Condition monitoring on complex machines.

Subtitle: Correlated data for a reliable monitoring solution

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Introduction

In the following it is intended to put today's tasks for condition monitoring (CM) systems up for discussion.
First it will be described, how condition monitoring encounters new challenges in many industrial areas. New service concepts are being developed involving not only end-users and plant engineers but also component manufacturers.
Secondly new technical achievements in the fields of computer technology and electronics will be discussed and how they influence the actual development in condition monitoring.
Thirdly, it will be identified what the main findings are regarding new orientation in the industry. It is to be shown how the development in condition monitoring responds to the new assignment and how new products are being defined according to the market needs.
Finally, a brief picture will be drawn of today's status on the introduction of new condition monitoring products.

1 Condition monitoring - an expert field

Traditionally handling of condition monitoring systems belonged into expert hands and thus had to be an expensive means of process reliability enhancement. A condition monitoring expert is imperative for detailed vibration analysis and final decisions about the interpretation of complex failures. Today, newly designed condition monitoring systems contain the necessary information and processing possibilities to take over parts of the expert tasks.
As a company in condition monitoring since 20 years, Industrial Services has built up expert knowledge for the development, installation and analysis around condition monitoring. Initially the original focus was laid on monitoring of bearing condition. In the meantime more components of a process can be monitored.

2 Changing monitoring challenges up to present day

The variety of industrial processes reaches from single machine applications to complex systems. They all have in common, that continuous development takes place in order to enhance stability, transparency and reliability of the core process.

2.1 Market pressure entails the need for raised process efficiency

The development of industrial processes was always aiming to raise output and/or quality and at the same time lower production time and cost. While improving machines, processes and qualification of personnel on one side, there is a significant need for machine and process monitoring. Within the ongoing competition for higher efficiency, the industry constantly improves their equipment and production methods. Companies can at the same time watch their breakdown and maintenance history to see potential for improvement through condition monitoring. A better insight in machine and process parameters makes it possible to prevent sudden or even unnecessary interruptions of the process.
Where in earlier days experienced technicians decided if a machine “sounds good or bad”, the requirement today is to gain objective, traceable and comparable information on the monitored process or machine.

2.2 Automated processes require reliable monitoring

To raise efficiency of industrial processes to a maximum, all information that supports the stable operation has to be gathered, compiled and forwarded in the most reliable way. Related to the growing integration of electronic components in mechanical processes and the automation of processes, the stability of running processes has become more and more important. Changes in machine status or process parameters are indicators for possible upcoming trouble that may – if not looked after carefully – influence the whole process and even lead to an unplanned shutdown. Condition monitoring, which is factually the gathering of process and machine data with the goal to interfere as soon as necessary to prevent an instable process.
An up to date condition monitoring system has to be able to produce information about the machine status, that can be delivered to a control system and be integrated into the control loop. Systems that produce false alarms would herein not be able to improve the process. On the contrary, it could be cause for automation shutdowns although the plant is fully functional.

2.3 Nowadays service: keep the process running – avoid repairs

Industrial Service contained in former times repair and maintenance of machines. If a machine broke down, a long downtime had to be expected. To avoid this costly break, prediction of a machine breakdown is taken into the focus of state of the art service. To be able to react right in time, a longer prediction time is highly valuable in complex processes.

