WHITE PAPER

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Reliable Vibration Monitoring in the Offshore & Marine Industry

For a better lifecycle management and a higher availability of rotating assets in the marine and offshore industry.

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Summary

Predictive and proactive maintenance already has a proven track record in a vast majority of industries. Also in marine and offshore applications, the maintenance strategy on board has evolved from breakdown to predictive maintenance based on condition monitoring techniques. These techniques were initially developed for the military, but are currently applied to most marine and offshore vessels and installations. Confidence in condition monitoring based on vibration measurement and analysis is growing and fleet managers, chief engineers and crews are adopting vibration monitoring due to the cost reducing capabilities and the convenience of planned overhaul compared to unscheduled breakdown maintenance. Additionally, the vibration monitoring technique is frequently used in approved Machinery Planned Maintenance schemes by Class societies these days (such as Lloyds Register, DNV-GL, etc...) and may lead to descriptive notes being assigned for inclusion by these Societies.

Condition monitoring with non-destructive vibration measurement techniques may not be the only predictive technology available, but it certainly is the most appropriate one when it comes down to the diagnostic of rotating equipment because the measurement results identify - up to component level – where the malfunction originates from and which machine component is actually damaged or worn. With this valuable information, fleet managers, superintendents and chief engineers will carry out precise maintenance actions in order to avoid unnecessary downtime, hazardous situations and consequential damage.

"Vibration measurement is the most appropriate condition monitoring technique for rotating equipment"

There are other important condition monitoring techniques leading to an increase of the machinery availability, but vibration monitoring is by far the most appropriate CM[1] technique for rotating equipment due to its cost/return ratio and the broad application range it covers. In addition, vibration monitoring is easy to automate. Nevertheless, in combination with other techniques such as oil analysis and thermography, it significantly contributes to a higher availability of the asset.

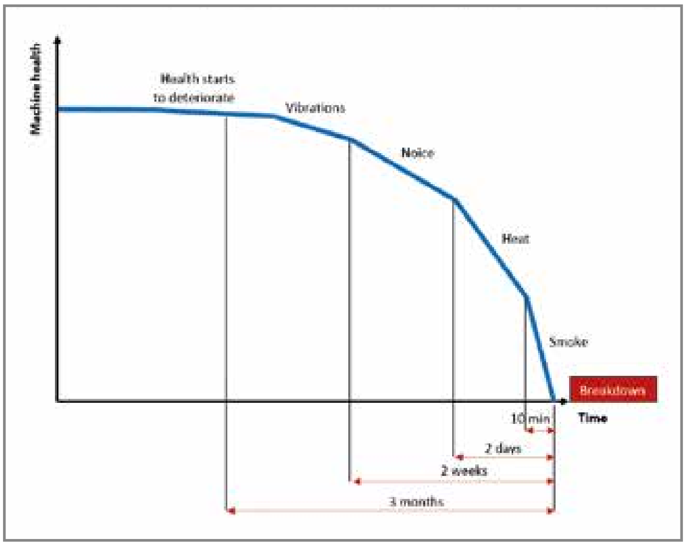
However, due to lack of experience and knowledge as well as to misinterpretation of measurement results, it can lead to wrong decisions and unnecessary repairs. That's a shame, because after a substantial investment in measurement equipment and crew training, one should expect – or even demand – appreciable savings in maintenance costs and an increased availability of rotating equipment.

"Appreciable savings in maintenance costs"

In this whitepaper we will discuss how condition monitoring with vibration measurement techniques on board can be implemented successfully given the right tools, a correct choice of systems, a good training strategy, practical common sense and a professional support. The result is a prolonged machinery lifetime and continuous operation of rotating equipment in a reliable and controlled way. This leads to a minimum of consequential damages and unforeseen downtime.

