Report on Predictive Maintenance Technology for Equipment by Vibration Measurement

Introduction of Network-based Predictive Maintenance System

1. Introduction

The maintenance of facilities and equipment in manufacturing plants is shifting from preventive maintenance and breakdown maintenance to "predictive maintenance." Preventive maintenance is performed at regular intervals and timings, and corrective maintenance is done by maintenance and repairs after a failure, loss of production capacity or defective products. In contrast, predictive maintenance is maintenance, where signs of failure are detected in advance and repairs and maintenance are performed at the appropriate timing. We have also been developing a tablet-type abnormal vibration detection system[1)]. At sites where maintenance activities are performed by patrolling, this system measures and analyzes on the spot the vibration state of the maintenance target using sensors to confirm the chronological changes in the state using charts and numerical values. In this way, the system allows us to systematically implement predictive maintenance, when an abnormality occurs, by displaying according to the degree of abnormality. This is a so-called portable predictive maintenance system, but with the advancement of sensing and IoT technologies, the market has begun to see a wide range of services based on models that store and analyze data on servers and clouds via networks. The system enables remote status confirmation and predictive maintenance from the network. However, the reality is that at actual sites that our customers are facing, there are many cases where it is not possible or not allowed to upload sensing data to an external network or the cloud server for various reasons. We have developed a system that allows them to proceed even at such sites by predictive maintenance using a local network. This report introduces the network-based predictive maintenance system and the predictive maintenance technology it incorporates.

2. Overview of Predictive Maintenance System

2-1) System configuration

A schematic diagram of the network-based predictive maintenance system in operation is shown in Figure1. The basic configuration consists of a "vibration sensor," "sensor unit," and "predictive maintenance analysis program" (to be installed on a PC for use). The sensor

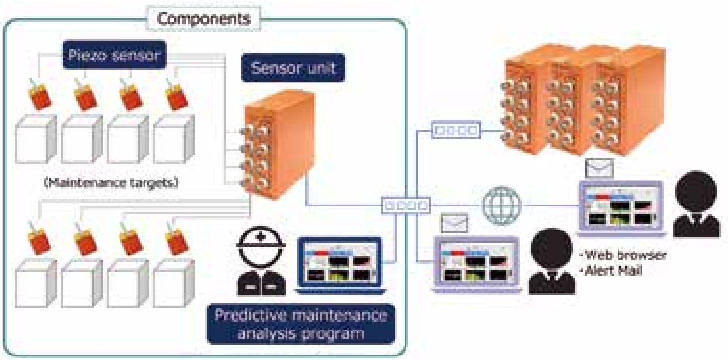


Figure1 Schematic diagram of the maintenance system

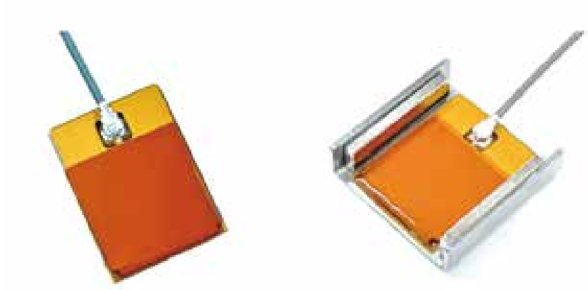
and the sensor unit are connected with the supplied low noise cable. The sensor unit and the program (PC) are connected using a LAN network. The LAN can also use an existing network. It is operational even with this basic configuration, making it easy to handle. Moreover, by increasing the number of sensor units with a switching hub, it will also be possible to increase the number of maintenance targets and sensing points, check their status from a networked location via a web screen on another PC and receive alerts by e-mail according to the degree of abnormality of the maintenance target (a mail server to be separately required).

2-2) Components

The following are the three components.

2-2-1) Organic piezoelectric vibration sensor

We have developed a thin, compact, and lightweight vibration sensor that uses an organic piezoelectric element[2] that can be easily retrofitted. It is fixed by attaching it to the mating surface, but due to its flexibility, it can be fixed to a slightly curved surface. Using a special magnetic bracket will also make it possible to fix it with magnetic force (Figure2).