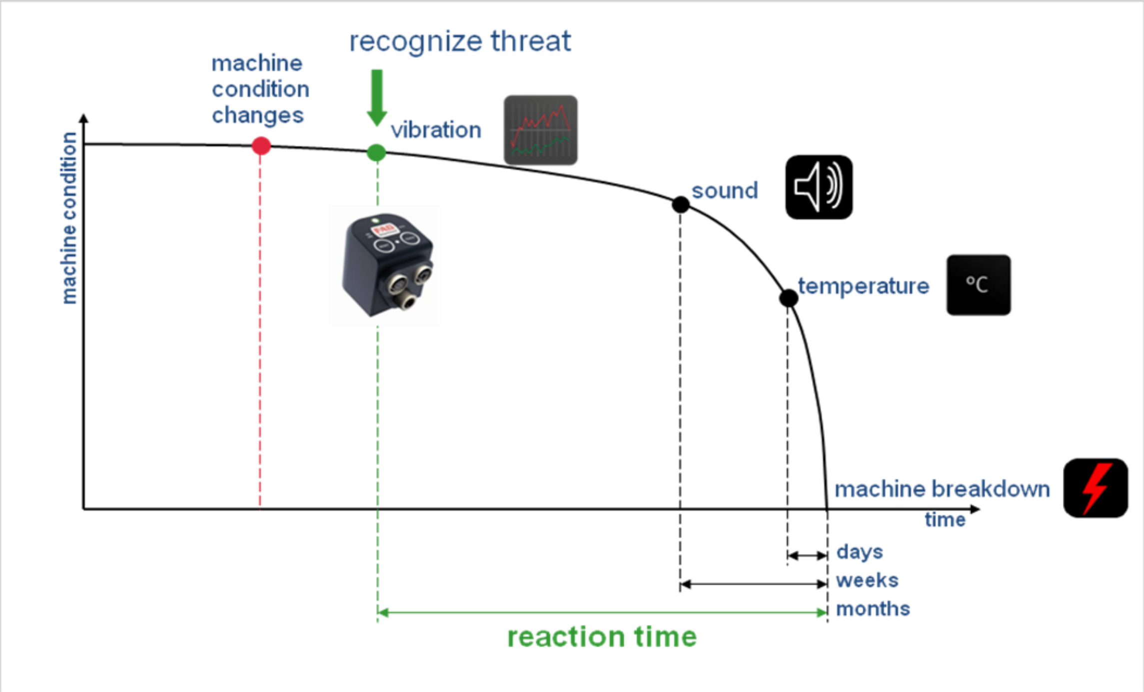


Fig. 1: Comparison of reaction times using different machine parameters

3 New technical possibilities

Condition Monitoring of a machine or a process consists of four steps:

Measuring

Calculation

Analysis

Recommendation for action

The technical innovations described in the following have been integrated in one of the above steps of condition monitoring:

3.1 Computers of minimized size

Comparing today's PCs with the ones used 10 years ago, it is clearly visible how fast computer technology is developing. Mainly lower size and better performance of computers have been developed.

In condition monitoring this leads to a whole new concept:

In established condition monitoring systems, the sensor (measuring) is placed onto an aggregate and in a remote position, the electronic part of the system (calculation) is built into a control cabinet. The analysis and recommendation for action is then executed by experts that receive the calculation results in regular intervals or through a permanent connection. New developments use the advantage of small, affordable computer components to unite measuring, calculation, basic analysis and a basic recommendation for action in one single device. Depending on the monitoring task, this device can provide results, that are sufficient for plant operators to decide about further measures – even without vibration analysis background. The small device is in this case the only item that has to be installed to introduce monitoring to an aggregate.

3.2 Data storage on the measuring device

Traditionally online monitoring systems are separated in the measuring and the processing unit. Data is stored in additional downstream equipment such as a PC. The capacity of hard disks encountered a vertiginous rise starting in end of the nineties. A comparable picture can be drawn for flash drives starting end of the last decade as it is shown in Fig. 2: **Data storage development for retail storage products in Gigabyte**.

