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In this edition:

PRÜFTECHNIK News

CMS: An important onboard tool

Every newly GL-certified offshore wind turbine must be equipped with a suitable Condition Monitoring System (CMS). Why, then, shouldn't ships on the high seas be able to rely on this type of monitoring technology as well? Marine drives are subject to similar availability requirements as are wind turbines.

This calls for far-sighted policy on the part of the manufacturers and operators of ships, where accelerometers are not as easy and sometimes almost impossible to retrofit e. g. on inaccessible thrusters – including azimuth thrusters. In this issue of *telediagnose.com*, we will briefly introduce the capabilities that CMS technology offers for condition-based maintenance on ships.

Condition Monitoring Service

Iron content in thruster gears

Dr. Edwin Becker

When analyses of oil filters and oil reveal a raised metal content, this immediately suggests that damage of some type has occurred. Especially when dealing with gears, the damage should be identified as soon as possible to permit assessment of failure risk and remaining service life. Limits for metal content, as they typically arise in gear oils, are shown in Table/Diagram 2. However, caution should be exercised in the use of these limit values if information on the oil quantity is not available. While an iron content of 20 ppm in a gear with 20 liters of oil is harmless (= 400 mg), the same content in a gear with 500 liters of oil can indicate an acute operational risk (= 10 g).

Let us look at a specific case as it occurred out in the field: During a routine oil analysis on a tanker, a raised oil content was discovered in an azimuth thruster gear. Although an oil change was performed immediately, the classification society demanded that the entire thruster be replaced. Because this would have meant an unscheduled dry-docking of the tanker, a less costly alternative was sought.

The shipowner and classification society ultimately agreed to contract a specialist for in-depth diagnosis to determine the cause of the raised level of wear. A great asset to this endeavor was the fact that vibration levels were already being measured and archived on a regular basis as part of the condition-related maintenance program in place on the tanker.

The PRÜFTECHNIK Diagnostic Center was contracted to evaluate the existing vibration measurements and to perform additional in-depth measurements, including videoscopic inspection where necessary, on all thrusters.

On the high seas off the Scottish coast, systematic measurements were taken using the VIBXPERT® mobile data collector and a temporarily installed VIBNODE® online CMS. They revealed typical and atypical excitations in the vibra-

Fig. 1: Condition analysis of oil filter after removal

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tion spectra of the azimuth thruster. Although sensors were not installed in the lower part of the thruster, the gear mesh frequency of the lower bevel gear could still be determined despite the long distance of travel of the structure-borne sound. Of concern were the high levels of vibration in the long spacer shaft, which were identified both in the vibration velocity spectra and in the envelope spectra. Possible causes were local tooth damage, bearing wear and wear in the gear coupling. To isolate the cause, systematic measurements were taken using the VIBNODE® online CMS. The purpose of these measurements was

Fig.3: The VIBNODE® online condition monitoring system was installed temporarily

to determine how the running characteristics, the vibration behavior and the disturbing frequencies of the azimuth thruster changed as a function of varying loads and rotational direction.

Tooth damage was ruled out by the in-depth diagnosis measurements. *'The iron content can definitively be attributed to coupling tooth wear. Therefore, the tanker can continue to be operated without risk until the next scheduled shipyard layover'* – in the words of Dr. Becker, who made the final diagnosis.

The results were documented in a report for the classification society. The shipowner was given the OK to continue operating the tanker until the next scheduled dry-docking, under the condition that vibration measurements and oil analyses be made on a regular basis. A year on, the diagnosis confirmed itself – the iron content in the oil had normalized. ■

