

## DOSSIER ON CONDITION MONITORING OF ROTATING MACHINERY



### Expert in predictive maintenance for large turbo groups

Laborelec has been an expert in predictive maintenance for large turbo groups since the 1980s. Vibration monitoring, oil analyses, and thermographic studies are just a few examples of the techniques that we apply to assess the condition of machinery. We also develop new methodologies to improve condition monitoring. The introduction of SmartSignal for a combined follow-up of process parameters is one such recent example. In this edition of Laborelec News you will find an overview of our expertise in assessing turbo group behaviour.

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## RDM simulations helpful in root cause analyses

*What is causing the vibrations on a certain rotating machine? Is it an unbalance or an alignment error? During root cause analyses, Laborelec investigates multiple possibilities. Thanks to rotor dynamic modelling (RDM), our experts can simulate errors and quickly learn which possibilities should be examined first. To do so, our experts first need to build a RDM reference model of the machine in its normal operating conditions.*

### Building computer models of existing rotors

Our experts build a RDM reference model of a specific rotating machine based on available geometrical data. They gather input from the machine's rotor (material, dimensions, etc.) and bearings (dimensions, oil type, etc.). Then they input this data into the MADYN 2000 software. Based on a reduced finite elements method, this programme simulates modal rotor deformations at critical speeds and estimates the dynamic behaviour and forces in the bearings. Laborelec currently has RDM models of a Siemens V94.2 (SSC5-3000E) gas turbine and the Saint-Ghislain shaft line.

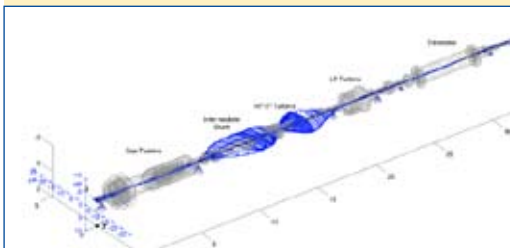
### Root cause analysis based on RDM models

During vibration root cause analyses, our experts use the RDM reference model of a specific machine to simulate various errors that could be causing the large vibrations. Our experts have already used a RDM reference model during a root cause analysis for a generator at the Herdersbrug plant. When large vibrations occurred on the machine after an overhaul, they suspected an unbalance near the excitation end of the generator rotor. When simulating the unbalance in the machine's RDM model, the vibration results matched the real-life readings. A simple balancing correction at a well-defined part of the rotor was sufficient to get the unit up and running again, with minimal unavailability.

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## Indaver oil bath goes bad after only four years

### Discussion with oil supplier and Laborelec to find solution

**Indaver needed to replace its steam turbine's 10,000 litre oil bath after only four years. Discussion with the oil supplier and Laborelec created awareness of the important role of temperature on oil quality. This eventually led to a solution prolonging the new oil's life expectancy.**

Laborelec regularly analyzes the quality of Indaver's steam turbine's oil bath. These tests revealed that the oil's quality had deteriorated so badly after only four years that it needed to be replaced.

The oil's demulsibility had become worrisome, but its water content was still quite normal. In addition, the oil's low rotating bomb oxidation test (RBOT) value indicated weak oxidation stability. Before actually changing the oil, Laborelec scheduled a meeting with the oil supplier and the Indaver steam turbine maintenance staff. Our experts indicated that temperature weighs heavily on the oil's quality. However, continuous measurements of the steam turbine's temperature did not reveal any hot spots or abnormal temperatures. Based on this discussion and the results of Laborelec's regular oil analyses, our experts advised to change the oil during the next scheduled stop. In the meantime they monitored the most critical parameters on a monthly basis.

After emptying the oil bath, the Electrabel maintenance workers noticed a steam pipe underneath the oil basin, which wasn't insulated properly. The pipes were very hot, probably creating a local hotspot in the oil bath. Electrabel decided to insulate these pipes to ensure the new oil bath a longer life expectancy.

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## Gas turbine overhaul contaminates lubrication oil bath

**Phenolchemie Antwerp replaced the lubrication oil bath of its gas turbine during an overhaul. After the oil change, an oil analysis revealed a rather high level of impurity, most likely due to contamination during the refilling of the oil bath. Laborelec's advice to incorporate a by-pass filtration system helped restore the purity level and avoided any downtime.**

After the overhaul and restart of Phenolchemie's gas turbine, our experts conducted an oil analysis to ensure the quality of the new oil bath. This analysis revealed that the oil bath did not meet the pre-defined purity levels.

