# Acoustic Expert – We listen to your plant

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*A new approach for maintenance assistance is Acoustic Expert from Primetals Technologies. During the uptime of hardware, different sounds occur, which can give information on the status of the equipment. Recording and analysis of these sounds lead to a wide field of applications for asset but also for process monitoring. This 24/7 acoustic monitoring system enables a new way in predictive maintenance. Applications at environmental plants, steelmaking facilities, casting & rolling and material handling show the universal usability of the described system. Using several example installations the method is described in detail. Achieved results are provided as well.*

*The main benefits and an outlook conclude the paper.*

## 1. Introduction

Maintenance efforts are a significant part of the overall production costs. Four strategies co-exist in every plant with the goal to reduce the maintenance costs as much as possible while at the same time to keep the pure repair costs and also any consequential costs for production outages low. Which strategy is the most appropriate has to be decided for each equipment individually (**Figure 1**).

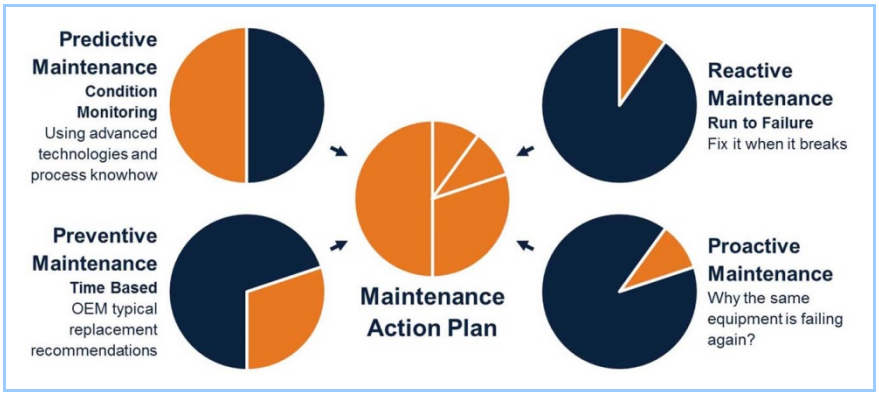


**Figure 1 Maintenance Strategies**

In this report the focus is on predictive maintenance or condition based maintenance. Several measuring techniques are applied to determine the condition of the equipment and come up with an estimate of its remaining life time. This allows to minimize unplanned outages and also to better utilize planned maintenance shutdowns.

One approach which is hardly used is the analysis of sound to mimic and improve the hearing analysis capabilities of experienced maintenance personnel, which is able to determine the condition of equipment just by its emitted sounds.

During the uptime of various hardware, distinct tonal sounds that are characteristic for a particular component can be detected. These sounds can provide very accurate insight into the current state of the equipment.

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# 2. Acoustic Expert

## 2.1 Basic Concept

Using this bionic approach Primetals Technologies designed the Acoustic Expert. Acoustic Expert monitors plant equipment and components continuously using acoustic sensors like microphones or hydrophones. Analysis of these sounds leads to a statement whether the equipment operates in proper conditions or not. This system enables monitoring or operation mode verification of plant equipment at new fields of applications. Leakage detection or switching procedures in valve stations as well as nozzles monitoring of torch-cutting machines in continuous casing plants can be realized with this system.

Long-term analysis of sound emitted by plant equipment enables detection of creeping wear and objective determination of state. This relieves the pressure on maintenance staff, to help them focus on the important tasks.

## 2.2 System Topology

The system consists mainly of an acoustic sensor, a signal processing unit and an evaluation system. If additional information of the process is needed industrial interfaces are used. Sophisticated mathematical sound analysis algorithms enable a robust analysis. Therefore, results are not interfered by disturbing noises in the background. Audio data is recorded for analysis only and subsequently deleted after processing. Furthermore, for keeping privacy, Acoustic Expert does not identify human voices (**Figure 2**).