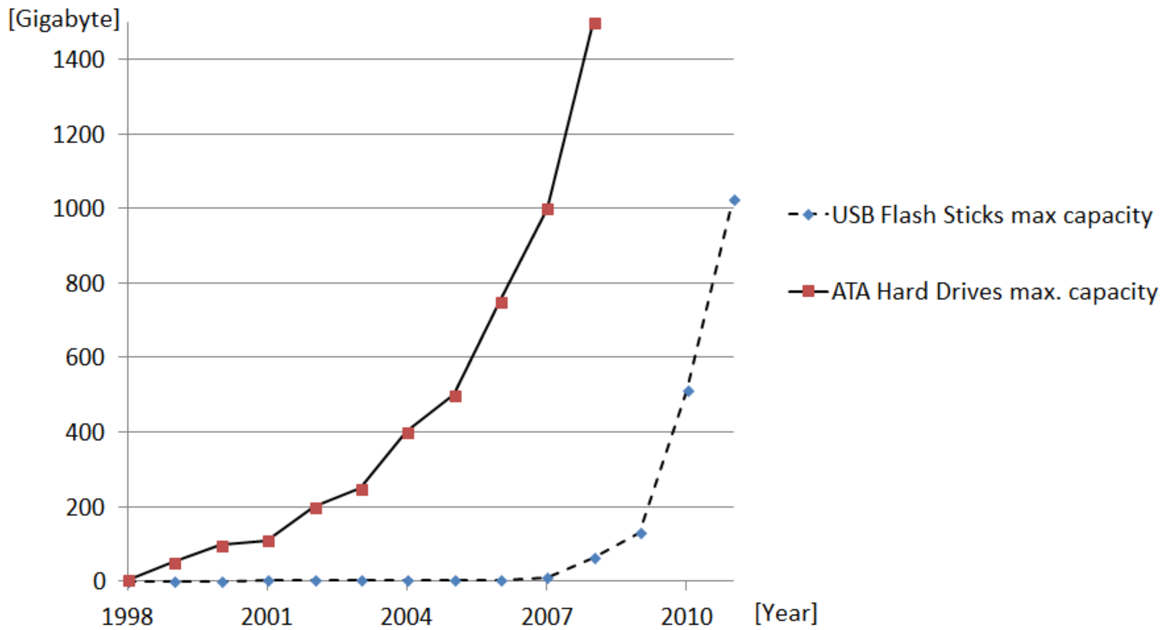


Fig. 2: Data storage development for retail storage products in Gigabyte

Together with a capacity growth in storage devices, a constant price drop can be recognized (Fig. 3: **Indicative price development for hard, flash and disk drives 1955 – 