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telediagnose.com

The condition monitoring magazine of PRÜFTECHNIK AG and Flender Service GmbH

Use the synergy of telediagnosis

telediagnose.com magazine now always industry-specific

Future issues of *telediagnose.com* will be dedicated to a particular industry. The last issue dealt with the subject of "Wind power". This issue focusses on strip mining and material moving technology. Increasingly, this industry is using variable speed drives which in turn require modern and high performance diagnostic algorithms.

PRÜFTECHNIK and Flender Service have obtained techniques, methods and diagnosis algorithms after intensive development work for Condition Monitoring of dynamic speed wind energy plants, which in future will provide new innovative diagnosis possibilities in other industry branches.

In this issue:

Condition monitoring application in Brazil:

Housing crack on a bucket-wheel excavator

Dr. Edwin Becker, Flender Service

A gearbox of a bucket-wheel excavator suddenly lost oil after many years of trouble-free operation due to cracks in the housing. Attempts were made to weld the cracks and to carry out vibration analysis, all without success. The cracks increased and more oil leaked out. An identical replacement gearbox was mounted. The unusual cracks also appeared in the output area of the housing of the replacement gear. Flender Service was commissioned to search for the cause of these housing cracks in the largest iron ore mine in the world. Mobile torque measurements and targeted system analysis on site identified overloads and housing tensions as the cause. The recommended measures to strengthen the excavator and gear were carried out together with Flender Brasil.

But one step at a time: Bucket-wheel excavators are being used around the world for strip mining and material moving technology to continuously excavate and load material and bulk goods. In bucket-wheel excavators, the gears mostly "ride" on the bucket wheel and, as well as matching the motor speed to the bucket-wheel speed, have the task of directing the torque safely to the supporting structure.

The motor is directly mounted on the torque support of the gear. The active forces on the bucket wheel from the swivel motion have to be taken up by the gear housing.

The excavator performance that is achieved increases in the case of loading excavators if the bucket-wheel speed and/or the bucket-wheel volume is increased. This results in increased static load for the excavator and also additional deformation, tilting and strain in the entire bucket-wheel head. Sometimes there can be extremely high dynamic additional loads which can only be proven by highly sensitive torque measurements. Based on their experience, Flender Service Condition Monitoring immediately offered the Brazilian mine operator systematic torque measurements to identify the source of the problem.

The figure on the left shows the installation of a torque measurement location on the bucket-wheel shaft in the Brazilian rainforest. Despite extreme iron ore contamination, strain gages were carefully mounted and the mounting of a telemetry for the transmission of non-contact measured values including the Drive-Analysator® continued until late in the night. The measurement cables were then fed into the driver's cab and connected to the notebook computer for

evaluation. The torque measurement location itself was calibrated using a shunt resistor (Figure 2).

Before taking the measurements, it was agreed to mount a new gear in order to exclude the effects on the measurement signals of any preliminary damage to the gear. Figure 1 shows the mounting of the gear.

The following day, the first measurement results already showed extremely high loads which, during excavation in the upper crust, even exceeded the safety torque (picture 3). The hydraulic coupling mounted as a safety coupling did not separate; Here, the oil filling was increased after employment of new larger buckets. However, what was the use of detecting increased loads? The cause of the cracks had to be found and the stabilization measures determined. After all, the delivery rate of the excavator was supposed to be increased.

The disassembled bucket wheel gear was examined more closely. A red-white test on the housing revealed that there were further cracks in the area of the internal gear of the drive planetary stage. The planetary stage of the old gear was targeted for inspection as the next step. Unbalanced tooth damage on the internal gear of the planetary stage was a visible indicator of uneven lateral support in the planetary stage. Figure 5 shows an FEM model from the Bochum Ruhr University of how tilting can occur in bucket-wheel gears of this type as a result of the intrinsic weight and as a result of lateral forces during excavation. This tilting causes local overloads which, in Brazil, led not just to uneven lateral support, but also to housing cracks. In the past, Flender Service has gathered extensive experience, especially in bucket-wheel excavators for brown coal technology.

The operator was recommended to strengthen the gear in the vicinity of the planetary stage. The integration of a torque support in the bucket-wheel excavator should be constructed so that, during the swivel action, there are no warping or tipping forces on the gear housing and, particularly, on the teeth of the planetary stage.

