comprise a base oil, thickeners and additives; in some cases, solid lubricants are added, *Figure 3*.

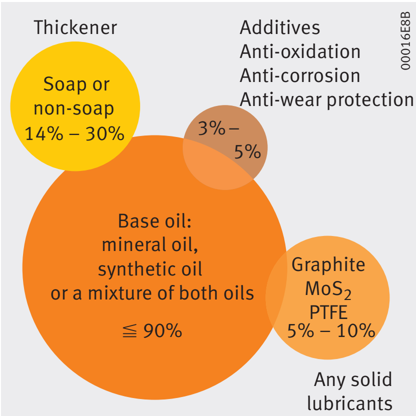

Figure 3: Basic composition of greases

If a preventive maintenance approach is applied, the grease operating life becomes the determining factor if it is shorter than the bearing rating life. In this case, bearings are generally relubricated halfway through the so-called grease operating life.

The major disadvantage of this common procedure is that absolutely nothing is known about the condition of the grease. Would it have been possible to continue using it for a period? Had it already been changed so significantly by external influences such as temperature or the ingress of water that damage has already occurred in the bearing? If the user wanted information about the grease in the bearing, the only option previously available to him was the removal of a sample followed by expensive and time-consuming analysis in the laboratory.

With the new grease sensor, relubrication is changed from time-based to demand-based. Monitoring of the grease condition during operation is now appropriate in principle for every rolling bearing. The grease sensor is, however, a particularly attractive proposition for use in machinery and plant. It is in such cases that the failure or unscheduled maintenance of the rolling bearing generates high downtime and repair costs. If the lubricant sensor were used in this case, preventive grease changes would be superfluous, since it would be precisely apparent when the lubricant is no longer providing optimum lubrication. This could give considerable savings in costs and resources as well as protecting the environment.

Design and function of the grease sensor

It became clear that optical near infrared reflection was the ideal method for determining the condition of the lubricant during ongoing operation of the rolling bearing.
The method, developed in conjunction with the Fraunhofer Institut ENAS in Chemnitz, Germany, is based on the infrared process used in laboratories to measure grease quality but has been adapted for the type of measurement carried out on the rolling bearing during operation. The know-how involved is not only in the design of the sensor, but also in particular in the evaluation of the measured signals. The method involves the rotationally symmetrical irradiation

of the grease at an angle of 45° using certain wavelengths within the infrared spectrum by the sensor, *Figure 1*.

The sensor head is embedded in the lubricant. The reflected light is then measured perpendicular to the grease. This enables shadow effects and surface inhomogeneities to be completely excluded. At the same time, a reference system exists that undergoes ageing in parallel is subjected to the same temperature but does not have any contact with the grease. The measured signal is compared with this reference system. The reflected light is evaluated in terms of the quality of the grease. One method known from laboratory practice is the infrared spectroscopy of grease samples, in which not only the opacity but also the development of various bands over time is evaluated. The knowledge gained as a result gives the experienced expert information for assessment of the lubricant quality, *Figure 5* right. In the monitoring of greases, the characteristic changes in the near infrared spectrum are used for automatic quality assessment, *Figure 5* left.

Power is supplied and signals transmitted from the sensor to the electronic evaluation system by means of cables. A wireless solution can also be provided if required.

The penetration depth of the signal extends from the surface of the sapphire glass on which the lubricant is located to a few millimetres into the lubricant, *Figure 4*.

The optimum measurement point varies from application to application. In this connection, it is advisable to draw on the know-how of the Schaeffler Group application engineers, who can specify precisely where the sensor should be positioned in the specific application. Tests using the rolling bearing lubricant test rig FE8 (to DIN 51819-1) have shown that it is not necessary for the sensor to measure the grease at the rolling contact, since highly homogeneous grease conditions are also present in areas adjacent to the raceway and therefore comparable measurement results can also be obtained there.

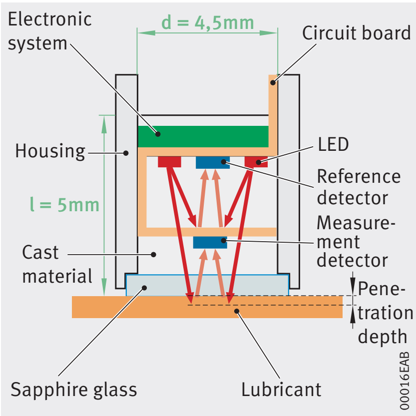

Figure 4: Schematic design of the sensor head

During the validation phase, precise analysis was carried out to determine the influence of individual contaminants in greases on the signal.

