Online condition monitoring has developed into the state of the art for certain systems. At the same time, the market shows that it is often not enough to simply deliver a functioning system consisting of sensors, hardware and software. Many system operators also want to purchase a diagnostic service in the form of telediagnosis by a competent partner, as they do not possess the necessary know-how themselves. The industrial sector of wind-powered energy can be cited as a typical example. A number of respected insurance companies will only insure the systems if certain components are replaced after a specified inspection interval. An extension of the interval can only be achieved by suitable continuous torque measurements during operation in the steel mill could help here. To meet the adverse environmental conditions, the 900 mm diameter transmission drive shaft was specifically modified during the construction phase to allow the strain gages and telemetry components being installed in a protected area. The installation and the calibration of the strain gages were carried out even before the first pilger-mill stroke, so that the stresses in the new type of drive were available during the start-up phase. After the first pilger-mill rolled tubes, the load trends showed themselves to be more severe than were specified and the stresses had to be continuously measured with a sampling rate of 1000 Hz, i.e. with 1000 measured values per second. No problem for the DriveAnalysator® in the way it was installed by Flender Service. Fig. 1 shows four measurements in which the...
The condition monitoring magazine

As a result of the general conditions and requires a great deal of experience. For this reason, Flender Service and the PRÜFTECHNIK Condition Monitoring have agreed to collaborate very closely in this field. Together, both companies are in a position to offer optimized solutions. ■

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CONDITION MONITORING³. Therefore, some insurers demand that –in addition to suitable monitoring systems– telediagnosis must be carried out by a competent partner. The reasoning behind this is the complexity of the monitoring task. Condition diagnosis on the high-performance gears and drive trains employed by these systems is extremely exciting.

torques were automatically recorded with a 1 second prehistory and 15 seconds of posthistory if they exceeded 4 million Nm. In less than 1/10 second, the torque of a pilger stroke increases steeply from almost zero to 4 million Nm. The flywheels (Fig. 2) then momentarily ensure that the machine continues at the same RPM during the pilger stroke. A pause (0.8 sec.) then follows during which the motor accelerates the drive up to the nominal RPM again before the next pilger stroke occurs. If a protection shut down occurs due to overload, the shift overseer checks the current switch-off torque and activates the overload coupling again. “Without torque measurement, we could not continue”, was the comment from Mr. Fahl, in Düsseldorf.

Since then, 4 years have passed. Thousands of tubes have passed through the pilger rolling mill. Both the performance ratings as well as the working RPMs were increased step-by-step in a controlled fashion by the mill operator using the results of the torque measurements. Temperatures, vibrations and displacements are also monitored by the DriveAnalysator®.

Similarly, loads as well as wear and tear can also be monitored in other applications and industrial sectors. Fig. 4 shows an installation on a turbocompressor where the torques are measured and evaluated in the same way and, if limiting values are exceeded, the measurement results are remotely transmitted immediately by eMail. Thus, even rarely occurring overload phenomena such as terminal short circuits can be measured and incorporated in the drive dimensioning. ■

Fig. 1: Four automatically recorded stress curves with a 1-sec. prehistory and 15-sec. posthistory.

Fig. 2: Assembly of the gear with the oil station by Flender Service

Fig. 3: Safety clutch before assembly

Fig. 4: Installation of a strain gage on a turbocompressor drive
Online condition monitoring systems should automate the monitoring of machines and systems as far as possible. For years there have also been efforts to automate the diagnostics with the aid of knowledge-based algorithms. The problem is that, in complex aggregates and special machines, an extensive learning period is required for the system. The diagnostic system must either be supplied with a representative learning sample, consisting of the relevant diagnostic features and assigned condition and damage categories, or it must be capable of learning by itself. However, without any additional information or extensive diagnostics, it is only able—at best—to determine general deviations from normal operating conditions.

There are almost never sufficient learning samples available or, alternatively, the overheads used for the system configuration are disproportionately high in the case of complex aggregates, with possibly the most diverse operating conditions, and, consequently, very expensive.