201**) that makes it possible to add a data storage component to the measuring device. Data no longer needs to be transferred to a remote computer to be saved, it is gathered, processed and stored almost instantly.

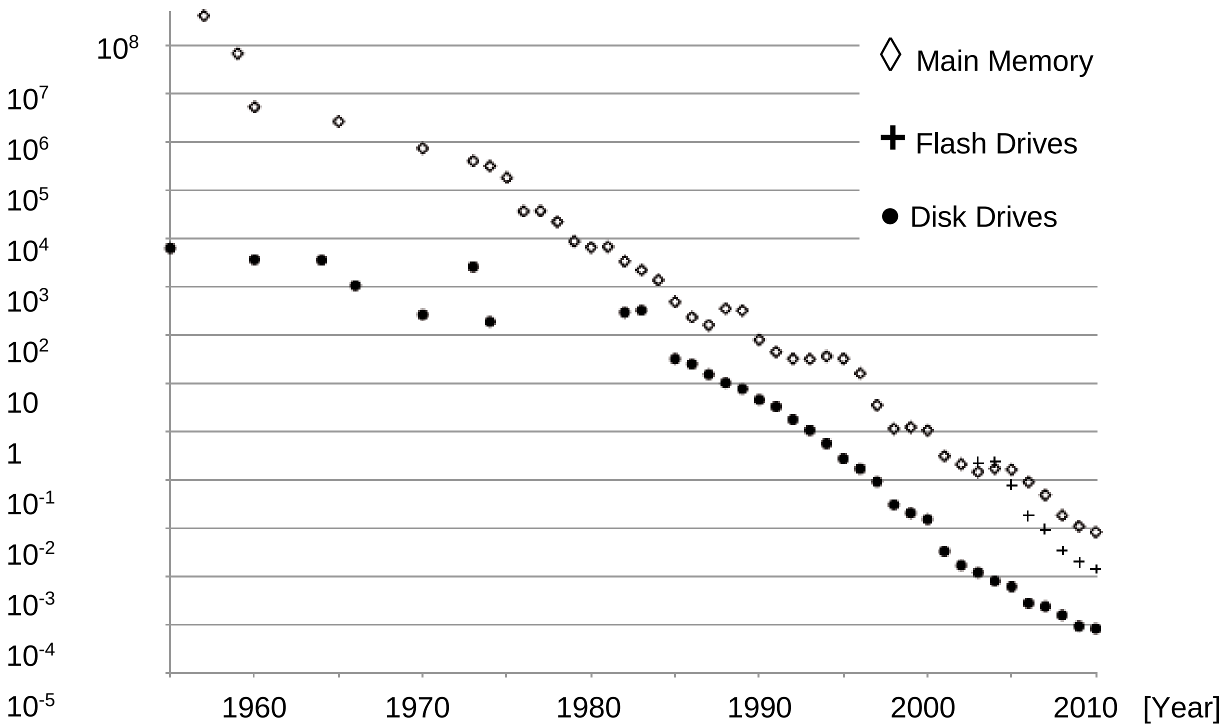
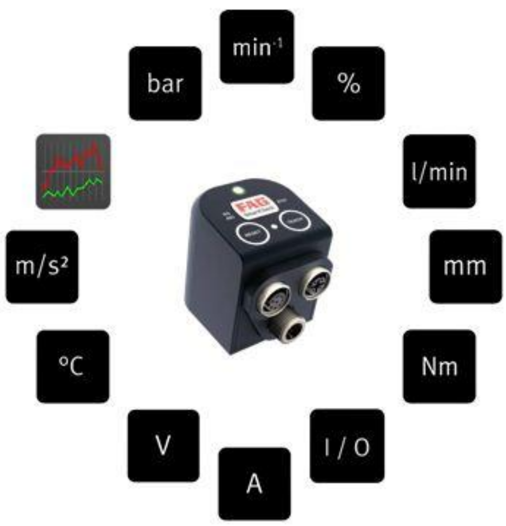