Our experts advised the incorporation of a by-pass filtration system, intensifying the filtering process. To make sure this would improve the oil's purity level our experts took weekly samples of the oil. These regular oil analyses demonstrated that the additional by-pass filtering had restored the oil's purity level. Hence it was

no longer needed and could be removed. If the by-pass filtering had not improved the oil's purity, the turbine would have had to be stopped for 10 to 12 hours for a boroscopy to find the cause of the fouling. If the boroscopy failed to reveal the underlying issue, the turbine would have even had to be shut down for several days. The extra filtering step and frequent monitoring of the gas turbine enabled to avoid serious downtime.

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## Oil analysis helps determine condition of equipment

**An oil analysis is usually conducted to establish the state of the lubrication oil. However, it can simultaneously be used to assess the condition of the equipment. In a recent case, an oil analysis at the Doel nuclear power plant was the basis for carrying out repair works on a water extraction pump.**

The Doel nuclear power plant has three water extraction pumps on site. Two of them are permanently in service, while the third serves as a backup unit. Each pump is equipped with a 45 litre lubrication oil basin. The Doel maintenance team regularly checks the state of the oil in their own lab. A recent analysis revealed unexpected fouling in the oil bath of one of the pumps. The maintenance team sent an oil sample to Laborelec for a more detailed analysis. Our experts filtered the oil sample and extracted small metallic particles. A close

examination of the particles in one of our electron microscopes revealed that it was white metal, the same material from which the bearings are made.

The Doel maintenance team then opened up the pump and discovered that part of the pump's interior had been scraped off. Since that pump was not in operation at the time, it did not cause any major problems and it could be fixed without any interruption of plant operations.

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## Oil analyses confirm vibration analysis

**In July 2008, the Laborelec vibration monitoring system (LVMS) detected large vibrations on a coal mill reducer at the Ruien power plant. An oil analysis indicated the root cause of the problem – low viscosity of the lubrication oil.**

In September 2007, the Ruien power plant maintenance team revised its coal mill reducer and found no abnormalities. Ten months later however, LVMS started registering large vibrations on the reducer, necessitating a closer investigation. Opening the reducer showed significant wear on the gear wheels. Oil

analysis revealed that the lubrication oil needed to be replaced by a more viscous type. Regular vibration analyses will have to confirm whether this solves the problem.

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## Auditing lubrication oil sampling and follow-up practices

### Optimizing sample collection at power plants

**Laborelec has conducted an audit of the collection of lubrication oil samples at Belgian power plants. The audit provided our experts with a clear view of oil sampling practice. It also enabled them to optimize the sample collection points and enhance the quality of the oil analyses and recommendations.**

Laborelec has been monitoring the quality of turbine and other large rotating machinery's lubrication oils since the 1970s. In order to update their knowledge of the existing oil circuits and sampling practices, our experts decided to screen oil baths in various Belgian power plants. They made an inventory of all oil circuits and their current and potential sampling points. In certain cases they advised to adapt the regular oil analysis programme.



#### A clear view of the process of collecting oil samples

The audit generated better insight into the oil sampling process. Our experts learned who is collecting the oil samples, how they are collected, and at which location in the oil circuit. The audit resulted in recommendations to alter some of the oil sampling locations as well as adding new taps to ensure that

oil samples are taken at the optimal location in the oil circuit. This location has a direct impact on the oil analysis and the interpretation of the results. For instance, the interpretation of a SEM-EDX (Scanning Electron Microscope - Energy Dispersive X-ray spectroscopy) analysis largely depends on the location where the sample was collected.

#### What happens with Laborelec's advice?

During the audit, our experts also investigated what happens with the recommendations and maintenance guidelines provided by Laborelec based on the analyses of the oil samples. The audit revealed that in most cases the local maintenance team takes up on the advice. But it also revealed that not all maintenance team members have the specialized know-how to correctly interpret the advisory report. This fact led our experts to organize training sessions.

#### Improving mutual collaboration

The audit not only improved our experts' view of the sampling practice, it also improved collaboration between Laborelec, the Electrabel Maintenance Competence Centre, and the Belgian power plants. The latter are now more eager to provide feedback and ask questions. Good communication enables us to do our analyses more profoundly and to enhance the quality of our results. It leads to interesting cases such as the Indaver, Phenolchemie, and Doel articles in this edition of Laborelec News.

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## Reliable thermographic analysis

**Infrared thermography is a non-contact predictive maintenance technique, mainly applied to identify failures in electrical equipment. However, in combination with vibration analysis it can also be used to inspect rotating machinery. Laborelec's close collaboration with the Electrabel Maintenance Competence Centre (MCC) guarantees the expertise necessary to ensure reliable measurements, analyses, and results.**

During a thermographic analysis, a state-of-the-art infrared camera establishes heat distribution images of electrical and mechanical equipment. These images are then used to identify a wide range of issues such as hot spots, loose connections, corrosion, or worn bearings. The technique does not require any physical contact with the measured equipment, making it especially useful in assessing the state of equipment that is hazardous or difficult to access. The analysis can be performed at distances of up to 200 metres, without any loss of production or downtime. Moreover, repeating the analysis enables the collection of historical data.