Metal	Possible sources in gears	Limit values in mg/kg (ppm)		
		Mobile industrial gears	**Stationary industrial gears**	**Worm gears**
Iron (Fe)	Gear wheels, roller bearings, oil pumps, guides, cast housings, piping, welding residue	15 – 850	50 – 1500	10 – 220
Chromium (Cr)	Roller bearings, multiplate clutches, alloy component (high strength gear wheels)	2 – 40	4 – 60	2 – 35
Aluminum (Al)	Worm wheels (alubronze), couplings, oil pumps, friction lining from couplings or brakes	5 – 250	8 – 300	5 – 600
Copper (Cu)	Worm wheels (bronze), plain bearings, roller bearing retainers, coupling lining, piping, oil coolers, synchronizing disks, seal rings	10 – 180	5 – 360	6 – 600
Lead (Pb)	Plain bearing running surfaces, bronze wear debris, synchronizing disks, rarely EP additive in old oil	3 – 80	6 – 145	15 – 90
Tin (Sn)	Plain bearing coating, soldering joints, component of ester oils	2 – 40	2 – 60	2 – 35
Nickel (Ni)	Gear wheels, alloy component of special steels, high strength gear wheels	2 – 25	2 – 35	2 – 15
Molybdenum (Mo)	Synchronizing rings, EP and AW additives with an organomolybdenum base, MoS_2 additives, special steels	3 – 500	10 – 500	5 – 25
Zinc (Zn)	Filter cores, galvanized piping, paint, additive with an organozinc base	15 – 400	18 – 450	40 – 600

Fig.2: Limit values for specific types of metal content

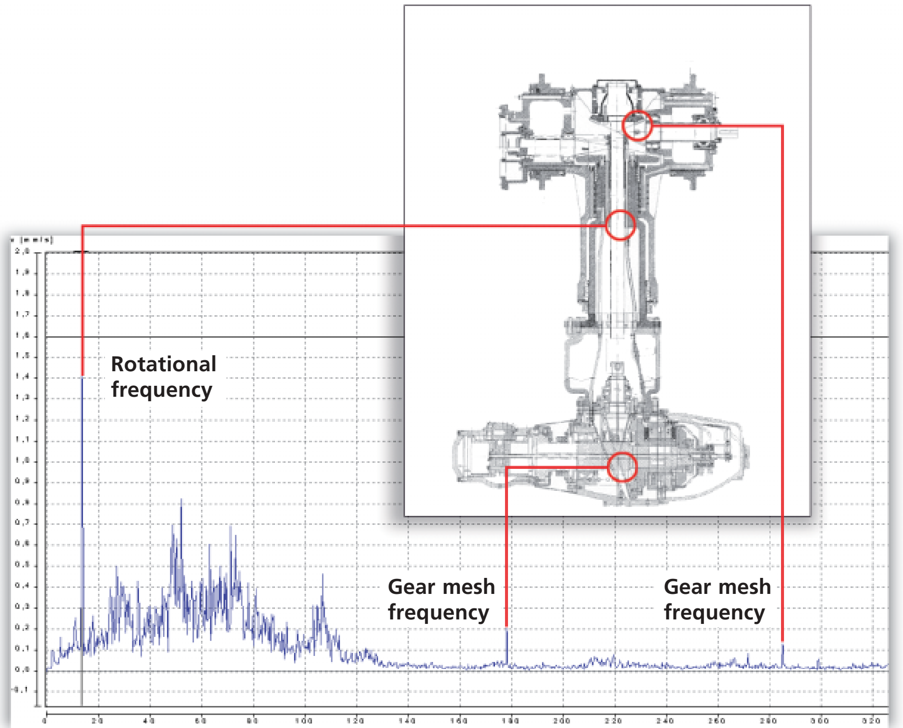


Fig.4: The velocity spectrum showed increased excitation of the long spacer shaft

Condition Monitoring Technology

Reducing vibrations and structure-borne sound levels

Dr. Edwin Becker

Ships are subject to general vibrations throughout their hull, localized vibrations caused by the machines operating aboard ship, and primary and secondary vibrations generated by structure-borne sound propagation. Frequency-based measuring instrumentation and evaluation software can be used to record the vibrations and identify dominant vibration exciters.

Ship vibrations

In addition to heave, pitch and yaw, roll and sway are the major types of ship vibration (Figure 1). These vibrations generally lie between 1 Hz – 90 Hz and are a function of the ship's design, loading condition and the state of the surrounding water. Depending on how the vibrations enter the human body, they result in vibrations that either propagate throughout the body or are concentrated in specific body areas or organs. While vibrations above 90 Hz are 'merely' an irritation, low frequency vibrations even of mild intensity can have a negative influence on the human organism, causing considerable discomfort and, in the case of long-term exposure, leading to health problems. In ships, therefore, it is necessary to measure and evaluate, under specific conditions, the frequency-weighted RMS values of the vibration acceleration as a function of the direction, daily exposure time and vibration type.