At the moment, one realistic strategy is the automation of data recording (depending on operating conditions), data preprocessing (with threshold comparison) and data provision (auto-upload, eMail). The in-depth diagnosis itself is then carried out by an experienced vibration specialist who—due to his experience—is able to consolidate even ambiguous data material into a relatively reliable diagnostic statement.

**Characteristic value trends**

The basis of condition monitoring is the recording of characteristic values in the form of characteristic value trends. These values can simply be broadband characteristic values, such as the effective vibration velocity \( v_e \) acc. to ISO 10816/3, or complex characteristic values such as the spectral performance in a narrow frequency band. Using an adaptive storage algorithm that evaluates the amplitude changes of measured value to measured value, the trend data are compressed so that the storage of an average trend history is possible even if system resources are limited.

**Vibration signals**

After commissioning or auditing, the reference signals, e.g. amplitude spectra of the vibration velocity or envelope spectra of the vibration acceleration, should be recorded in order to use them for comparison with the original condition in subsequent diagnostics. The most crucial vibration signals should be recorded cyclically or triggered by specific conditions, and continuously updated in a ring memory.

In order for these signals to be suitable for diagnosis, they must be measured during representative operating conditions. For example, in aggregates with an instationary running behaviour, it may be necessary to release diagnostic measurements that depend on the load and RPM (measurement only at “rated load” and “rated RPM” or, if necessary, during “idling”).

If the thresholds of characteristic overall values are exceeded, alarm signals are automatically measured and stored while alerting the operator to an alarm condition.

In this way, the diagnostic specialist can immediately access authentic data material after logging into the system. This is the crucial factor that actually enables the effective functioning of telemonitoring systems at all.

This especially applies to systems with changeable operating conditions. In this case, it is possible that, when the expert dials into the system, representative operating conditions are not present and, thus, manual resolution of a diagnostic measurement would make no sense.

**Data storage**

Vibration signals are also held in ring memories in the same way as the trend data, so that the most current signals are always available in the data memory of the monitoring system. From here, these data can be sent over the Intranet or Internet by an integrated eMail server. As a result, this enables optimum data management in the case of an alarm. All the relevant diagnostic data are immediately and automatically sent to the specialists via eMail and are thus available for immediate diagnosis—an enormous advantage in being able to react to changes in condition.

Provided that a database is used for long-term data archiving, the data can be automatically transmitted from the monitoring system to the database by the data server.
Java applets:
Java applets are program modules that are written in the Java programming language. These program modules can be embedded in HTML pages and are transported to the client computer in these pages. The program modules are carried out automatically in the virtual machine on the client computer.

Virtual Machine:
The virtual machine is the program that carries out the Java applets on the client computer.

Characteristic values of roller bearings
Dieter Franke

For many years broadband characteristic values have been successfully used for the evaluation of high frequency vibrations in the diagnosis and monitoring of roller bearings during operation. However, in contrast to machine vibration, there are some restrictions and measurement rules that must be observed. Consequently, their use is restricted to simple roller bearings, which have no other source of vibrations that could be “louder” than the roller bearing. Thus, they are applicable for the majority of all machines on fans, motors, pumps and belt-type drums.

High frequency vibrations are caused by frictional processes as well as by the rolling components of the roller bearing. This does not involve the vibration of whole components with their large mass in a measurable deflection, but shockwaves that pass through the body. Everyone is familiar with “listening to” a roller bearing with a screwdriver and hearing the typical audible rattling sound or humming “running noise”. The main evaluation variable for this is the vibration acceleration with its higher temporal deflections. These are recorded in a linear frequency range of the acceleration transducers that is as wide as possible, up to 10 or 20 kHz. The lower frequency limit recommended for this is 1 kHz or lower in order to separate high frequency vibrations from machine vibrations. The range above the 10 times multiple of the rotating frequency has been proven to be suitable. These measurements can also be carried out up to 40 kHz for example, also including the transducer resonance, that then react more sensitively. Peak values (max. value in the case of the shock pulse) form characteristic values that –put simply– result from the shock to the roller race of passing through a pot hole. The effective value (carpet value in the case of shock pulse) that reproduces the “rolling noise” of a smooth or rough race is also deter-
Part 4: Calculating roller bearing-specific excitation frequencies

The roller bearing condition in gear transmissions cannot be diagnosed using simple characteristic values, as the gear mesh dominates the measurement signal. Consequently, the envelope spectrum has been used for years to filter out roller bearing-specific components of the high frequency vibrations in order to be able to diagnose race damage (see VDI 3839 sheets 1 and 2 for more information). At the same time, a search is made for the so-called rotating and overrun frequencies of the roller bearing components from the rolling process.