Figure 1: Mounting the replacement gear on the Brazilian bucket-wheel excavator

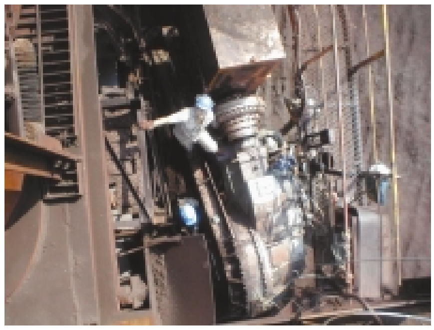


Figure 2: Calibration of the strain gages measurement location

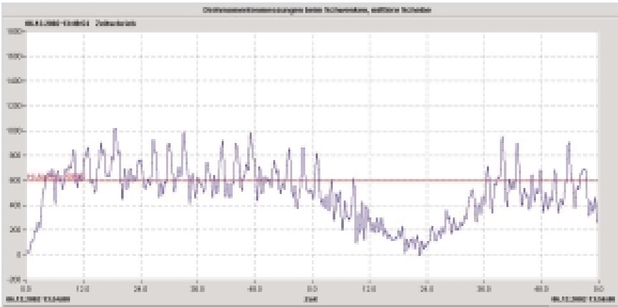


Figure 3: Example of torque measurement over 2 minutes

Figure 4: Unbalanced tooth damage on the internal gear

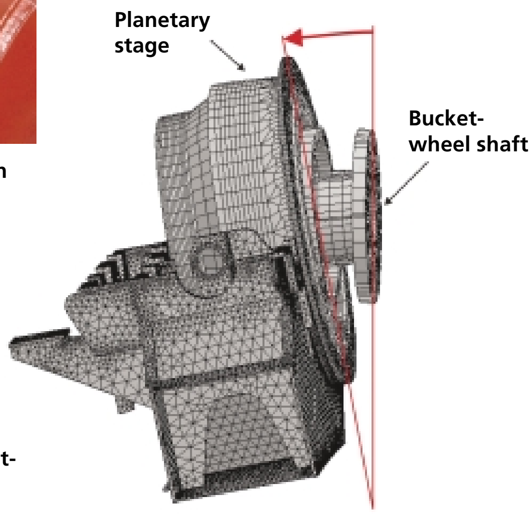


Figure 5: FEM model of bucket-wheel gear

Since then, a year has passed. The modifications were implemented and housing cracks no longer appear. The larger shovels used by the operator have increased the delivery rate as desired.

PRÜFTECHNIK Technologie

Online vibration diagnosis and load monitoring on bucket-wheel excavators

Mathias Luft, PRÜFTECHNIK

Figure 1: 80 ton gear on the main drive of the bucket wheel

In four active surface mines in the Lausitzer brown coal mining district, the Vattenfall Europe Mining AG mines 59.3 million tons of raw brown coal (status 31.12.2002). This represents 33% of the German brown coal requirement.

For years, the main aggregates such as bucket-wheel excavators, belt stackers and belt drive stations have been equipped with systems for operative diagnosis in the early detection of problems in mechanical and electrical units. Currently, the main drives of bucket-wheel excavators are changing over to a standardized concept. This opportunity can also be used to upgrade the systems for online vibration monitoring as an integral part of the operational diagnosis.

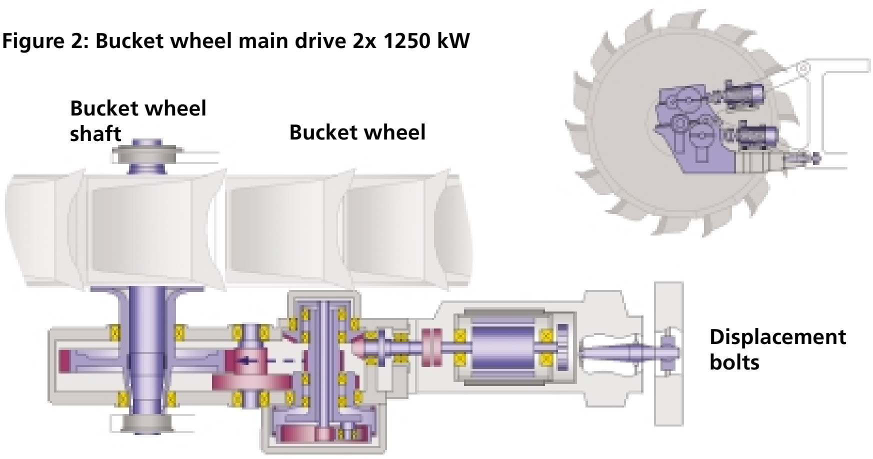
The practical implementation on one of the two largest bucket-wheel excavators is described at this point.