Machine vibrations

Onboard machines and systems can cause localized vibrations in the ship or lead to discomfort from structure-borne sound propagation. As a general principle, it is therefore important to design hulls and machine foundations that are low in vibration and whose drive and machine components exhibit minimum vibration levels. This means that in engines, gears and machines, frequency-weighted structure-borne sound levels of the vibration velocity are increasingly becoming a competitive factor and a purchase argument.

Measuring structure-borne sound levels

Frequency-weighted structure-borne sound levels can be calculated from the measured vibration velocities according to the following formula:

$$L_v = 20 \cdot \log\left(\sum \frac{v_x}{v_0}\right) dB$$

$v_0 = 5 \cdot 10^{-08}$ m/s
(acc. ISO 1863: $v_0 = 10^{-09}$ m/s)

Figure 2 shows how accelerometers were positioned on the base of a diesel engine during acceptance measurements for the purpose of recording frequency-selective structure-borne sound levels.

It proved to be valuable that very narrow-band frequency spectra are recorded alongside third octave bands, as shown in Figure 3. Engine and ship manufacturers not only receive information on the structure-borne sound levels, but also obtain measurement results that can be used to identify the dominant exciter. Design and development engineers can use this information to decide on active measures for reducing vibration or passive measures such as housing reinforcements and flexible struts. Acceptance measurements of this type are among the services offered by PRÜFTECHNIK. ■

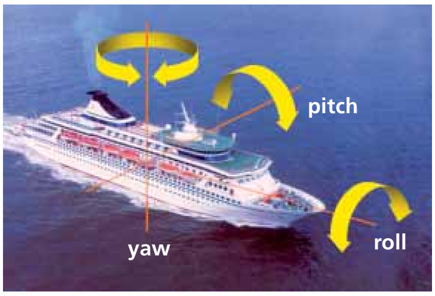


Fig.1: Typical ship vibrations

Fig.2: Accelerometers installed on a diesel engine base

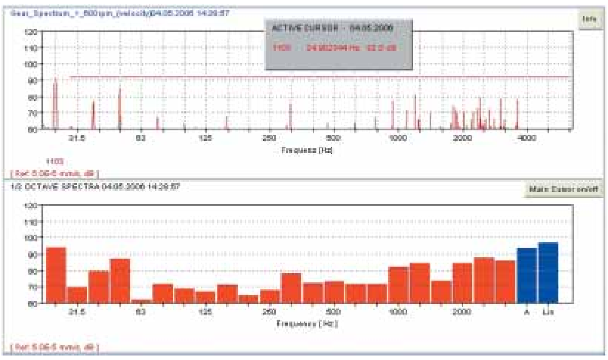


Fig.3: Third octave and narrow band spectra of an acceptance measurement

Condition Monitoring Technology

Implementation of Condition Based Maintenance (CBM) on s

Johann Lösl

Condition Based Maintenance (CBM) has become a standard method of machine monitoring in many sectors of industry, and its advantages have been reported in numerous trade publications. In the field of marine technology, CBM not only offers well-known benefits such as the avoidance of unplanned machine failure, but also features a significant cost-saving advantage: Certain machines aboard a ship must be regularly inspected and tested for fitness by classification societies such as DNV, GL and ABS. Lengthening of the inspection intervals is only approved if the inspected machines are monitored with CBM technology, the crew has been trained in operating these devices and the data are collected regularly. As well, the measurement data must be analyzed by trained personnel. In general, machines can be monitored by offline or online systems. Which system is used depends on the significance of the machine, official regulations and, finally, the user.

Offline systems aboard ships

Machine condition data are measured regularly every 6 – 8 weeks. The device for collecting and evaluating data consists of a portable data collector and associated PC software. The measurement routes are configured on a PC and then loaded into the data collector. Getting reproducible results with offline measurement systems is a challenge that calls for certain precautions. Ideally, the data should always be collected by the same well-trained crew members, a policy that will ensure a consistently high quality of data. However, because taking vibration measurements is only one of many tasks that a crew member must accomplish, it is questionable whether obtaining high quality data will always receive top priority. In this context, systems that are easy to operate and that rule out incorrect measurements are invaluable. Incorrect measurements can occur, for example, when measurements are taken at the wrong location, in the wrong direction or if sensors make poor contact. In addition to the magnetic mounting of the sensors, permanently affixed measuring pins are the best solution for collecting reproducible measurements of vibration signals. To reliably identify measurement locations, systems with barcodes and coded measuring pins – such as VIBCODE® measurement locations – have proved highly effective.