(Pilot model)　　Magnetic bracket

Figure2　Organic piezoelectric vibration sensors

(Pilot model)

Figure3　Sensor unit

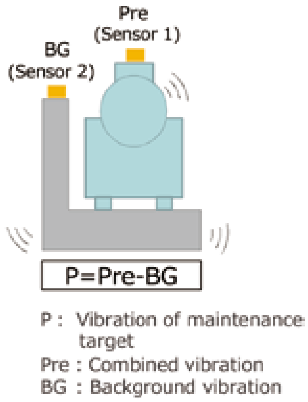


Figure5　Elimination of background vibration

2-2-2) Sensor units

Since each sensor unit is equipped with eight input channels, all of which have built-in charge amplifiers, charge output type sensors can be connected as they are. Therefore, in addition to the organic piezoelectric vibration sensor mentioned above, commercially available vibration and acceleration sensors can also be used. In the sensor unit, the sensor signal is digitally converted and transmitted from the LAN terminal to the PC on the analysis side through the network. The LAN connection also allows for distributed placement of sensor units, making it possible to build a multi-point sensing environment flexibly and cost-effectively (Figure3).

2-2-3) Predictive maintenance analysis programs

Octave analysis is conducted on vibration sensing data, based on which predictive maintenance is performed by conducting "MT method (degree of abnormality analysis)" and "trend analysis (state analysis)" from the data. For each measurement point, the "time waveform," "FFT analysis," "octave analysis," "MT method," and "trend analysis" can be checked on the screen dashboard (Figure4).

It also has a function to differentiate data (Figure5) to eliminate background vibration from the environment as a disturbance signal. To check the current status of the maintenance target, the screen displays the status and alert level corresponding to the threshold value. In case of an abnormality (every time the status changes to Caution, Maintenance, or Danger), an alert e-mail can be sent to the maintenance staff.