Fig. 3: Indicative price development for hard, flash and disk drives 1955 – 2010

3.3 Correlate gathered measuring data and compile them to useful information



Picture 1: Example input values for a CM system

Measured parameters show the machine condition from different points of view.
Parameters like speed, load or flow rate are used to control the operation. Temperature, vibration amplitude or noise levels describe the way in which the aggregate is affected by the operation. All parameters have in common, that they can be narrowed down to specified set levels or ranges. In this way a set-actual comparison can be carried out for each one of the monitored parameters. Beyond monitoring of single parameters, their influence

among each other brings up valuable information regarding aggregate status, the different ways of operation and the way they influence the aggregate's behavior.
Further the interpretation of values becomes much more informative, when taking into account, that vibrations are influenced by e.g. speed or load. State of the art condition monitoring systems are able to accept numerous kinds of input data, depending on what influences the process (Picture 3).

As to be seen from Fig. 4, a machine can be operated at one single speed, but show different wave amplitudes caused by different pressures. If additionally the speed changes during operation, vibration monitoring has to be able to correlate the vibrations and varying input values. The result of monitoring is then reliable and informative.

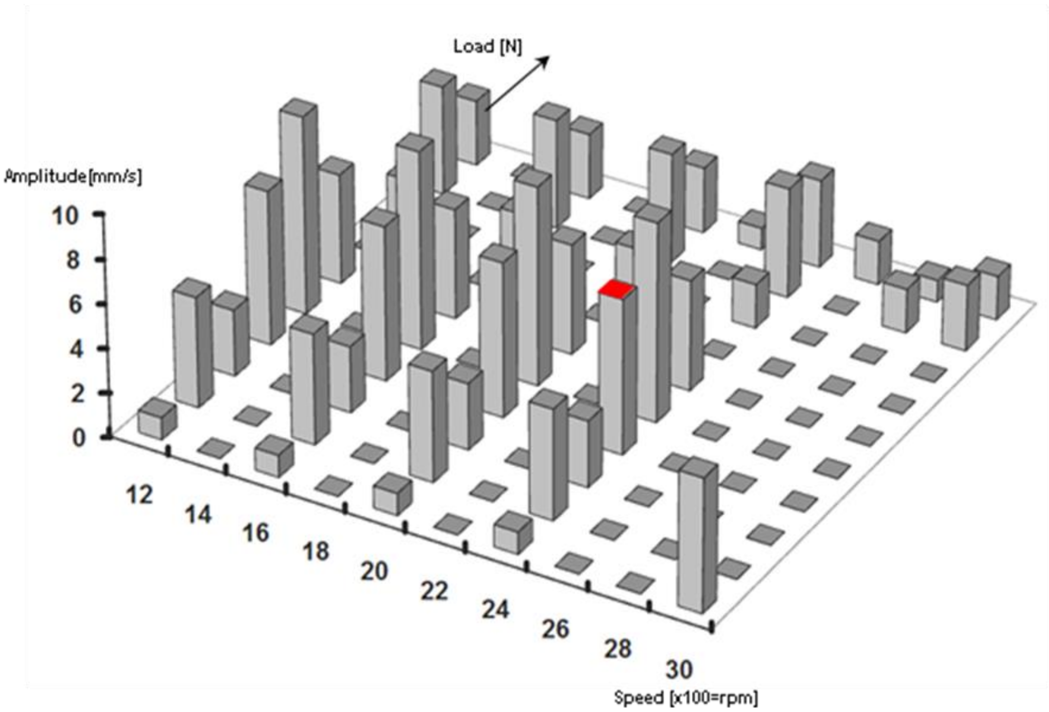


Fig. 4: Example for correlation of vibration, speed and load in a smart measuring device

4 How to react to the new challenges and possibilities

To recognize new possibilities can only be useful when followed by clear decisions. These can be taken based on a sufficiently detailed insight into the focus markets. Bearing suppliers who also provide condition monitoring have the opportunity to identify the customer requirements from two points of view – first the mechanical point of view as a bearing supplier and secondly the electro technical point of view. Both together form a broad basis for development of customer oriented products.

4.1 Identify the requirements in screw machine applications

Screw machines such as compressors and pumps are installed in various parts of a plant executing a wide range of different tasks. To cover as many of them as possible, the goal is to recognize what requirements exist for the majority of applications.

First, a general result of market research is that the price should be reduced to a level, where monitoring of smaller aggregates and peripheral processes will be feasible at reasonable cost. Furthermore the level of required expert knowledge should be revised. A screw machine manufacturer needs a system, he can use without the permanent necessity of an external expert, but be able to create a condition monitoring service for their customers.

4.2 A wide range of applications can only be covered by a flexible system

Turning speeds, the kinds of handled media and the application size vary enormously between the different aggregates, but also between the operating modes of one and the same unit. Therefore a condition monitoring system should be able to be adapted to changing preconditions and operating points.

Flexibility requires the system to be programmed in different ways, depending on the imminent task, a notable amount of parameters must be accessible to the operator of the monitoring system in order to find the right way of monitoring. Many options and settings may lead to a complicated system as they already exist.

To gain flexibility without creating a complicated system, an easy to use programming wizard is imperative. This programming wizard must provide solutions for typical applications with especially configured preset settings. Further, designed as a blackbox, the wizard has to contain the expert knowledge in the background.