Interpreting measurement data correctly

For reasons of crew capabilities and capacities, the data is almost never evaluated onboard ship. The OMNITREND® PC software makes it possible to export the data to a file as they are being read out of the data collector and immediately forward them in an eMail to a recipient at the operator headquarters or Diagnostic Center. The data base on the ship is thus a copy or subset of the main data base on land. In return, changes to the measurement parameters can also be made via a file. Thanks to this 'offline synchronization' via eMail, the communication paths do not need to meet any special requirements. The data quantities are small, keeping transmission costs low.

On a ship, access rights to the OMNITREND® PC software can be restricted so that the only tasks available onboard are the transfer of the measurement route to the data collector, the viewing of data and the generation of certain reports. The CBM program is fully controlled by the specialists at the headquarters or by the Diagnostic Service Partner. The crew still retains control over data collection and can, if desired, inspect machines with an alarm condition and evaluate trends. The diagnosis of 'critical' machines is performed by specially trained personnel.

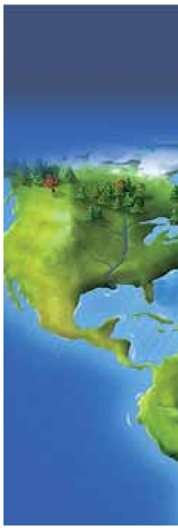
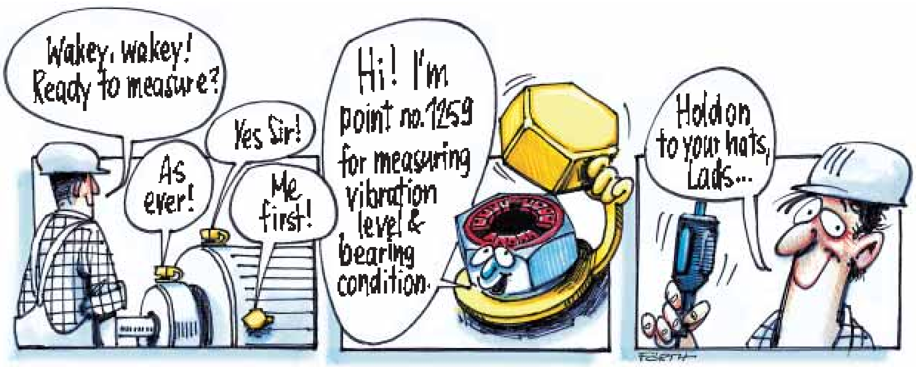


Fig.2: The measure
provider



Monitoring concept

Generally, characteristic overall values for the machine vibrations (e.g. according to ISO 10816-3) and roller bearing condition are recorded for the purpose of using their trends to detect a change in condition. A more in-depth machine diagnosis requires additional signal measurements (spectra & envelope spectra).

Fig.1: VIBCODE® stud

100% reliable connection

The patented VIBCODE® sensor provides absolute measurement reliability by ensuring reproducible measurements at unmistakable measurement locations.

When inserted, the sensor system automatically recognizes the measurement location and knows which measurement settings to use. The measurement location is coded by simply removing certain teeth from the red code ring.