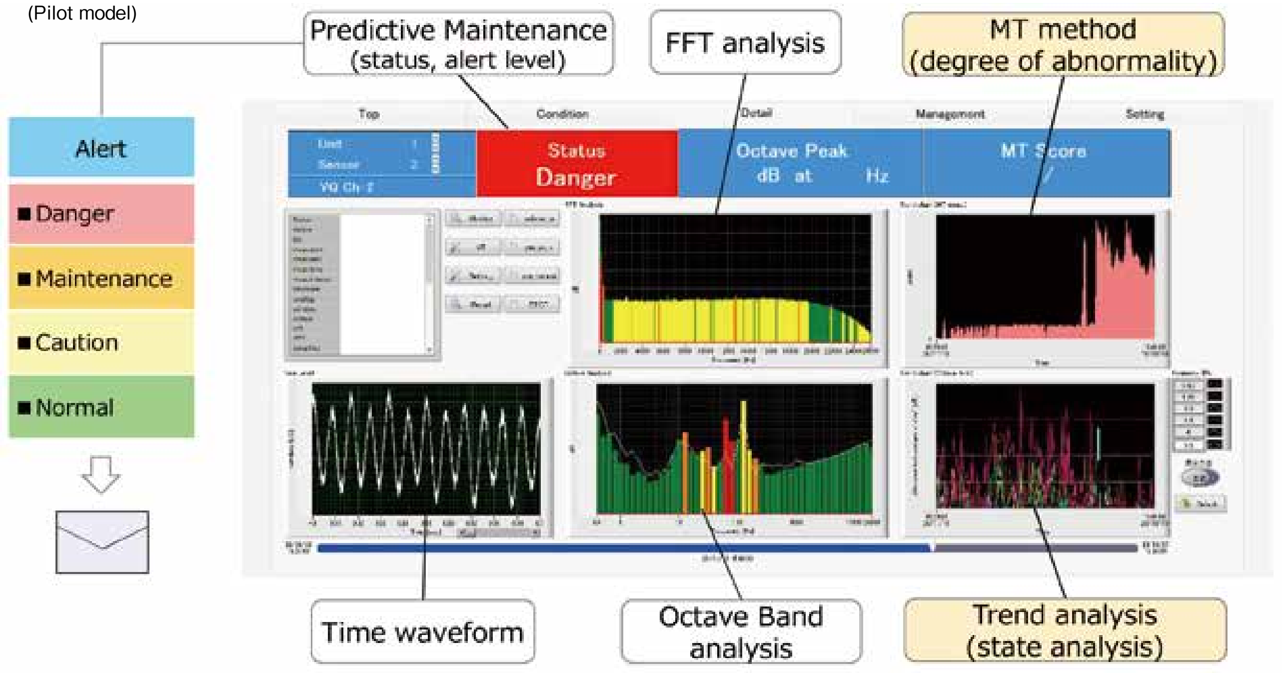


Figure4　Predictive maintenance analysis programs

3. Predictive Maintenance Methods

To perform predictive maintenance based on changes in the vibration state of the maintenance target, it is necessary to capture the changes in the vibration state of the maintenance target from sensing data. This system uses the vibration data on which octave analysis has been conducted. We have adopted this method because it is very compact compared to the amount of data in FFT analysis, which is widely used in vibration analysis, and it is suitable for analysis using the trend analysis and MT method described below.

3-1) Trend analysis (state analysis)

This method uses the vibration data of the maintenance target in normal (regular) operation as a reference to conduct the initial measurement. By using the difference value between the vibration data and the subsequent vibration measurement data to draw a trend chart of how much the vibration intensity has changed/differed, it will be compared with the threshold value to capture signs of abnormality. It is a trend analysis characteristic to focus on relative changes rather than absolute changes, and signs of abnormality will be captured through this kind of analysis of the state of vibration. For the frequencies to be used in the analysis, the top five frequencies with the maximum change in vibration intensity from the octave analysis data and another one (one can be selected arbitrarily) are automatically selected. Alternatively, all of them can also be selected manually (Figure6).

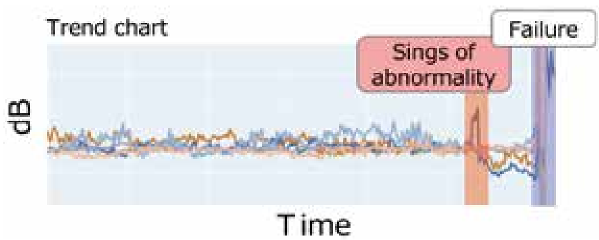


Figure6　Overview of trend analysis

3-2) MT method (degree of abnormality analysis)

The MT (Mahalanobis-Taguchi) method[3] is a pattern recognition method that aims to determine normality and abnormality based on the Mahalanobis distance. It is widely used for various types of judgment, and since it is simple and can easily detect the degree of abnormality, it is incorporated into the predictive maintenance analysis program together with the trend analysis described above (Figure7).

This method captures the degree of abnormality by creating a unit space from the vibration data obtained when the maintenance target is operating normally (steady-state) and then calculating the Mahalanobis distance (MT score) with the subsequent vibration as data space. However, by preprocessing the data to adjust the number of analysis dimensions, we have found that the time of appearance of the MT score indicates the degree of abnormality. The predictive maintenance analysis program is equipped with this function to adjust the number of dimensions, making it possible to detect signs of abnormality based on the MT score right before the failure of the maintenance target or with enough time to spare before such an incident. Thus, the function can be used effectively by the style of the customer's maintenance activities (Figure8).

The abovementioned methods of "trend analysis" and "MT method" are installed and conducted simultaneously in this system. Capturing changes in the vibration state and the degree of abnormality numerically has improved the accuracy of its predictive maintenance.