Operating conditions

In the part cut, bucket-wheel excavators are used for the removal of the first tailing stage. The aggressive loads on the bucket wheel can be particularly problematic, e.g. if the soil properties change from sandy soil to a strong loamy soil or larger boulders are excavated. In addition to the monitoring of the rolling bearings and meshings of the main bucket-wheel drive, therefore, the acquisition and monitoring of the highly dynamic changing loads has special significance.

The main drive of the bucket wheel of the large excavator being monitored has two drive motors, each with 1250 kW drive power and gear which weighs approx. 80 tons (Fig. 1). The gear reduction of each drive is realized by a bevel gear stage and subsequent planet gear stage with load distribution via a turning stage. This transfers the drive torque to the gear via four pinions and further to the bucket-wheel shaft via the hollow shaft (Fig. 2).

Figure 2: Bucket wheel main drive 2x 1250 kW



Torque monitoring on the displacement bolts:

The digging forces place a strain on the buckets and, thus, the drive torques of the gear which are supported on the bucket wheel bearing and on the displacement bolt that acts as the torque arm of the gear. A feature of the online monitoring installed is the measurement of this torque on the displacement bolt with the aid of a strain gage measurement bridge (Fig. 3).

As soon as larger or even unacceptably high torque peaks occur, the corresponding time domain of the torque signal is pre-triggered and post-triggered, and saved together with the curve of the load, speed and the displacements with prehistory and posthistory. This is carried out by an automatic event recording function. If necessary, the saved event can be examined more closely (Fig. 4).

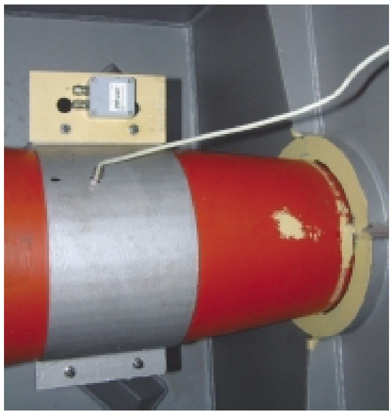


Fig. 3: Torque measurement

Wear monitoring on the bearings of the driven shaft

The main monitoring task on the very slow-speed roller bearing drive shaft (3.6 rpm) is the detection of critical wear limits. For this, two inductive displacement sensors were installed at less than 90 degrees on each of the two sides to directly monitor displacements due to changes in load and increased amounts of play.

Glossary of terms

Did you know?

Web service
A Web service provides services via networks (LAN, Intranet, Internet). W3C protocols are used for communication and support. The special feature of Web services is that they are generically compatible and mesh with one another because they all use the same open standards for communication.

W3C (World Wide Web Consortium)
The definition of the Internet protocol is made by the independent World Wide Web Consortium (W3C), which, in addition to Sun, IBM, Microsoft and Apple, includes a further 400 companies and institutions.

W3C Web Service UDDI protocol
(Universal Description, Discover, Integration) for the publication, finding and integration of Web services.
WSDL (Web Service Description Language) For the descriptions of Web services.
XML (EXtensible Markup Language) is the notation for the transport of data.
SOAP (Simple Object Access Protocol) for XML-coded calls of Web services.
HTTP / SMTP (HyperText Transmission Protocol / Simple Mail Transmission Protocol) is the transport protocol of the Internet.
TCP/IP (Transmission Control Protocol / Internet Protocol) is the network protocol of the Internet.

Web service security
For the transport security of Web services without additional hardware costs, SSL (Secure Socket Layer) encoding with code lengths of up to 1024 bits is available. Firewalls and VPN routers can also be used without any problem. Access to Web services can be individually restricted according to user or user group.