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ships

ment data are evaluated on land at the operator headquarters or by a service

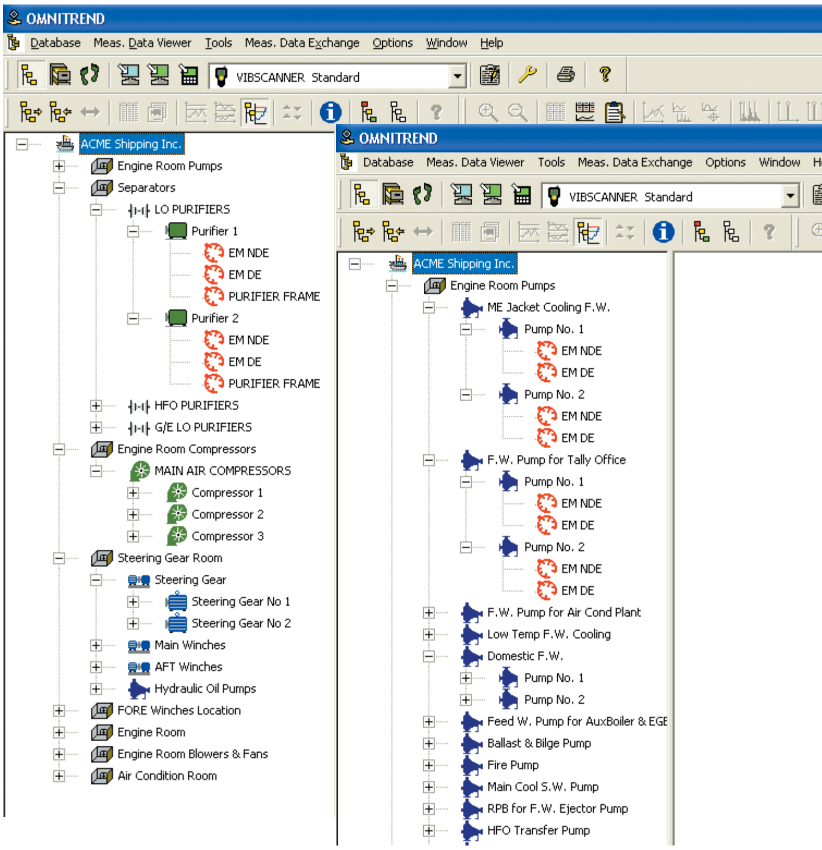


Fig.3: The tree structure in the OMNITREND® software shows all components monitored on the ship

Online systems aboard ships

The installation of online systems on ships is only justifiable for certain machines or areas. These include, for example, drive trains, inaccessible thrusters and important auxiliary units in the engine room (engine room fan, main generator, turbocharger and fuel centrifuges).

In certain types of ships such as cruise ships or car carriers, online monitoring of inaccessible ventilation systems is highly recommended.

With today's technology, online monitoring can be easily integrated into the ship information system. The onboard network infrastructure is usually Ethernet-based. This communication channel can be used for fieldbus protocols such as Modbus TCP or Ethernet-supported protocols typical for marine applications. By these means, certain characteristic values and status information can be displayed in the control room. ■

Fig.4: Vertical pumps equipped with 4 VIBCODE® measurement locations each

Fig.5: Offline measurement on the ventilator side of the motor bearing using VIBSCANNRT®

Alignment Application:

Bearing race measurement following crankshaft bearing damage

Ole Holstein

After the catastrophic failure of a reciprocating engine such as a marine diesel engine, the question is always whether the engine block bearing race was damaged and, if so, to what extent.

A quick decision is then required on the necessary scope of maintenance: Is the crank shaft bearing race damaged? If so, what repairs are necessary?

Whether or not the right measures were taken will become clear no later

Fig.1: Laser equipment for monitoring the bearing saddles

than the final check, in which the crankshaft deflection is measured. If the crankshaft does not run properly at this juncture, there will only be a limited scope of corrective measures that can be taken. And this can lead to considerable expense.

'Time is money' and 'only as much as is absolutely necessary' are mottos that illustrate the constraints under which the damage is identified and maintenance requirements are calculated.

A single day of ship laytime costs around 10,000 euros. Depending on the degree of damage, repair costs may result in additional expenses of up to 500%, which is why the damage should be identified as precisely as possible.

In addition to bearing race alignment, the roundness of the bearing seat should be checked for deviations. This requires damage pattern measurements that provide information on the geometry of the bearing block: In what way is the bearing seat deformed? To what extent and where is the geometry out of round? This information is vital to determining the minimum amount of material to be removed if boring should become necessary later on.

With the BORALIGN® laser-optical measurement system and suitable accessories, a bearing race can be measured relatively quickly directly in the ship after the crankshaft is removed. New engine designs with hanging crankshafts are also easy to measure with this system, even in a half shell that is facing downward.

Only after information has been gained in this way is a reliable assessment of the necessary repairs feasible.

Unlike a complete set of drill pipes, which would fill a standard 12-foot container, BORALIGN® can be easily transported to the measuring location in two carrying cases. BORALIGN® achieves a reproducible level of accuracy that is impossible to achieve by conventional methods given a comparable time investment and scope of reporting. In addition, the enormous amount of effort that goes into taking measurements with drill pipes and dial gauges is hardly justifiable, especially when the findings are negative (no repairs necessary). If the BORALIGN® measurements result in positive findings that lead to the conclusion that additional work is necessary, the complete bearing race can be bored using mobile boring apparatus. The advantage is that the boring apparatus is not used unless it is actually required.