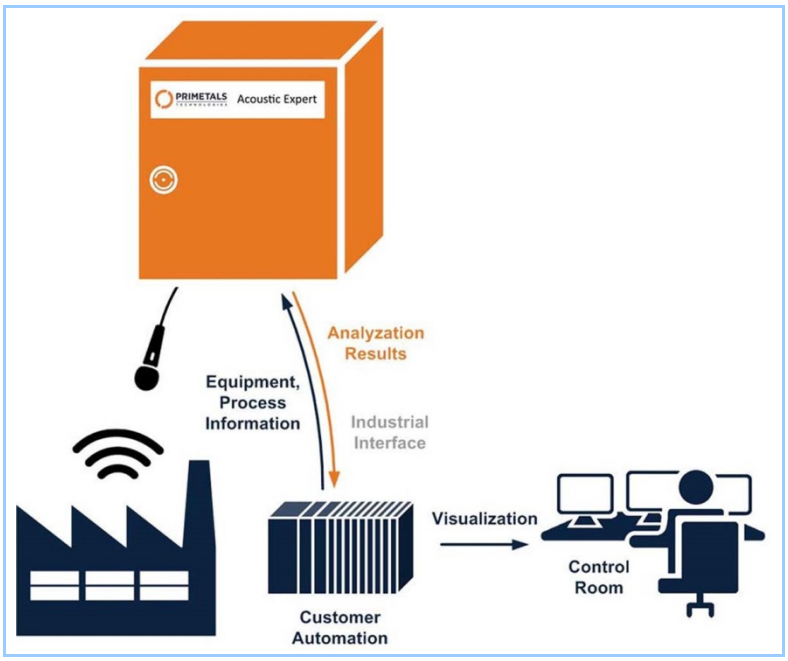


**Figure 2 Acoustic Expert - System Overview**

## 2.3 Key Features

Sound analysis algorithms are mainly based on key feature, representing the properties of a signal. Largely, key features make use of the Fourier transformation, where based on signals in time domain, representations in frequency domain are calculated.

Following equation shows the definition of the Fourier transformation

$$F(\omega) = \int_{-\infty}^{\infty} f(t)\, e^{-i\omega t} dt$$

Using the inherited discrete Fourier transformation (DFT)

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-i\frac{2\pi}{N}nk} \qquad k = 1, 2, \dots, N-1$$

and divide-and-conquer method we get the fast Fourier transform (FFT).

## 2.4 Bagfilter valve monitoring

Acoustic Expert was put to test for the first time ever in a dry dedusting system (**Figure 3**). In this bagfilter plant cleaning pulses are generated by means of activating special high flow solenoid valves, which are responsible for cleaning the filter bags and cause a characteristic sound when activated. In this application, Acoustic Expert monitors the plant by using the sound of cleaning valves. This sound is recorded and analyzed with a set of features. Additional plant information, e.g., identification of the actual activated valve is received by the industrial interface. The profile of each cleaning pulse is recorded and evaluated immediately afterwards. Following data evaluation, the results are visualized in the customer's HMI (human-machine interface).

Until the introduction of Acoustic Expert, this type of plant monitoring was not used in the steelmaking industry for these applications.

**Figure 3 Dry Dedusting Plant**

## 2.5 System flexibility

In combination with an online connection, it is also possible to utilize Acoustic Expert as a cloud-based service. Using a cloud the whole monitoring information of different plants can be merged into one single database. In this case, the system can be separated from the local IT network to enable a fully stand-alone monitoring solution. Additionally to the visualization on a HMI, analysis results are made available to end-user at a fingertip using an intuitive app on mobile devices.

**Figure 4** shows results of three different cleaning valves. The green area on top represents a proper working process. Whereas the red area on the bottom of the graphic stands for a malfunction. In addition to the historical trend the estimated kind of error is given too.