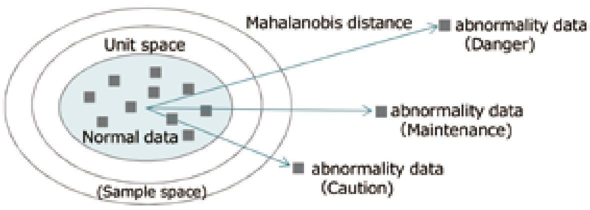


Figure7　Overview of MT method

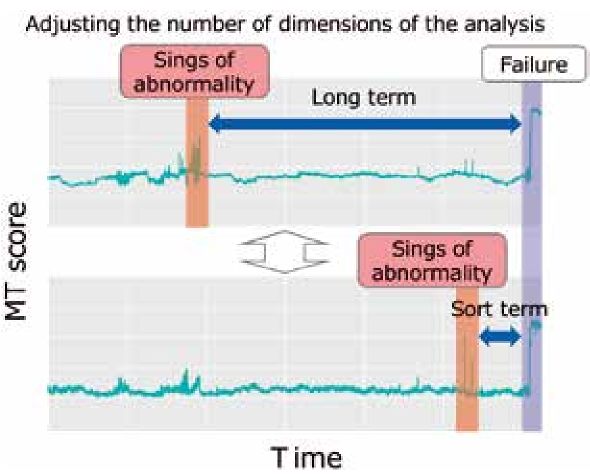


Figure8　Overview of adjustment of analysis dimensions and predictive timing

4. Opportunities for Use and Pre-verification Activities

The maintenance targets assumed for this predictive maintenance system are pumps, motors, engines and other machinery whose status can be sensed with vibration. However, it is essential to verify in advance at the customer's site whether or not predictive maintenance is possible for the maintenance target. Therefore, obtaining cooperation from the customers considering the introduction of the system, we ask them to allow us to make trial measurements in advance. We also ask them to consider the possibility of predictive maintenance and its cost-effectiveness after installation.

5. Specifications

The specifications of the organic piezoelectric vibration sensor are shown in Table1, those of the sensor unit in Table2, and those of the predictive maintenance analysis program in Table3. In actual use, the number of units and the number of sensing units will determine practical measurement settings and the number of PCs in the predictive maintenance analysis program. Thus, the frequency of data collection and the scale of sensing will need to be confirmed and planned with each customer.

＊The specification values are from the pilot model data and may differ from the product.

Table1　Specification summary of Organic piezoelectric vibration sensors

Element	Organic piezoelectric element (Thickness 1mm)	(Reference value)
Sensitivity	0.1pc/m/s^2	(Reference value)
Frequency range	0.4～10,000 Hz	(Reference value)
Dimensions	24×20×0.5mm	(Reference value)
Cable	Low noize (3m standard)	(Reference value)
Weight	approx. 1g (Cable not included)	(Reference value)

Table2　Specification summary of Sensor unit

Input Ch number	8ch (Built-in charge amplifier)
A/D Conversion	24bit (8ch at the same time)
Sampling frequency	51.2kHz
Input frequency range	0.16Hz～20kHz
Protocol	UDP/IP
Ethernet	1ch, 10/100/1000Mbps, RJ45
Trigger	Photocoupler (Requires external power supply DC24V)
Power supply	DC24V
Dimensions, Weight	W52×H126×D128mm, approx. 450g
Operating Environment	0-55℃, 95% relative humidity, non-condensing

Table3　Specification summary of Predictive maintenance analysis programs

Analysis function	FFT analysis, Octave analysis (1/1, 1/3, 1/6, 1/12, 1/24)
Predictive maintenance function	Trend analysis (state analysis), MT method (degree of abnormality analysis), Alert display and email delivery by threshold
Other functions	Background signal removal, Measurement by trigger, Remote panel connection using a web browser
Storage capacity of analysis data	[Example] approx. 160GB / year ※1 (Settings: 8ch, 1/3 octave analysis, 10-minute interval measurement ※1 When not saving the time waveform data)
Operating environment	OS: Windows10, Processor: Intel Core i5 equivalent or higher
Connectable unit	VALQUA Sensor Unit ※2 (NI9234 [National Instruments], connectable) ※2 The number of connected sensor units depends on the measurement settings and network environment, so advance planning is required.

6. Conclusion

This "network-based predictive maintenance system" has been developed based on the concept of a system that can be used immediately at the manufacturing site, and we hope that it will be considered as a benchmark for installation. This system will be a part of our VALQUA Predictive Maintenance System product range, and we hope that it will contribute to the maintenance of production sites in various industries.

7. References

1) Makoto Haneda (MOL Techno-Trade, Ltd.), Hisataka Sato, Tetsuya Komeda, Yasushi Aburatani: *Valqua Technology News*, No.36, 3-6 (2019)

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Hisataka Sato

Frontier Development Team,
Advanced Technology Development Department,
Research and Development Division