The challenge: reliable Vibration Monitoring in Offshore & Marine applications

Over the past 40 years, vibration monitoring has been introduced progressively into the offshore and maritime industry. Among all other valuable CM techniques, such as IR thermography, oil analysis and electrical measurements, vibration monitoring technology has potentially more benefits due to the fact that vibration monitoring technicians are able to identify the exact cause of mechanical problems and wear and to diagnose machines on a component level while using non-invasive techniques.



1 CM or Condition Monitoring

Additionally, vibration monitoring is a condition monitoring technique that is easy to automate in a cost effective way. This leads to reliable measurement results and a significant reduction of the workload for a crew on board and the organisation onshore.

Nowadays, fleet management and crew have been familiarized with vibration measurements. Confidence in these techniques is rising as well as the belief in opportunities it offers to perform reliable predictive and proactive maintenance based on the results of the vibration measurements.

"Vibration monitoring has proven itself"

Nevertheless, how successful is CM actually on board of vessels and offshore platforms? Is the workload truly reduced due to CM and did predictive maintenance really decrease the costs of repair and reduce unforeseen downtime? Do offshore and marine companies, with less knowledge and experience in CM, rely for 100% on the measurement results? Does management or crew make the right decisions based on an overall vibration level that has exceeded an alarm level?

With vibration monitoring, technicians are able to make "everything visible" regarding the condition of rotating equipment. Based on these results it is important to make the right decision and execute the correct maintenance action.

Inadequate decisions based on a general alarm notification are common. A mix of ´not sure what the problem is´ and ´let's repair to be sure´ increases maintenance costs. In addition, the machinery lifetime decreases due to unnecessary overhauls and the workload for the crew and the onshore personnel rises. The result is a lack of confidence in condition monitoring.

"Skills and knowledge are needed for the best results"

Successful implementations require more than just installing and commissioning the right condition monitoring systems. Professional support during start-up and throughout the entire lifecycle of the monitoring system itself is essential. The aim is to use 100% of the full potential of the newly commissioned system right from the start. Of course fine tuning of alarms, measurement setups and interpretation rules is desirable, but this step comes after an initial period of operation that will generate measurement data that can be used as a reference. Only when benefits are noticeable and quantifiable, preferably a short time after commissioning or the sea trials, the condition monitoring scheme will be broadly accepted.

"Vibration measurements make machine health visible"

A reliable and profitable condition based monitoring program on board of vessels and offshore installations requires a number of implementation related decisions to be made.

- **Choice between offline or online vibration measurements**
  Based on criticality, availability, health and security risks, skill of crew, etc … ?
- **Equipment ranking**
  Which machines should we measure and how often?
- **Selection of the correct measurement locations and tasks for each machine**
  Equilibrium between a minimum of measurement points and maximal results.
- **Who takes care of the analysis and reporting**
  First analysis on board and in-depth diagnostics by specialists onshore.

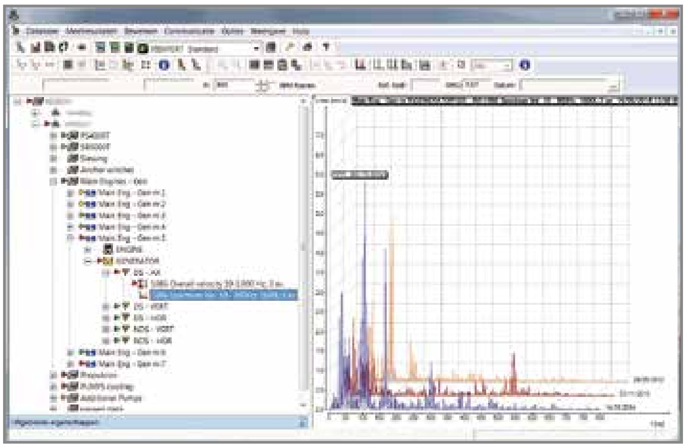
Off- and/or online monitoring approach

There are two basic ways to perform systematic vibration measurements: offline and online monitoring. Both approaches have advantages and disadvantages, but in many cases a combination of both techniques leads to the most cost effective condition monitoring implementation.