JAVA
Java is an object-oriented and platform-independent programming language that was introduced by Sun Microsystems in 1995. Meanwhile, it has become the standard programming language for web-capable software. Meanwhile, leading software companies such as SAP and MRO (MAXIMO) have changed over to JAVA.

JAVA Webstart
Java Webstart is a new technology by which Java software can be distributed from a central location (Server) to the user PCs (Clients) where they can be continuously updated. As soon as a user connects with the server, JAVA Webstart automatically checks that all necessary program parts are available and whether they are up to date. If necessary, the relevant parts of the program are automatically transferred to the client and stored there.

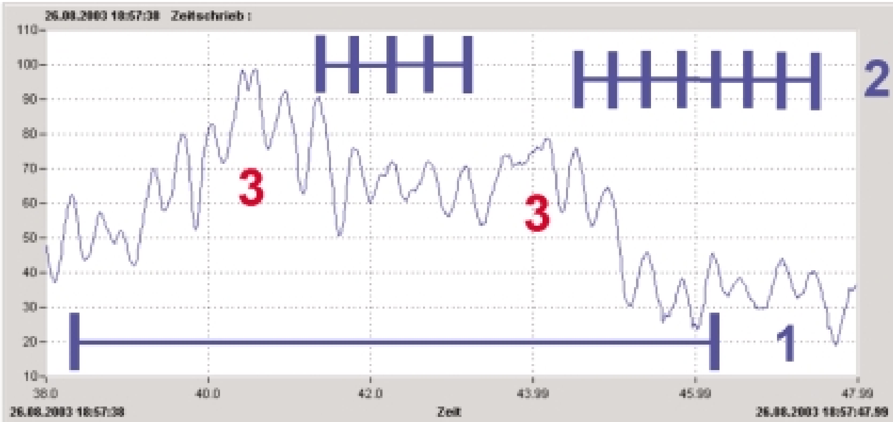


Figure 4: (1) Period for a revolution of the bucket wheel
(2) Periodic engagement of the buckets at negligible load
(3) Transient drop in speed due to heavier torque loads

Monitoring of the rolling bearings and meshings

Vibration transducers have been installed on the motors, gear input stages and intermediate shafts to monitor them.

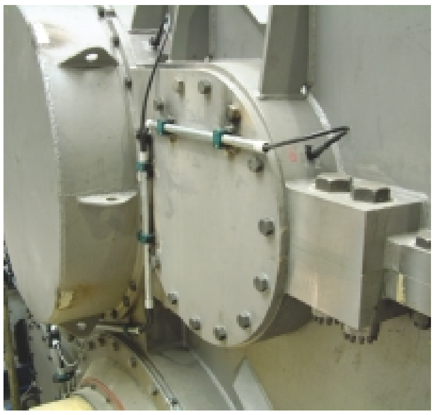
In addition to frequency-selective characteristic vibration values, the online system at regular intervals also saves a complete set of in-depth diagnostic signals (time signals, amplitude spectra, envelope spectra) that are only measured at representative load and speed. This furnishes the diagnostic specialist with a current set of data at any point in time, even when the bucket wheel excavator is not currently in operation.

If an alarm occurs, the operation monitoring is automatically immediately notified. A complete set of in-depth diagnostic signals is also measured at the affected measurement points in order to later evaluate the cause of the alarm with the details of the event.

System connection

The central measurement system is located in the VIBRONET® control cabinet immediately behind the main drive and connected via fiber optic cable with the factory-wide Vattenfall network. This network also enables PRÜFTECHNIK to access the online system at any time.

Displacement
Inductive displacement sensors on the hollow shaft



Vibration
Accelerometers on rolling bearings

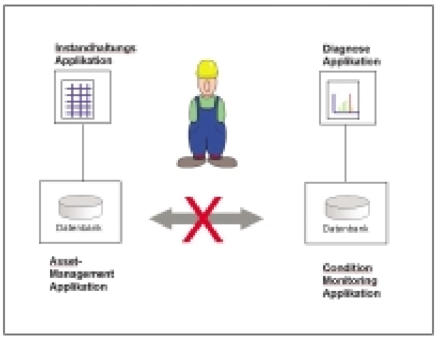
New technology

Uniting information systems with Web services

Roland Schühle, PRÜFTECHNIK

Firstly, in order to understand the advantages of this new technology, the user must be aware of the problem:

For example, in many of today's main-



tenance departments, machine and system data are still entered in Asset Management systems and in Condition Monitoring systems. In addition to the high expense of maintaining both sets of data, the responsible maintenance engineer must also be trained in the respective software packages. However, networking both systems can only be realized with high programming expenses and covers only a small part of the necessary functionality.