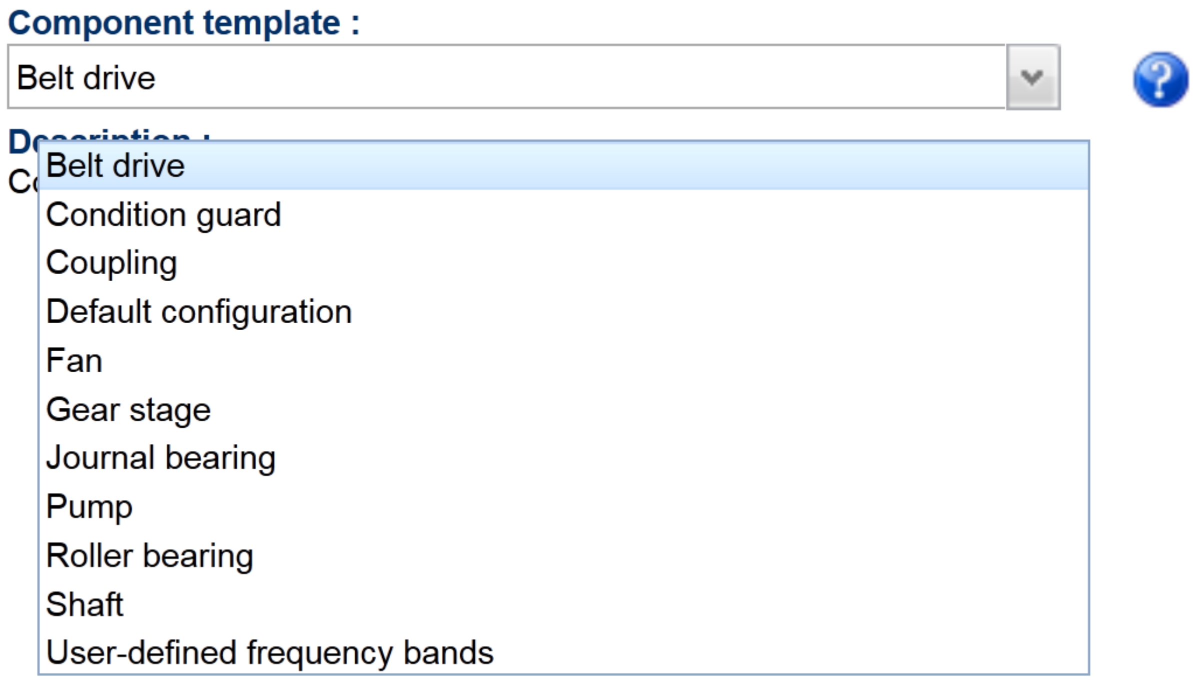


Fig. 6: Preset measuring jobs in condition monitoring for non-expert-configuration

Flexibility also implies the possibility to use monitoring systems starting from one single measuring point up to an almost unlimited number of measuring points. Beyond that, flexibility comprises means of adapting existing monitoring systems by size.
A modularly designed condition monitoring system provides this flexibility. It should e.g. be possible to install a number of autonomously working condition monitoring units and add supplementary systems easily. Even connecting them to a network and integrating them into a plant control system has to be possible with only a minimal extra cost and effort.

4.3 Develop a tailor-made unit

Creating a unit that covers all of the requirements described above is only feasible since technical and commercial preconditions have been fulfilled.
Leading Condition Monitoring companies have designed systems with the goal to cover these requirements. An effective system should incorporate the following features:

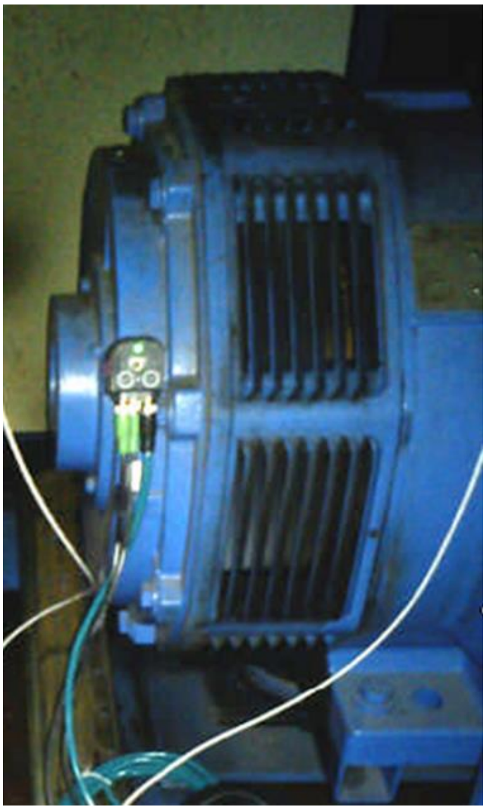
- Measuring of vibration and temperature
- Additional measurement values can be entered
- On board programming wizard
- Processing of measured data
- Storage of processed data

All necessary interfaces to facilitate communication between the CM-device and PLCs or even wider networks