With offline vibration measurement techniques, a crew takes periodic readings with a handheld device during planned measurement campaigns. The crew performs the so called ´route measurements´ along the machinery and collects vibration readings with a mobile sensor, usually an accelerometer. These readings are taken at predetermined points equipped with measurement studs. It is very important to place the sensor on the right ´spot´ in order to avoid mismatching results in the trend graphics and to perform repeat measurements on exactly the same measurement location and direction in order not to compromise trend data. Otherwise this will lead to wrong diagnoses and incorrect maintenance recommendations following the common rule: ´garbage in - garbage out´.

To avoid mistakes and confusion as far as the measurement location is concerned, clever technologies such as ´graphic routes´ and measurement point identification are highly recommended. With automatic measurement point recognition, data collection is 100% reliable, avoiding mix-ups leading to incorrect trends and wrong maintenance recommendations.

When data on all measurement points are collected, the readings are uploaded to a software platform where trends and spectral results are displayed and stored for further analysis and historic back-up.



With online measurements, an intelligent ‘black box’ with fixed sensors on critical machine positions is installed. The online systems can be hooked up to an existing network or can act ´standalone´ with a direct connection to an existing PLC on board.

“A combination of off- and online system implementation is often the most costs effective approach for reliable condition monitoring”

During commissioning the database with measurement instructions and alarm settings is sent as a ´route´ into the online system. The online system then works autonomously and performs the measurements as well as a first routine evaluation based on the chosen alarm settings. The measurement points are scanned 24/7 and the results are visualized on a monitor through the existing network on board of the vessel. In addition, digital outputs connected to a PLC or data sent through a fieldbus take care of the immediate alarm notifications.

System and Equipment ranking

The decision to use either online or offline vibration measurements – or a combination of both – is determined by the following criteria:

- Criticality of the installation;
- Accessibility of the measurement locations;
- Measurement duration (cycle time of the equipment, frequency range);
- Workload on the organization;
- Health/safety and environmental criteria.

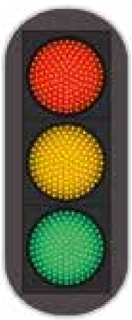
As an example to illustrate the above, let’s look more closely at the following application: PRÜFTECHNIK implemented a combination of off- and online condition monitoring on board of dredging vessels. The cutter gearbox with its motors as well as the submerged pump are installed on the ladder and are not accessible during production. These machines are equipped with online systems. All other – accessible and less critical – rotating equipment on board of the dredging vessel is periodically monitored with offline equipment.

The online readings are automatically visualized in the EMC room for the primary follow-up by the crew. Additionally, all the results are archived in the asset monitoring software suite for analysis. The periodic offline readings are stored in the same software. In this case, all off- and online data is sent to shore for potential in depth analysis and storage. The result of the remote analysis is summarized in a monthly class approved report. Additionally, in case of emergency, a more detailed trouble-shooting is executed within 24 hours with a direct reply to the technician in charge on board of the dredger.

With this ´combination approach´ the critical machinery is monitored 24/7 with online systems and ´less critical machinery´ is monitored by offline measurements on a monthly basis. This has led to a reliable and cost effective condition monitoring program and an overall lower workload for the crew on board.

"An alarm will be a trigger for in-depth analysis, not necessarily for machine overhaul"

In general, the results on board based upon overall alarm levels can be visualized as a ´traffic lights´. The green colour means that the installation operates normally, the yellow and red colours indicate an increased vibration level due to a defect or a deficiency which should be analysed.



However, this colour approach should not lead to immediate repair or replacement of a machine! This is just the first indication of ´a change in condition´. Based on a subsequent in-depth analysis and in cooperation with the crew, the cause of an increased vibration level is identified and the most practical maintenance action is recommended in order to avoid unnecessary repair and downtime.

It is important to emphasize that vibration measurement results should also be used to keep machines running when the trends show high, but stable results! The analysis phase will determine the right action to be taken and very often a controlled prolonged operation with a known machine fault condition is the outcome.