The origin of the overrun frequencies is very similar to the wheel rims of a train running over joints in the rails that is clearly noticeable by the passengers. The audible rhythm of the repeated overrunning of the rail joints changes noticeably with the speed of travel and is determined, moreover, by the spacing of the wheel sets.

In the roller bearing, the rotating frequencies of the rolling member and those of the rolling member set or –more simply– the cage rotating frequency arise from the inner geometric dimensions of the components and the shaft revolutions. In turn, these determine the overrun frequencies of the race damage on the rings by the rolling member number. As the inner geometrical dimensions are not contained in roller bearing catalogs, for some time a number of bearing manufacturers have offered software together with their frequency catalogs for this. This requires only the RPM to be input as accurately as possible.

In the standard case, the calculation can be made from the geometrical dimensions of the stationary outer ring and rotating inner ring according to the formula on the right.

As a result, the race damage can be ascribed to the components from the different overrun frequencies or, vice versa, their absence from the envelope spectrum indicates damage-free races.

In the cases of rotating outer ring and stationary inner ring (centrifuges) or the rotation of both rings (planet wheels) other formulae apply for the cage RPM. These can be taken from specialist literature or VDI 3832 (draft in preparation).

The rolling member overrun frequency is 2nd. order as a result of the overrunning of damage in the outer ring and from the rotating frequency in the case of inner ring contact. Since, beyond the load range, only the outer ring is overrun and these shocks are “louder” than those from the inner ring (longer vibration path), a first order frequency also arises from this.

Modulation frequencies are visible in the envelope spectrum as well as the overrun frequencies. If a rolling member or inner ring damage passes through the load zone once per revolution, it becomes “louder” under greater load. Consequently, amplitude modulation (in addition to phase modulation) can occur in the case of inner ring damage with the rotor rotating frequency and in the case of rolling member damage with the cage rotating frequency.

The modulation frequencies are present as background frequencies in the envelope spectrum and as sideband families in the order of overrun frequencies.

It must be noted that geometric deformations of the roller bearing rings or too little bearing play can also cause these overrun frequencies. Even short-term overrunning of foreign bodies can cause these frequencies. In the case of very widespread and advanced damage, perhaps to several components, the frequency families disappear in the increased background noise level in the spectrum.

This makes it necessary to also repeat the trend evaluation of a measurement in the envelope spectrum. On the other hand, further signal evaluations are required anyway to form a reliable diagnosis.
**An unusual rendezvous: Tornado meets ROTALIGN®**

**Aligning a test stand for injection controllers used in Tornado engines**

Michael Stachelhaus,
PRÜFTECHNIK VD

The Tornado is a multi-role combat aircraft with two turbofan engines designed for two-fold ultra-sonic flight (Mach 2.2). The aircraft has a length of 16.7 meters and has been in series production since 1979. A total of about 1,000 planes have been delivered to date. Current plans have the Tornado being built until the year 2020. The price of the aircraft is estimated at 35 million Euro.

The Pierburg Luftfahrtgeräte Union (PLU) supplies the injection controllers used in the Tornado. Since it is important that Tornado engines operate with absolute synchronicity, the injection controllers must be adjusted to a very high degree of accuracy.

For this purpose, Pierburg Luftfahrtgeräte Union operates several test stands at their plant in Neuss, at which the controllers are charged with kerosene, run-up to 10,000 rpm and then adjusted.

The controllers are 100 x 40 x 50 cm in size. They are equipped with approx. 100 different adjustment components for metering kerosene injection and their operation is fully mechanical. To be able to adjust all parameters as accurately as possible, it is crucial for the test stand to be largely free of vibration.