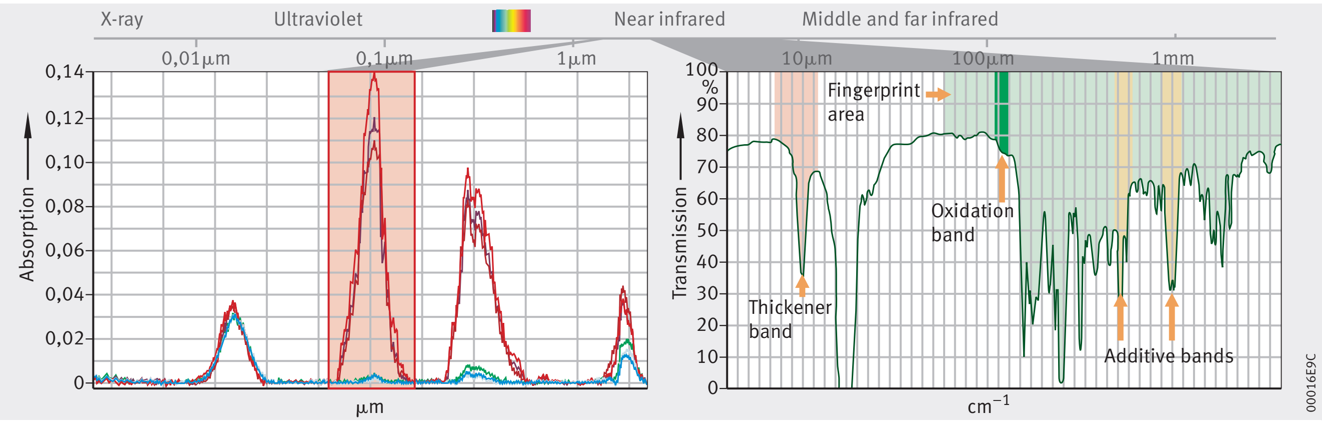

Figure 5: Sensor signal and subsequent analysis of the grease using the electronic evaluation system of the grease sensor

The sensor can be used to determine four parameters relating to the lubricant:

- water content
- opacity
- wear (thermal or mechanical)
- temperature.

The electronic evaluation system processes these parameters to generate an analogue signal (4 – 20 mA) from which the customer can quickly and easily see the condition of the grease, *Figure 6*.

In addition, it is also possible by setting a trigger threshold (limit value) to generate a digital signal that indicates whether the grease condition is good or poor.

The measurement method can be applied to most greases. Approximately 95% of the generally available products are suitable on the basis of their composition. The Schaeffler Group, working with Freudenberg and Klüber, has now validated the method for a large number of greases. Through evaluation of the grease condition during operation, it is possible to analyse any sudden changes, draw conclusions as to their causes and use the digital signal to achieve a rapid response. With the aid of the method, it is also possible to quickly determine possibilities for optimisation in the design and selection of the rolling bearing.

Summary and outlook

Due to the intensive partnership work, a sensor suitable for practical use together with an electronic evaluation system was developed that can be used to determine the quality of grease in a rolling bearing during operation for a very wide range of greases.

Ongoing analysis of the lubricant makes it possible to detect any changes in the grease at an early stage. This means that the lubricant can be replaced when a specific lubricant quality defined by the customer is reached before damage occurs to the rolling bearing due to inadequate lubrication. As a result, it is no longer necessary to carry out time-based relubrication with its many disadvantages.

The demand-based relubrication that can be realised with the grease sensor allows grease to be used with optimised costs and improved environmental benefit.

Further advantages of the new grease sensor include possibilities for optimisation of rolling bearings and bearing positions, since it is possible to assess from the behaviour of the lubricant quality whether, for example, a rolling bearing has been overdimensioned. If there is a sudden, critical failure as a result of water ingress into the rolling bearing, for example, an emergency shutdown can be initiated. This can reduce the risk of damage to other components.

The sensor is positioned directly in the rolling bearing. A further solution is under development for integration of the sensor in the rolling bearing seal.

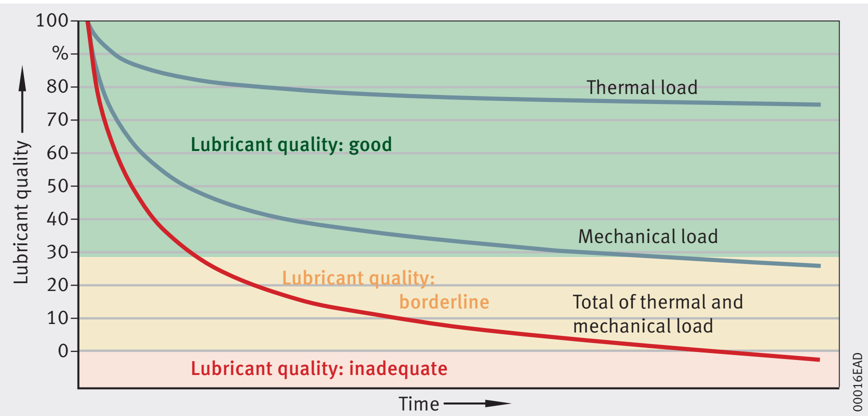

Figure 6: The output analogue signal gives the customer rapid and transparent information on the condition of the grease in the rolling bearing

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