Then if external diagnostic specialists are also integrated, it is difficult for the maintenance engineer to integrate measurement results and reports (which are mostly supplied on paper) into the existing data systems.

A solution to this problem could be as follows

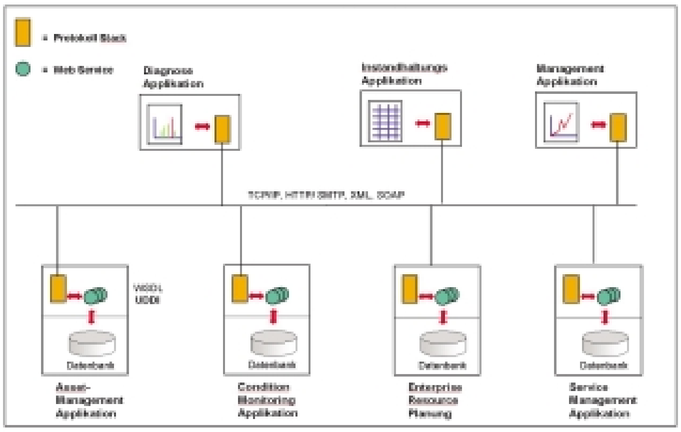
The maintenance engineer works with one software program, and data which are entered only once such as asset names, bearing data, measurement results or diagnostic reports are available in all systems. In the ideal case, the manufacturer, operators, maintenance engineers and service all use the available machine, service and diagnostic information for their planning and decision-making. For the respective subareas of a company, there is a multitude of specialized information systems

- Condition Monitoring Database Systems (CMDS)
- Operating Data Recording Systems (ODRS)
- Condition-Based Maintenance Systems (CBM)
- Service Management Systems (SMS)
- Maintenance Planning and Control Systems (MPCS)
- Production Planning Systems (PPS)
- Asset Management Systems (AMS)
- Enterprise Resource Planning Systems (ERP)
- Knowledge databases and expert systems

However, any interdepartmental or site-wide integration of the information systems mostly fails due to the high technical demands and the negligible degree of standardization. In some cases, data must be transferred manually between the systems so that the respective projects frequently fail due to a lack of acceptance by the users.

Naturally, these problems are not new and in the past there were a number of solution approaches such as Corba. However, unlike the Internet, none of these solutions became a general standard.

In the Internet, the most varied information can be called in the form of HTML pages. Information such as images, tables and texts can be easily absorbed by the user, even if something changes in the design of the page in the meantime. However, for computers, such changes would have been fatal until now as their software would first have to be adapted.



To solve this problem, the new Internet protocols SOAP, WSDL and UDDI were defined by the World Wide Web Consortium (W3C) that together with TCP/IP, HTTP, SMTP and XML form the basis of Web services.

Web services create a system-independent communication level on which the most varied databases and services can be linked via existing network computers to form an information system. At the same time, it does not matter how the data are saved on the individual systems and in which programming language the system is realized.

Meanwhile, Web services are available in all common programming languages and already integrated in several data management systems. Web services can be realized at low cost as the technical requirements are low, and the hardware for it does not have to be renewed and most systems are networked anyway.

In the areas of Asset Management, Resource Planning and Condition Based Management, Web services are also already integrated in the following products:

- MAXIMO® from MRO,
- mySAP ERP® from SAP
- FLEDAS® from FLENDER
- OMNITREND® from PRÜFTECHNIK

Preview

Our next edition covers the main field of extruder technology:

CM application: Reducing vibrations on twin-shaft extruders

CM technology: (Remote) Monitoring of oil qualities

CM application: Vibration monitoring via the Internet on the world's largest single-shaft extruder in Malaysia