The test stand and gear box are situated in an explosive atmosphere due to the highly explosive nature of kerosene. The test stand is located directly in front of the gear box (Fig. 1), which in turn is connected by a long spacer shaft to the drive motor outside of the Ex zone. The spacer shaft, which reaches into the Ex zone, has a length of approx. 1.2 m. For this reason, and because of the small size of the wall opening, the use of dial gauges to align the machine proves virtually impossible.

The shaft is terminated at both ends by universal joints that are rigidly connected to the drive motor and gear box. The motor runs at a maximum speed of 2,500 rpm and the gear box translation ratio results in a maximum speed of 10,000 rpm.

**Alignment procedure**

Because of its configuration, the system had to be aligned in two steps. First, the gear box was aligned to the test stand. Next, the DC motor was aligned to the gear box. The initial measurement revealed severe misalignment of all units (Fig. 6).

**Aligning test stand and gear box**

The laser and receiver units of the ROTALIGN® measuring system were mounted between the test stand and the gear box (Fig. 2). Due to the construction at the test stand, the rotation angle during measurement was restricted to about 90° (Fig. 3). The display showed that alignment was far out of tolerance (Fig. 6).
Aligning motor and gear box

The motor and gear box had to be aligned through a narrow opening in the dividing wall between the non-Ex zone and the Ex zone (Figs. 1 and 5). This opening restricted measurement to a small 75° angle centered around the 6 o'clock position. The laser and receiver were mounted as shown in Figs. 4 and 5.

The alignment procedure revealed severe misalignment of the drive motor (Fig. 6). Due to the extremely large offset, shimming alone could not correct the misalignment. The foundation required redesigning.

Final check

The alignment between the test stand and gear box and between the gear box and motor was measured again. The offset and gap values were found to be within tolerance (Fig. 7).

Summary

The test stand had become conspicuous due to the repeated failure of its bearings (twice in two years), which was brought about by excessive vibration levels. When operating under a full load, the test stand showed vibration levels as high as 10 mm/s (rms). This made adjustment of the highly sensitive injection controllers extremely difficult. After realignment of the test stand, vibration values fell to below 1 mm/s (rms). The test stand bearings have not failed again since the alignment procedure was carried out at the end of 1996.

In addition, the time required to adjust the Tornado controllers was shortened and the lifetime of the test stand was extended considerably.

After alignment of the first test stand, a further order was placed for the overhaul and realignment of the other two test stands.
WinTControl® was developed for wind power systems. WinTControl® incorporates special modules, which are required for the condition monitoring of wind power systems. Attention was paid to the ability to retrofit existing networks and, above all, to self-sufficient operation. A separate diagnostic computer is not necessary. If warning criteria are exceeded, the results can be sent to the responsible service company without delay. The figure shows a photograph of an upgrade at a height of approx. 90 m, where the first step was to lift the measuring system including the assembly tools to the top by crane. Since being put into operation, the measurement results are sent by eMail so the diagnostician does not need to ascend the structure in high winds!

New CoMo Flyer from Flender Service in 10 languages

Condition-oriented service is becoming increasingly more global, and also requires information on suitable condition monitoring technologies in the respective native language. Thus, Flender Service has described the services of inspection/monitoring, diagnosis and analysis in the major ten languages Arabic, Czech, English, French, Italian, Portuguese, Russian, Spanish, Swedish, and, naturally, in German. More details are available on the Internet.

Online Monitoring

Find out how straightforward and economical it is to commence with online condition monitoring. Simply ask for our new VIBRONET® Signalmaster brochure, or download it from our Internet page.

VIBSCANNER now includes the analysis module

The new analysis module of the VIBSCANNER data collector now offers such useful functions as time signal, orbit/phase measurement, recording, etc. Further information is given on our Internet page.

Seminar calendar for 2003

Our seminar schedule for 2003 with 15 different topics is now directly available (free-of-charge) from PRÜFTECHNIK or you can download it from our Internet page.

Parallelism of rollers and cylinders

For the inspection and correction of parallelism of rollers and cylinders in the paper industry, steel and metal works, conveyor systems and the plastics industry, PRÜFTECHNIK now introduces the first inertial measuring system based on laser gyroscopes. With a minimum of preparation time, PARALIGN® provides a higher measuring precision than any previously used procedure.

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