When boring, the shaft of the boring equipment must be aligned with the axis of the bearing race by means of additional adjustable auxiliary bearings- he steady rests. At best, only a single bearing block will have to be bored to install an oversized plain bearing. In contrast, even if only a single bearing block were to need correction, conventional methods would still require the entire bore

Fig.2: The laser sensor, which can be rotated inside the bore

shaft to be installed to be able to relate it to the reference axis.

Modern laser measurement equipment can work without an end-to-end bore shaft since the partial segments only need to be positioned on the reference axis in the required working area. Basically, the measurement values are taken at the relevant reference points and the bore shaft is aligned to the (laser-optical) reference axis. After a verification measurement, boring with a 'half bore shaft' will be faster and more cost effective.

This reduces maintenance and transport costs to a minimum. When maintenance work is completed and the final check shows that all measurement values are within tolerance, the measurement technicians and maintenance staff will be proud to have done 'only as much as was absolutely necessary'.

Fig.3: The laser transmitter with magnetic mounts

Condition Monitoring Basics

Torsional vibrations in marine propulsion systems

Florian Buder

Lack of uniformity in diesel engine crankshafts generates torsional vibrations that dangerously resonate in drive systems, potentially leading to the fracture of highly flexible couplings (Figure 1). Further consequences may be increased gear wear, tearing or repeated tooth breakage.


Fig.1: Breakage in a highly flexible coupling


Fig.2: Strain gauges with a telemetric transmission facility – mounted on a ship's propeller shaft

A ship's main propulsion is required to undergo acceptance testing for torsional vibrations. It is state of the art that acceptance runs include torsional vibration calculations and torque and torsional vibration measurements. An inspector generally evaluates the resonance diagrams on the basis of measurements made using strain gauges. In addition to freedom of resonance, the following loads apply for main gears:

1) In the operating speed range (greater than 5% and less than 10%), the oscillating torques in the loaded gear stage should not exceed 30% of the average torque of this stage.

2) When starting up or shutting down the drive, the oscillating torques generated in the gear while passing through the resonance points should not be greater than roughly double the average transmitting torque for which the drive is rated.

3) Load changes due to oscillating torques are generally only permissible when passing through the lower speed range (up to 35%). Unallowable regions must be introduced at higher speeds. Figure 2 shows strain gauges with a telemetric transmission facility mounted on a ship's propeller shaft. The services offered by PRÜFTECHNIK include torque measurement, overload monitoring, determination of load spectra and evaluation of the overall system condition. ■

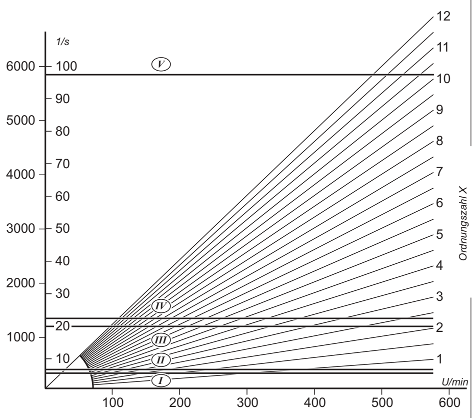


Fig.3: Resonance diagram

Glossary of terms

Did you know?

Sound
Sound is created by wavelike periodic vibrations in a flexible medium. Sound can be differentiated into air-borne, structure-borne and water-borne vibrations.

Speed of sound
The speed of sound is the speed at which sound waves propagate through a medium in meters per second. In air at a pressure of 1 bar and a temperature of 20 °C, sound travels at 343 m/s; in steel, the speed of sound is approx. 5000 m/s and in water at 10°C it is 1440 m/s.

Frequency
The frequency of sound is measured in Hertz and is perceived as the sound's pitch. A doubling of the frequency is equivalent to one octave or three one-third octave bands. In acoustics, the audible range is roughly 10 octaves.

Frequency spectrum
A frequency spectrum is a graph of the frequency components as they evolve over time. It is used to analytically characterize the noise or structure-borne sound. Spectrum types are octave, third octave and narrow band spectra.