CM application: Alignment of high-speed extruder drives

Level 1 Condition monitoring experiences

Easy: Monitoring contact patterns in bevel gear stages

Dr. Edwin Becker, Flender Service

Bevel gears are readily used in materials handling technology if the crossed bearing of the drive and output shafts offers advantages over the parallel arrangement. In the case of bucket wheel main drives, the so-called shear angle is greater and, in belt drive stations, very compact belt drives with drive powers up to several MW can be constructed using bevel/helical gears as shown in Fig. 1. The disadvantage of bevel gears is that the bevel pinion is mostly cantilevered, reducing the contact pattern, transmission performance and balance. Consequently, in the case of gears with bevel gear stages, the meshing frequency of the bevel gear stage often dominates the vibration and noise spectra which also means, however, that the running and operating characteristics of bevel gear stages can be very well monitored with regard to vibration.

Fig. 1 shows the three typical measurement points required to estimate information on the current operating and vibration response of bevel gear stages. Naturally, a stable sensor connection and the use of sufficiently high measurement times are important. Therefore, before making any mobile measurements, check the adhesive force of your magnets. Any dirt must be removed and the sensor must not tilt. Both amplitude spectra of the vibration velocity and envelope spectra should be used as diagnostic procedures. A minimum measurement time of 10 seconds and a frequency resolution of 8100 lines in the frequency range up to 3 kHz must be used to also safely resolve sidebands. If the amplitudes in the meshing frequency and/or in the harmonics then change over the operating time of the bevel drives, the contact pattern has most certainly shifted to the bevel drive. However, in bevel gears, a good contact pattern is the crucial requirement for a long lifetime. So if there are changes in the vibration spectra, the vibration diagnosis should be complemented by an inspection of the contact patterns and, if necessary, the flank clearances increased. Fig. 3 and Fig. 4 show correct contact patterns of bevel drives. If the tooth patterns in the bevel drive do not look like this, actions such as axle positional corrections on the bevel pinion and on the ring gear can still be taken to reset the contact pattern. Fig. 4 shows examples of the measures which can be taken to longitudinally displace the contact pattern. The arrows in the middle show the corrective measures required to achieve the optimum contact pattern as shown on the right. Before carrying out any new adjustments, however, the amplitude spectra of the envelope should be checked. If increased bearing clearance is present in the ring gear shaft and/or in the bevel pinion shaft, a bearing change must be planned because, in the case of bevel drives, increased bearing clearance very often changes the contact pattern. Increased bearing clearance is best identified in the envelope spectra. If pronounced rotational frequency excitations are present in the envelope spectra and first sidebands around the meshing frequency in the vibration velocity spectra, this indicates increased bearing clearance. Moreover, when carrying out corrections, the module-dependent flank clearances must be kept. For example, in the case of Module 8, a flank clearance of roughly 0.18 to 0.20 mm should be kept and, in the case of Module 16-18, a flank clearance of approx. 0.40 to 0.45 mm should be kept. After successful correction, the typical elliptical contact patterns are reached again and the vibration values in the vibration velocity spectra are lower again. If you discover further fluctuations in the contact pattern of your bevel drives or increased vibrations from the bevel drive, contact us at info@flender-cm.de. ■