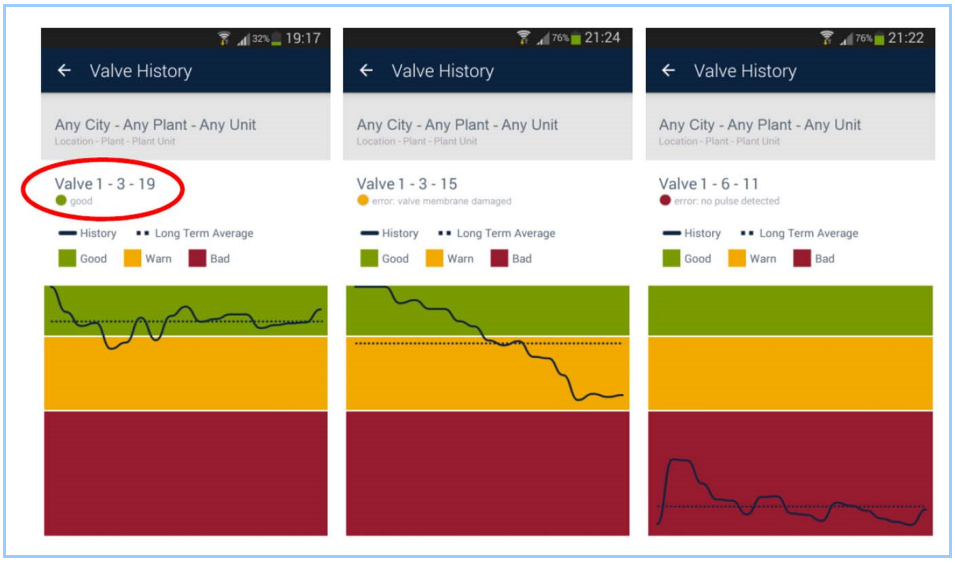


**Figure 4 Visualization of performance of three different valves on mobile device**

## 3. Large field of applications

Results of different test installations show its usability in a large field of applications - mainly for continuous diagnostics for production and maintenance support, even beyond heavy industries. Primetals Technologies, together with its partners, aims to employ this technology to keep maintenance and operation of metallurgical machinery as simple as possible. The flexibility of the Acoustic Expert system enables to continually develop new areas of application. A set of applications is explained in the following.

### 3.1 Material quality and material type detection at take-over points on conveyor belts

Transported materials generate sound at takeover points on conveyor belts (**Figure 5**). Different transported materials lead to different characteristic sounds. Fine sand and coarse-grained material emit different sound patterns, for instance aluminum sounds different from lime. Acoustic Expert uses this phenomenon to automatically detect the material type of transported materials.

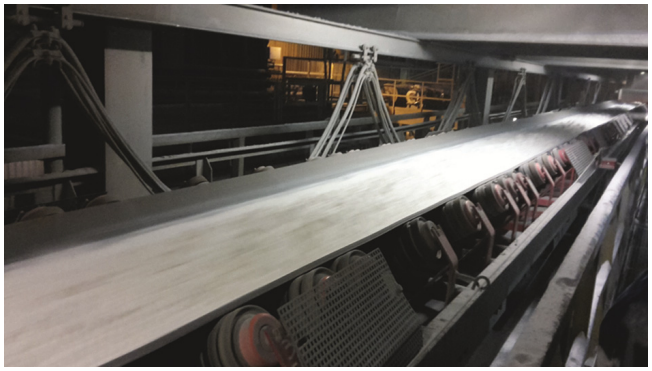

**Figure 5 Takeover Point on Conveyor Belt**

**Figure 6** shows the analysis results of two different materials. 20 key features are analyzed and compared to each other, where each line stands for a record of 10 seconds. Main distinctions of materials are in F1,F2, F3, F4, F17 and F18:

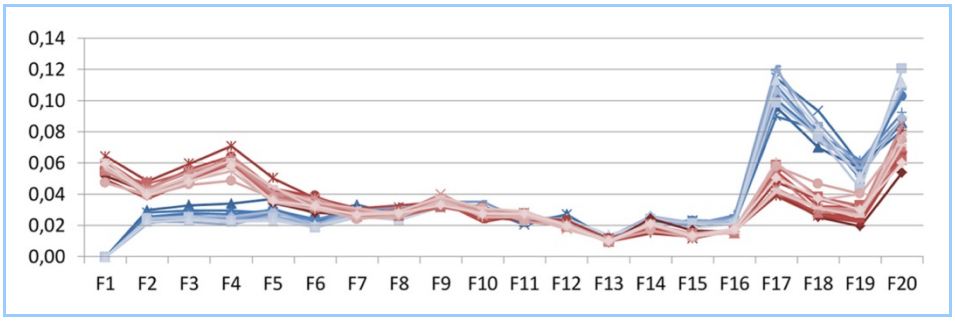


**Figure 6 Analysis features of two different material types**

Using differences in key feature analyses Acoustic Expert is able to detect the type of the material within seconds. The more materials are transported with the monitored conveyor belt, the more features are needed for the differentiation of materials.

Additionally to the type of the transported material Acoustic Expert is also able to determine the quality of material by categorizing the grain size.

### 3.2 Torch cutter at continuous casting machines

The torch cutter at the end of each continuous casting machine is crucial to the seamless operation of the plant (**Figure 7**). If cutting procedure fails, unscheduled downtime could become the undesirable result. Acoustic Expert monitors the acoustic signals produced during the cutting process. After detection of different process phases (ref. **Table 1**) by the evaluation of emitted sounds, a detailed analysis shows the current condition of the torch cutter nozzle while also providing information about gas-mixture levels and cutting quality. Furthermore another advantage is detecting a successful cut through of the slab.