Octave band
An octave band is characterized by its center frequency. Common values are 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz.

Level (in dB)
Especially in acoustics, levels are used because the numerical values of sound measurements extend over multiple powers of ten. Level measurement results can be compared if the reference values are known.

Preview

Our next issue will focus on pumps:

Diagnosis experience: Cause analysis of increased pump vibrations on an offshore platform

Technology: Order analysis according to the resampling method

Application: Improving balance quality

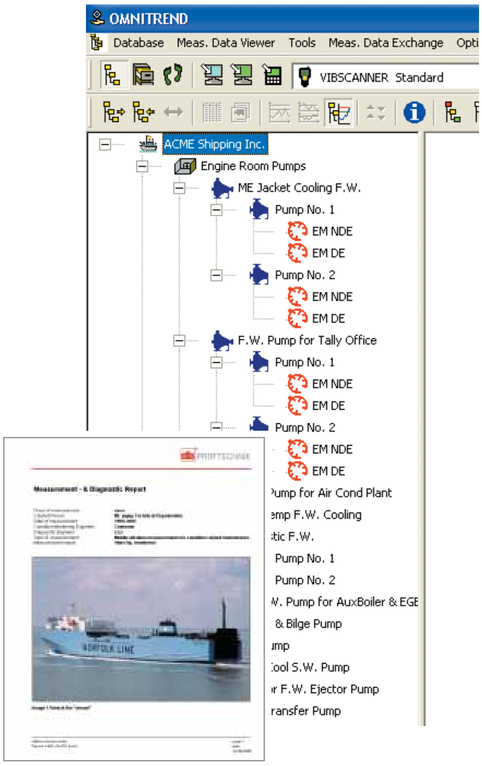
Application: Measuring crankshaft deflection

News

Remote evaluation service for ship measurements

Condition-based maintenance is becoming a standard procedure on an increasing number of ships. Usually, measurements are taken by crew members who work through their measurement routes with the aid of coded measurement locations (e.g. VIBCODE®), which ensure a high degree of accuracy. But who evaluates these measurements? Because a specialist is usually not onboard ship, PRÜFTECHNIK offers data evaluation as a remote service. On the basis of the measurement data made available to them via eMail, specialists at the PRÜFTECHNIK Service Center analyze critical machine conditions and document these in detailed measurement reports.

The figure shows a section of the directory tree, displaying measurements taken at about 120 machines from the deck to the thruster drives. ■



Dates

For dates of trade fairs, seminars and symposia that the PRÜFTECHNIK Group is participating in, please visit our website at www.pruftechnik.com. ■

VIBXPERT® – Now with additional functions

We have equipped the latest version of VIBXPERT® with a series of additional useful diagnosis functions:

- Order analysis
- Orbit measurements
- Impact testing
- Time-synchronous averaging in frequency and time domain
- Cepstrum
- Coast-down / run-up analysis (amplitude /phase, overall, spectrum)

In addition, VIBXPERT® can now be used as a sound level meter for sound source analysis. If, as a VIBXPERT® user, you are interested in this new feature, please contact your sales partner. ■

Condition Monitoring Partner Concept

With mobile vibration measurements being widely offered on the market today, price is only one of several factors to be considered when deciding on a service. Above all, the provider's expertise and experience are crucial to good service. But how can you find the right partner?

As part of its Condition Monitoring Partner Concept, PRÜFTECHNIK has established a wide network of expert service providers in over 70 countries across the globe who will support you in solving your vibration problems.

In addition, we are continuously expanding our Partner Network. If you would like to work with us as a service provider, please contact us at info@pruftechnik.com. ■

PRÜFTECHNIK moves house

PRÜFTECHNIK Alignment Systems is moving from its current address in the Oskar-Messter-Straße to an office building acquired immediately adjacent to the previous location in the Freisinger Straße. In light of the growth that PRÜFTECHNIK has undergone, especially in the last three years, this move has been foreseeable for some time. The new building includes a modern measurement laboratory equipped with highly advanced testing and measuring instrumentation. In addition, it will afford employees a more efficient and pleasant working environment. ■

The building acquired in the Freisinger Straße

www.telediagnose.com

Further issues of the PRÜFTECHNIK Service magazine can be downloaded from www.telediagnose.com. Each issue focuses on an individual industry – these include paper machines, extruders and wind power plants among others. ■

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