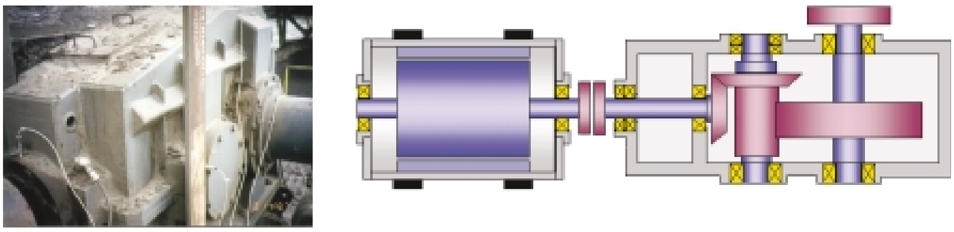


Figure 1: Typical sensor positions during vibration analyses on the bevel drive

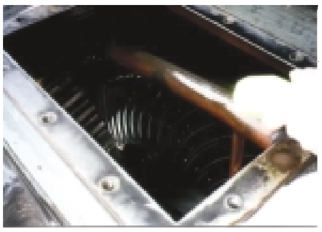


Figure 2: Gear with open inspection hole cover

Fig. 3 Ideal result of the contact pattern check

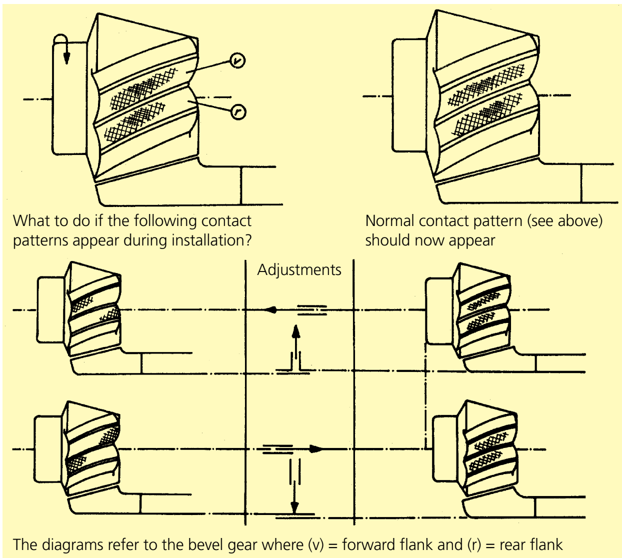


Fig. 4 Contact patterns of bevel drives can be adjusted

Level 2 Condition monitoring

Unbelievable: Resonances and their enormous force

Mathias Luft, PRÜFTECHNIK

PRÜFTECHNIK was called in to evaluate damage on a supply air ventilator. The site was a scene of destruction and devastation.

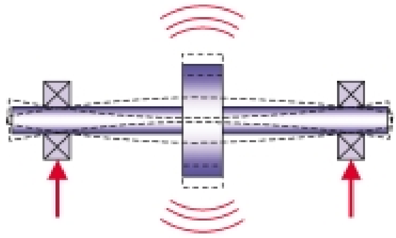
Both pedestal bearings of the ventilator shaft had been torn off and hurled away. The 80 mm thick shaft was bent by approx. 30 degrees on both sides of the impeller. The impeller itself had run into the left and right suction cones, completely destroying them and was itself badly dented. All fan belts were torn – in short, this aggregate was a total write-off. What had happened?

An important clue was the evidence from the operator who said the damage had occurred during the startup of the ventilator. As a ventilator of the same type was in operation nearby, it was possible to record a so-called Bode diagram or run up curve. This measurement records the amplitude of the rotational frequency vibrations (i.e. the part of the vibration caused by imbalance) as a function of the speed. It revealed a trend that indicated the crucial circumstantial evidence for the reconstruction of the damage progression (Fig. 1, right). At approx. 1130 rpm, and thus below the operating speed of 1300 rpm, a sudden rise in the rotational frequency vibration amplitude to more than 80 mm/s (!!) appeared which then abruptly fell again above this critical speed. Consequently, the signal path corresponds precisely to the behavior of a rotor when passing through its 1st flexing intrinsic vibration (Fig. 2). In addition to the distinctive rise in the rotational frequency vibrations, the phase rotation of 180 ° is especially typical.

It was clear from this that only a rotor resonance could have been the underlying cause of the damage. However, the actual cause could have been increased imbalance of the impeller that could still have been absolutely permissible at the operational speed, but caused too large a vibration excitation when passing through the resonance point.

How high the vibration increases at the resonance point depends mainly on the damping of the rotor and on the dwell time in the area close to the point of resonance. Heavy rotors such as the turbine rotors of large steam turbines require more time to build up to high vibration amplitudes than, for example, light impellers. Thus, in addition to the optimum balance of the rotor, rapidly passing through the point of resonance is also a key factor in avoiding unacceptable vibrations near the point of resonance.

Anyway, if the resonance point of the rotor is to be shifted, constructive changes are essential. In this case, the changing of the rigidity, the mass or the bearing spacing are the most important parameters although such measures are often not possible for cost reasons. However, as an additional measure in variable-speed aggregates, at least the speed range close to the resonant frequency must be blocked in the converter control unit.