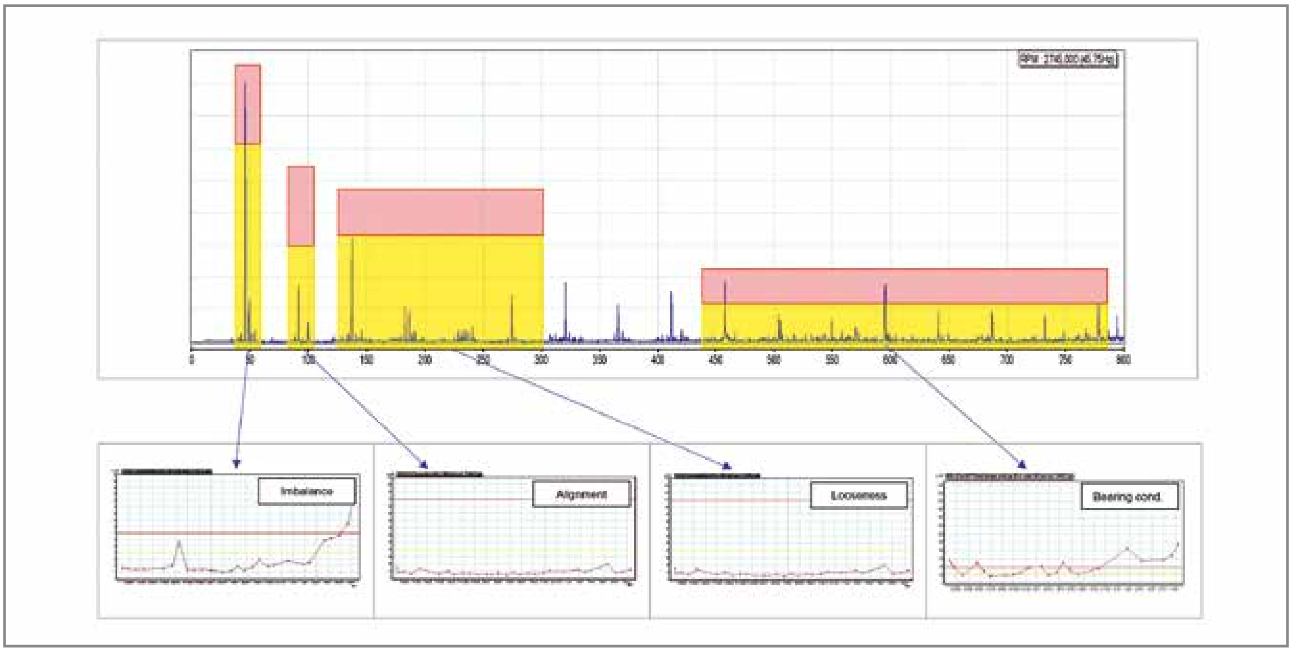
In a number of online implementations, owners prefer a condition based monitoring program without detailed visualisation on board. The measurement data is directly sent onshore for further analysis and reporting in that case. This approach avoids impulsive repairs or work interruptions due to local misinterpretation of the readings.

Proven and Smart Technology

The results of vibration measurements can be shown as overall values, which indicates the general vibration behaviour of the machinery, or as FFT spectra, which shows the related frequency peaks and amplitude levels for an in-depth analysis.

Usually, overall results are shown in a trend visualizing the general vibration behaviour of the installation over time. With FFT spectra however, we investigate the DNA-profile of the machine which exactly pinpoints the source of the aberrant vibration.

However, if one is not familiar with FFT analysis techniques, easy-to-understand graphics where relevant components of the FFT spectrum are shown as independent trend graphs for each vibration phenomenon will already point the engineer in the right direction. Common defects such as imbalance, misalignment, bearing damage, etc.... can be evaluated separately. This so called narrow- and broadband approach allows anyone to perform a primary analysis as a trigger to follow the machine condition, regardless of the skill level of the engineer on-board.