Experience is essential in order to generate accurate and reliable results. For instance, the location from which the thermographic picture is taken needs to be chosen with great precision to limit any distortion from the surrounding area. Also the correct emissivity value of the analyzed material is crucial. Laborelec is able to ensure reliable results. Our experts can rely on in-depth training sessions, close collaboration with Electrabel MCC's Predictive Techniques department, and extensive practical experience conducting thermographic scans on a wide range of machinery types. This broad experience enables our experts to accurately make and correctly interpret thermographic images.

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*A thermographic image visualizes temperature differences, identifying potential problems*

## First online vibration monitoring of generator stator end-windings

**Laborelec has developed an online tool to monitor the vibrations of generator stator end-windings. This new development enables our experts to gather a rich set of vibrations monitoring data at this point in the machine.**

A generator stator is subject to various forces when in operation. Some of these can cause it to take on an elliptic shape, which can damage the generator's epoxy materials. Such damage can result in electrical discharges and eventually require the replacement of the stator. This can be avoided by adapting the load on the stator according to the vibration level. To do so, end-winding vibrations need to be monitored continuously. Laborelec has now implemented such an online monitoring tool. Fibre optic accelerometers (FOA) installed on the end-windings measure the vibrations. The FOA readings are entered directly into the Laborelec vibration monitoring system (LVMS). This enables our experts to gather real performance data on a stator's end-winding vibrations. The data not only contains the amplitude of the vibrations, but also their phase, revealing more information than traditional monitoring tools.

Our experts have put this new monitoring system to the test in the Gelderland and Herdersbrug power plant generators. In the latter case, the system has already proven its usefulness when it discovered that vibration values surpassed the alarm level, due to a resonance close to 100 Hz. Our experts advised a modification of the stator end-winding design to limit resonance vibrations before it was able to cause any damage.

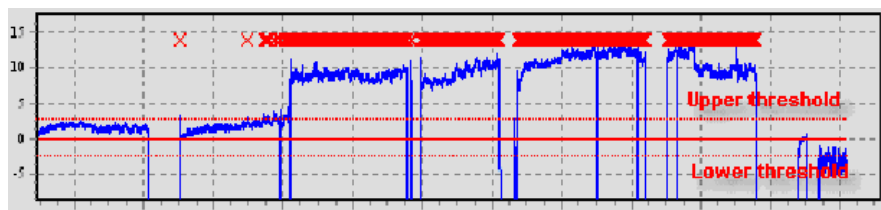
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## Major damage to generator bearing avoided

**Diagnostic Centre detects faults at an early stage**

**Laborelec's Diagnostic Centre uses SmartSignal to detect faults in power plant equipment at a very early stage. Recently, the tool detected an unusual temperature deviation in a generator bearing. It enabled our experts to investigate the issue in a timely manner so that the power plant was able to take actions that avoided any major damage.**



The early fault detection tool monitors the mechanical and operational behaviour of several combined cycle power plants (CCPP) in Europe. It reads data taken from vital parts within a power plant, compares it to reference values (algorithms estimate the reference value based on historical data), and triggers an alert if the deviation exceeds the dynamic threshold value. Detecting faults at a very early stage enables our Diagnostic Centre team to propose appropriate actions before any significant damage can occur.

### SmartSignal alerts Diagnostic Centre

The predictive monitoring tool proved its value recently when it helped avoid substantial damage to a power block. A CCPP cooling circuit had just undergone a thermal shock operation to clean its sea water pipes. Two days later however, the temperature of the generator bearing's metal had risen more than 2 °C above its predicted value, exceeding the dynamic threshold. Laborelec's Diagnostic Centre investigated the problem.

### Vibrations and oil analyses investigate cause

Our experts conducted an initial vibration analysis using the Laborelec vibration monitoring system (LVMS). This revealed that the shaft was not in its normal position in relation to the bearing clearance. The reduction of the bearing clearance caused for higher shear forces in the bearing's load zone, increasing the temperature of the bearing's lubrication oil and white metal

during operation. In this situation, there is a high possibility of rubbing between the shaft and the bearing. Subsequently, our experts recommended an analysis of the bearing's lubrication oil, looking for bits of white metal that might have been scraped off by the shaft. However, the oil samples did not contain any such evidence.

### Inspection reveals initiation of damage

The generator bearing's temperature continued to rise and the power plant maintenance team decided to shut down the unit so that they could have a closer look inside. They then discovered that the bearing's white metal was polished at the load zone of the bearing, confirming that there was indeed contact between the shaft and the bearing. The power plant maintenance team replaced and realigned the generator bearing. Since then, the new bearing has performed at normal temperature.

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