**Figure 7 Torch cutter nozzles at continuous casting machine**

**Table 1 Torch Cutter Process Steps**

| Process Steps | | |
|---|---|---|
| Name | Description | Sequences |
| Stand by | Pilot flame | 1-7 |
| Prepare for cutting | Increase gas flow | 8-14 |
| Synchronizing | Clamp on | 17-19 |
| Cutting Phase A | Cut into | 20-25 |
| Cutting Phase B | Cut through | 26-60 |

For the analysis the record is divided in sequences which last approx. 3 sec and are analyzed by using 3 features (F1-F3). **Figure 8** shows the results of an analysis with respect to the single sequences. According to the defined features F1-F3 the different process steps (ref. **Table 1**) can be evaluated.

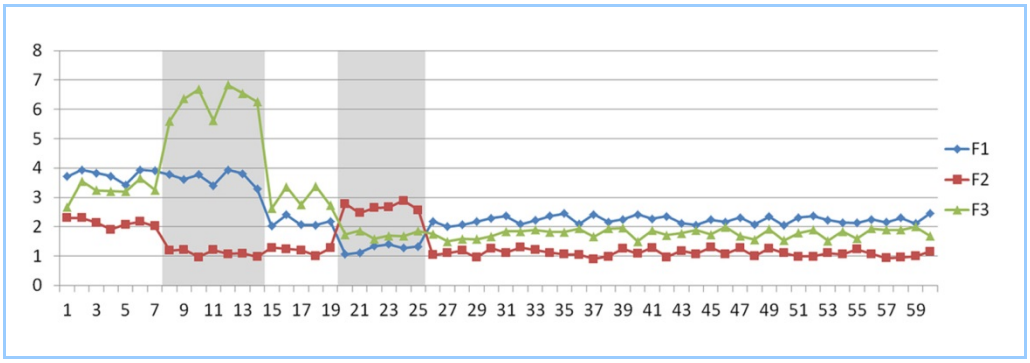


**Figure 8 Torch cutter analysis results**

## 3.3 Spray nozzle monitoring

One of the areas currently in focus is that of the rolling mill. The monitoring of spray nozzles, for both lubrication and cooling, has already been tested. Different clogging states can be determined by using the emitted sound of nozzles while in use. Additionally wear monitoring is possible with the Acoustic Expert system.

Spray nozzles can also be found in other areas, where the system can be applied using the same principle, for example cooling nozzles at the continuous casting plant (**Figure 9**).

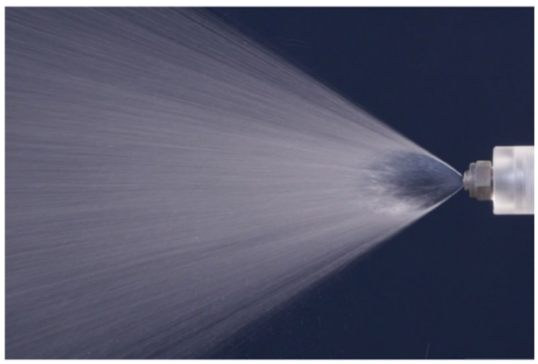

**Figure 9 Secondary cooling nozzle for continuous casting machine**

### 3.4 Rolling-mill monitoring

The most recent tests have been centered around the monitoring of the gear box and spindles in rolling mills (**Figure 10**).

**Figure 10 Hyper UC Mill**

## 4. Main Benefits

- Holistic plant monitoring, since several components together give a characteristic sound spectrum
- Cost-efficient plant monitoring: minimal hardware effort, mainly software-based solution
- Adaptable for a large field of applications
- Application beyond the steel industry possible

## 5. Conclusion and Outlook

The oldest method to diagnose the status of any equipment is having a human go to the equipment and look at the equipment, touch it and listen to it. The described Acoustic Expert mimics the last one, but in a reproducible and quantifiable way.

Since noises and production sound are generated all over the plants in heavy industries, the field of application of Acoustic Expert is continuously expanding. Feasibility tests of new use cases are done regularly and often in close contact with leading steel manufacturing companies. Even in other industries there is a great potential in using such systems.

## References

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