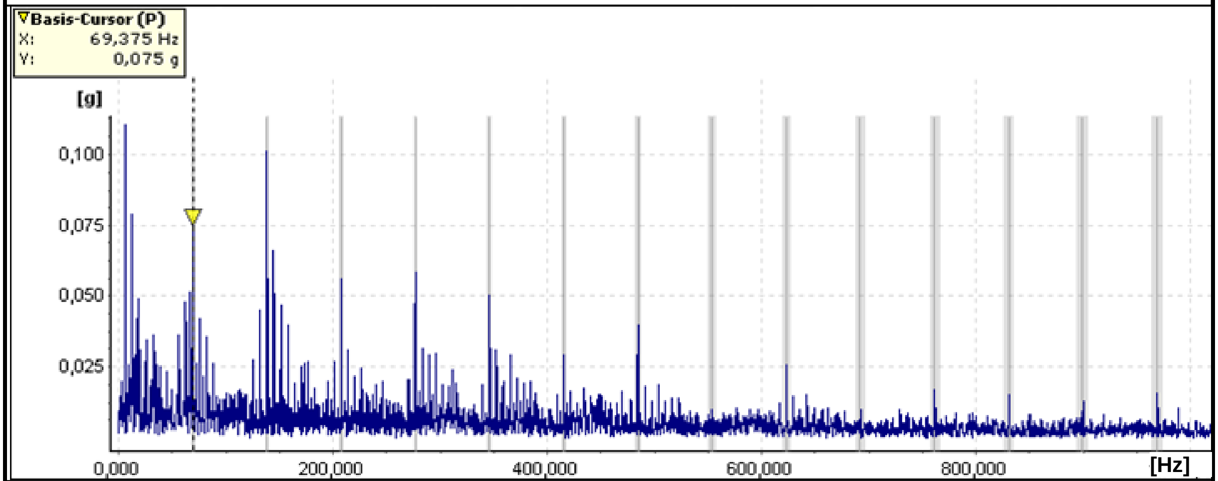
5 Measurement examples for online monitoring on a compressor motor

Picture 2 shows the compressor motor equipped with a modular one channel vibration monitoring system. The monitoring device is attached to the bearing shield vertical to the shaft. A speed signal from the frequency converter is transmitted to the monitoring device to provide the basis for correlation of input values and measured vibration signals. The speed signal allows to differentiate between start up, continuous operation and shut down. Further, different speeds during operation can be distinguished and put into relation with the corresponding vibrations.

The goal of this monitoring task is to detect a bearing failure and indicate which part of the bearing has been damaged. Fig. 5 shows a spectrum that was recorded by the monitoring device during operation with a fixed speed. It is visible that peaks can be identified precisely in the harmonics of 2x BSF (Ball Spin Frequency). This leads to the conclusion that a roller of the monitored bearing shows an upcoming defect.



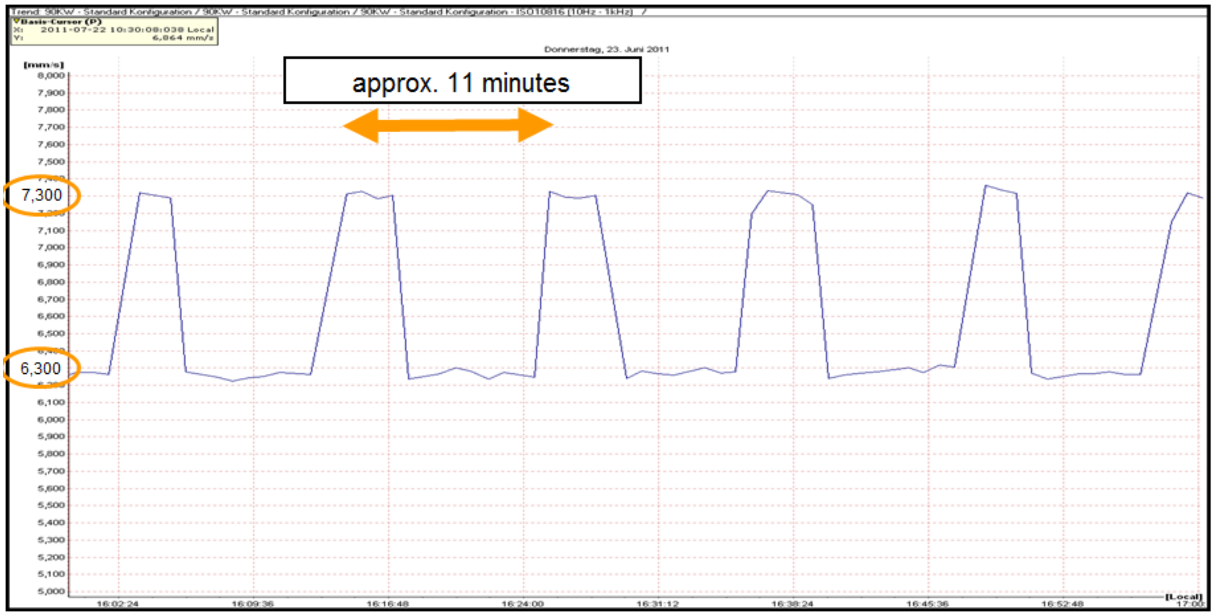
Picture 2: Compressor motor with condition monitoring device