Vibration form of a rotor

Amplitude curve

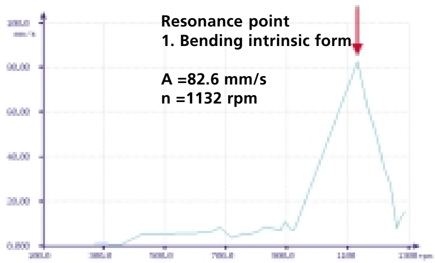


Figure 1

Bode diagram / Startup curve

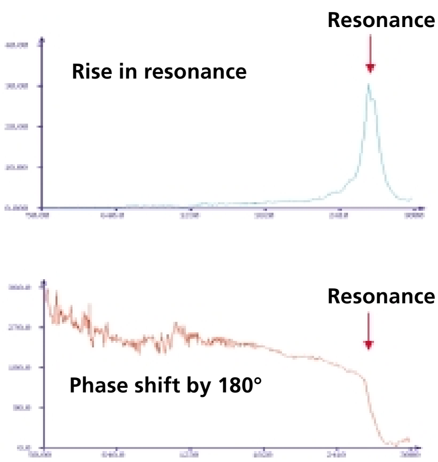


Figure 2

News

AddiControl® for analysis of oil qualities

Flender Service first introduced the AddiControl® to the general public at the 14th. International tribology conference in January 2004. The smell of the oil is measured to analyse the type of gear oil which is used, whether prohibited mixtures of oils are present or whether the additives are still OK.

GearController® for M/Y 'Limitless'

Flender Service supplied two GearController® units and the OMNITREND® software for the online monitoring of the gear and bearing conditions of one of the 10 largest private yachts in the world. Mounting and commissioning were required at very short notice and were immediately carried out on the Baltic sea by specialists of Flender Service and PRÜFTECHNIK Condition Monitoring.

PRÜFTECHNIK reorganizes domestic sales

The constantly growing range of products and ever growing demands in technical sales made reorganization of the PRÜFTECHNIK domestic sales division necessary, with the specialization of the sales team to a product segment each (Alignment or Condition Monitoring). Also in the future PRÜFTECHNIK customers can expect more competent technical advice and assistance in solving problems. With the reorganization of the domestic sales division in Germany, PRÜFTECHNIK has strengthened its position in the home maintenance market.

Relocation to a new Condition Monitoring Center

The Flender Telediagnosis Center has also moved into new premises and was technologically modernized at the same time. The move provided Flender Service with the ideal conditions for tackling the impending certification as a condition monitoring center by Germanischer Lloyd.

OMNITREND® goes variable

The new 1.80 version of OMNITREND® now also includes diagnostic functions for machines that work with variable speed and loads:

- Operating conditions
- Order spectra
- Cepstrum for gear diagnosis

Download your update (free of charge) from www.pruftechnik.com

Effective machine protection with VIBROTECTOR®

VIBROTECTOR® is the ideal vibration monitor for all machines that operate under almost constant operating conditions such as:

- Fans
- Ventilators
- Pumps
- Electromotors

new

VIBROTECTOR® records broadband machine vibrations and hands over the resulting characteristic value to the connected process control system as a current level (4-20 mA). This value is compared with the selected alarm thresholds and, if exceeded, warns operating personnel.

VIBXPERT® – new FFT data collector & signal analyzer

The new 2-channel analyzer was introduced at the Hanover tradefair. Information is also available on the Internet under: www.pruftechnik.com.

Dates

PRÜFTECHNIK AG and Flender Service:

Visit us at the following international trade shows and exhibitions:

WindEnergy Hamburg
with Flender Service at Booth 240 of the Winergy AG in Hall 6 on 11th - 14th May

PetroTech 2004
Rotterdam, Holland, 25th - 27th May

PulPaper 2004
Helsinki, Finland, 1st - 3rd June 2004

Practical seminar: "Condition Monitoring for the wind energy industry"
with PRÜFTECHNIK and Flender Service on 18.06/ 19.06 in Rostock and on 01.09/02.09.2004 in Hamburg

Special seminar "Modern Gear Service"
with Flender Service in Damascus/Syria on 26.04 and 28.04.04

Zellcheming 2004
Wiesbaden, 28th June - 1st July 2004

SMM 2004
Hamburg, 28th September - 2nd October

VDI conference "Electromechanical drive systems"
with Flender Service in Fulda on 06./ 07.10.2004

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