Online approach with Operating States

During the implementation process we have to distinguish between machinery operating at a steady state and machines that are experiencing significant variability due to operating conditions. Variation in speed and load (in most cases) will considerably influence the vibration reading, especially in gear driven machinery. The online monitoring equipment acquires data and processes it in relation to the actual load and speed conditions. With this approach it is possible to set the right alarm level for the related operating condition. This is an impossible task if we only look at the raw data without normalizing it to the operating state. With these so called ´Operating States´ it becomes possible to set reliable alarm levels for each range of operating conditions, to build reliable trend curves showing the evolution of damage and to avoid unnecessary alarm triggering leading to incorrect maintenance decisions.

Data reduction

Obviously it is important to collect enough reliable data. However, machinery can run for a long time without any significant change in condition. If the data is analysed onshore, the data is generally sent by e-mail. To avoid high costs due to sending large data sets, the online systems are programmed to only store valuable and meaningful data.

"With smart ´Data Reduction´ and ´Operating States´ only reliable and valuable data is captured and analysed"

With the implementation of the ´Data Reduction´ functionality, only valuable data – which shows a certain change in the machine condition – is stored and transmitted. This allows the system to send small (less expensive) files with only meaningful data from board to shore for further analysis.

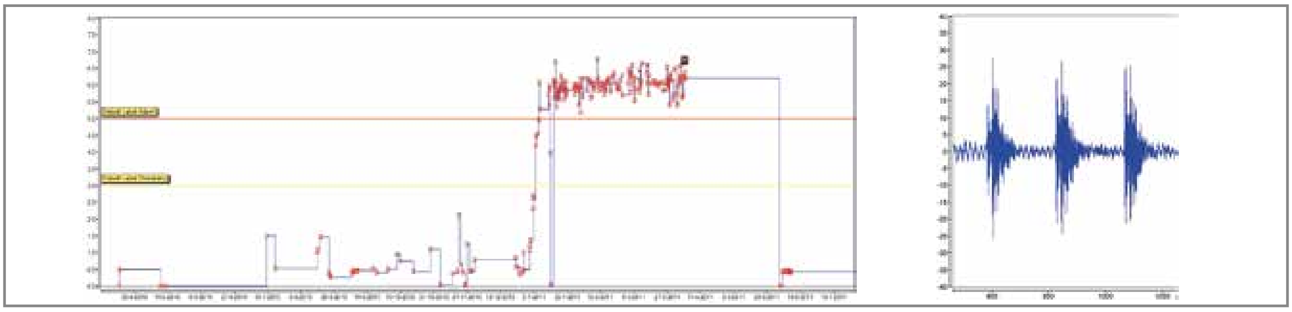
Self-monitoring equipment

In addition, reliable monitoring needs self-monitoring functionality in order to be sure that the online system continuously runs and measures correctly without malfunction. Self-monitoring equipment checks the ´health´ of the electronics as well as the vibration sensors themselves and periodically sends a message that the system is still alive and that the sensors work reliably. This feature detects errors in the monitoring system and increases the reliability of the condition monitoring system on board.

Service, commissioning and training

An essential but often underestimated aspect of CBM[2] implementations is the commissioning and follow-up of the project, including training and tuning of alarm parameters after an initial operating period. Failure to address these issues often leads to unsuccessful implementations due to unreliable alarms or worse; unnecessary overhauls. A comprehensive training should include management and not only be aimed at the technical staff because in the end, a better control

2 CBM or Condition Based Maintenance



Overall trend data of bearing deterioration and detailed time signal analysis of impact due to bearing damage

of the lifecycle of the asset will result in a higher profitability for the vessel or offshore platform. In order to be able to implement CBM, enough support from management is required and the support to implement CBM will only be given if it can be made crystal clear that the reliability of the vessel will increase and the maintenance costs will decrease which will significantly improve the overall profitability of the asset, increase the safety of the crew and diminish the environmental impact of the vessel.