Grey lines: Harmonics of 2 x BSF (ball spin frequency)

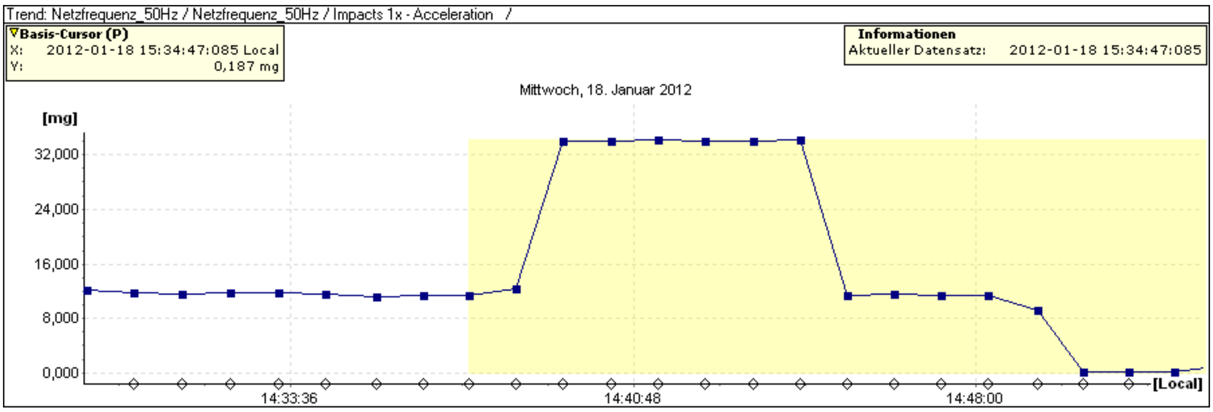
Fig. 5: Detection of a roller defect

Besides defect detection, it is also possible to record the different operating modes as it is shown in Picture 3. The varying amplitude corresponds to the varying operating modes. An actual-theoretical comparison of the aggregate is feasible and can provide potential for optimization. In this example the real-time process has shown to be running in a cycle enduring approximately 11 minutes. The difference between these cycles indicates that control improvement might be necessary.



Picture 3: Different operating modes recorded via a condition monitoring device

Data correlation is not only essential in regard of input signals, but also between the different vibration values. The monitored electric motor has had an electrical defect. Picture 4 shows how vibration monitoring, which detects mechanical vibrations, is also able to identify a change in electrical frequencies. At a certain point in time, the trend values double. In the analysis of the measured data, it became clear that an electrical frequency provoked that rise. A phase default was detected finally.



Picture 4: Phase loss detection in an electric motor

6 Present day – A growing system

A long field testing phase has lead to a system, that works fine in small, but also in large applications. After the product launch in 2011 the system is now running in various applications around the world.

An important factor is the continuous development of the product – including hardware and software as well as accessories that have proven to be practical when using actual CM-systems.

Customer Pilot projects with intelligent monitoring systems need to be accompanied by experts in order to ensure successful project starts and also to gain insight into the way customer's get along with the newly introduced products.

Finally to step into condition monitoring requires a training plan that is flexible regarding intensity and focus. For example, it is the customers choice, if the trainings should enable him to install and run the unit, or give a deeper insight in vibration analysis or even certify them to provide official condition monitoring service.

[1] P. Schmid, A. Roos: "USB Thumb Drive Vs. Hard Drive"; www.tomshardware.com: 2008

[2] H. Plattner, A. Zeier: "In Memory Data Management" 2012