Predictions about the return on investment are difficult to make due to the fact that initially we don't know what kind of potential defects we will be able to avoid. Nevertheless, it is very common, to see a payback time for monitoring solutions of only a few months.

Referring to our previous example in the dredging industry, let's consider the following case: the online remote diagnostic system on board of a dredger that was in operation in Dubai experienced a damage in one of the bearings of a main generator. The damage was detected in an early stage, got worse over time but then stabilised. In order to overhaul the generator, dry-docking was required. However, by analysing the bearing vibration by means of its spectral and time based signature and by closely monitoring the deterioration rate, we were able to postpone dry-docking by 20 days, allowing the vessel to complete its job in accordance to the contract the dredging company had signed. At an average cost of 120.000 $ per day in potential lost revenue and penalties, the prolonged operation of the dredger yielded 2,4 million $. The investment cost for the online monitoring of all critical equipment on board was less than 80.000 $. This is just one out of many examples but it shows that if the CBM system detects just one major defect, this is often enough to justify the investment.

Furthermore, the usage of condition monitoring systems has an influence on inspection intervals. For instance, on turbocharges and thrusters. Marine class societies accept to postpone dry-docking for inspection of thrusters if an approved condition monitoring program is implemented. For most vessels this implies a huge cost saving and even if no defects are detected, this aspect alone is often enough to justify the effort.

Conclusion

Condition monitoring based on vibration analysis applied to marine and offshore assets has proven to be a valuable asset lifecycle management tool. However, it requires more than just purchasing an FFT spectrum analyser or an online measurement installation.

A lack of experience and training, incorrect settings, too narrow alarm thresholds and a lack in professional support, leads to unnecessary repair and overhaul of rotating assets, unforeseen downtime and potentially a loss of confidence in vibration monitoring altogether.

Vibration monitoring is a very powerful tool that must be implemented in a correct way. This will empower both the crew and management in marine and offshore companies to make correct evidence-based maintenance decisions. Moreover, a CBM program can only be successful with reliable and easy to use equipment on board and performed by a motivated crew in combination with a specialist in vibration monitoring – generally based onshore - who will perform in-depth analysis. An external partner providing ´second opinions´ whenever necessary is one more line of defence against wrong decisions.

CBM packages that were implemented in the correct way have already led to an impressive number of successful results in the marine and offshore industry. Summarized, the keys to reliable CBM implementations are:

- **Knowledge and experience**
  Management, application- and service engineers who design and commission the condition monitoring systems are required to have many years of solid ´practical´ experience in rotating marine equipment, vibration measurement and analysis techniques, class approved reporting and RCM[3]. This generally comes with ISO 18436-2 CAT. II, III or IV certification for vibration monitoring and meets the requirements of DNV_GL and Lloyd's Register Class rules as specified in their documentation.
  The combination of knowledge and experience leads to confident conclusions and ´practical´ no-nonsense recommendations.

- **Proven technology**
  Continuous development of CM systems and related software is a must in a fast evolving technological market. Next to that a proven track record in marine and offshore applications is essential because the requirements are often different compared to industrial onshore applications. Aspects such as data reduction, splitting warning signs (on board) and complex analysis (onshore) and class requirements are very specific for marine and offshore implementations. Furthermore, relying on independent manufacturers specialised in the field of condition monitoring is the best guarantee for independent and unbiased decision making when it comes to overhaul and maintenance interventions.

- **Service, support and follow-up**
  Proper installation and commissioning leads – directly from the start – to reliable and cost reducing vibration monitoring. With remote data analysis and remote product service, adjustments in the systems and software can be made from ashore which will reduce follow up and travel expenses. The credo 'move the data, not the people' is equally true for the product service and for the analysis process. Furthermore, having service locations on every continent is very convenient for a mobile market such as marine and offshore.

Contact

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If you are interested in the rotating asset monitoring possibilities for your vessel or fleet, then feel free to give us a call for an overview of practical implementations and ´vibration case histories´ that directly relate to your application.

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- etc…

3 RCM or Reliability Centered Maintenance

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