Technical Report

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Overview of Equipment Diagnosis Device and System

Tsunemi MURAYAMA*

Abstract

Forty years have passed since Nippon Steel & Sumitomo Metal Corporation developed an equipment diagnosis technology mainly for rotating machinery, as a means to grasp deterioration signs at an early stage. In the meantime, many diagnostic apparatuses such as portable diagnostic devices for an inspector during patrol and online diagnostic systems for the long-term trend management of critical facilities were developed and have been utilized in many industrial fields. This paper describes an overview of the latest multi-function portable diagnostic device and an online equipment diagnostic system among the equipment diagnostic apparatuses of Nippon Steel & Sumikin Texeng Co., Ltd., as one of the affiliates (group companies), bearing the commercialization of equipment diagnostic technology developed by Nippon Steel & Sumitomo Metal Corporation.

1. Introduction

Approximately 40 years have passed since Nippon Steel & Sumitomo Metal Corporation developed the equipment diagnosis technology mainly for rotating machines as a means to grasp deteriorating signs at an early stage.[1)] Meanwhile, many diagnosis apparatuses ranging from portable diagnosis devices for use by inspectors during patrolling to online diagnosis systems for long-term trend management of critical facilities have been developed, and their application range and functions have been expanded and utilized in many industrial fields.[2)]

As Nippon Steel & Sumikin Texeng. Co., Ltd. has joined the development by Nippon Steel & Sumitomo Metal since the beginning, the company has received "Technology licensing with granting of the right of sales of equipment diagnosis technology and device" and is currently conducting sales of equipment diagnosis devices and systems and providing engineering and consulting services to various clients such as chemical, cement, and paper manufacturing companies in addition to Nippon Steel & Sumitomo Metal. **Figure 1** shows the history of diagnosis equipment business of Nippon Steel & Sumitomo Metal and Nippon Steel & Sumikin Texeng. (Nittetsu Electrical Engineering & Construction and Nittetsu Elex are the former company names of Nippon Steel & Sumikin Texeng.)

Equipment diagnosis device and system include diagnosis based on sound, motor current, temperature, and so on in addition to a vibration, multi-function portable diagnosis device equipped with measuring function such as a data logger (ELESMART™[*1]X); a rotating machine diagnosis management system, which is a software for managing data collected by ELESMART™X; a pencil-type simplified diagnosis device; and an online equipment diagnosis system.

This paper introduces the most updated multi-function portable diagnosis device released in October 2014 and the outline of the online equipment diagnosis system, which received Efficacy Prize of Excellent Product of TPM Award in fiscal year 2013.

2. Multi-Function Portable Diagnosis Device (ELESMART™X)

2.1 History of development

The previous type of multi-function portable diagnosis device[3)] is a product loaded with functions required for grasping the state of equipment, mainly of a rotating machine, based on various types of information such as sound, motor current, and temperature signal. However, renovation was decided because nearly 10 years have passed since its introduction in 2005 and depletion of spare parts has been observed. Furthermore, upon the development of a new type, incorporation of new functions and strengthening of existing functions have been contemplated by taking into account the users' voice and utilizing findings, technologies, and knowhow that Nippon Steel & Sumitomo Metal and Nippon Steel & Sumikin Texeng have compiled through the use of equipment and operation diagnosis.

[*1] ELESMART is a trademark registered by Nippon Steel & Sumikin Texeng. Co., Ltd. (Registration Number 4999606).

* General Manager, Head of Sensing & Diagnosis Solution Department, Sensing & ICT Solution Division, Electrical Instrumentation & Systems Unit, Nippon Steel & Sumikin Texeng Co., Ltd.
1320-4 Otsuka, Maeda, Yahatahigashi-ku, Kitakyusyu City, Fukuoka Pref. 805-8555

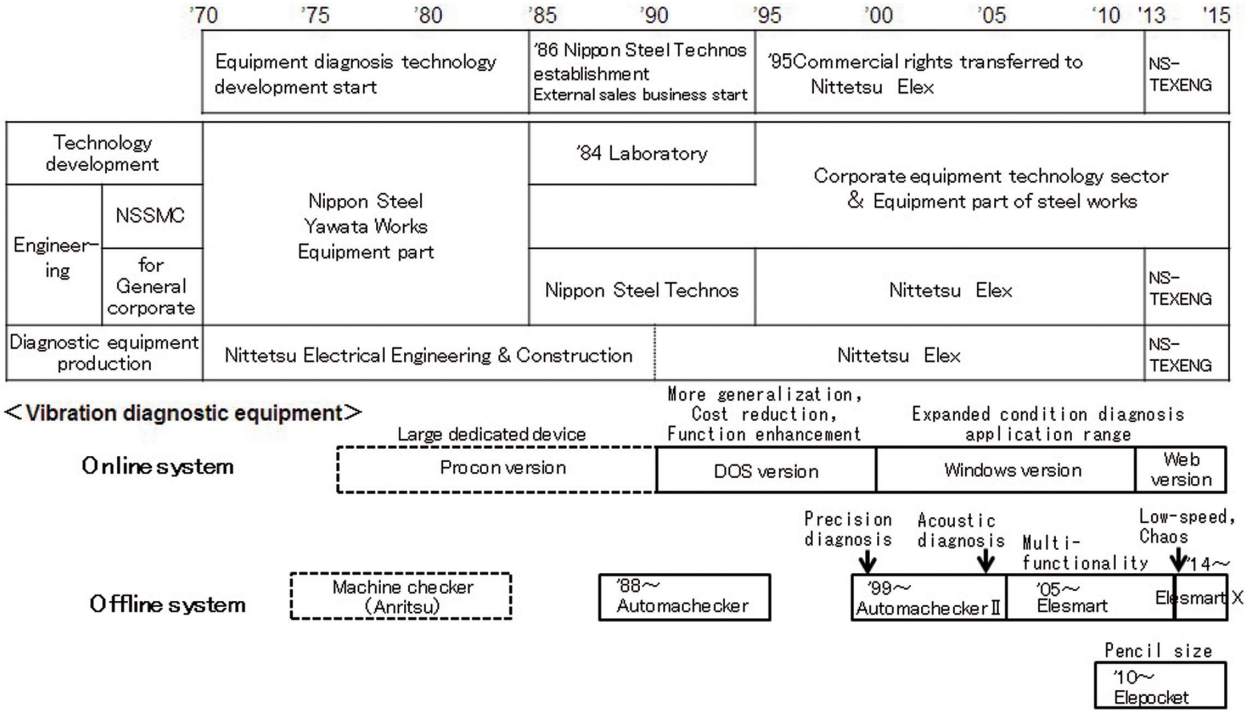

Fig. 1 Nippon Steel & Sumikin Texeng's transition of equipment diagnosis business
(Nittetsu Electrical Engineering & Construction and Nittetsu Elex are the former company names of Nippon Steel & Sumikin Texeng.)

2.2 Problems related to portable diagnosis device and trend of device

In recent years, with problems such as equipment deterioration and turnover of veteran inspectors in production sites, diagnosis devices with a diagnosis technology of a higher level, capability of conducting trouble analysis of various types and so on, and capability of providing easy operation and easy-to-understand diagnosis results were sought for.

2.2.1 Improvement in diagnosis accuracy (low-speed diagnosis technology)

The need for improving the diagnosis accuracy of low-speed rotating machines, which are widely observed in large-sized crucial equipment (below 100 rpm in general), are high because loss in a trouble is huge. However, striking energy generated when a rotating body hits a flaw on an outer ring is weak; therefore, the sensitivity for detecting abnormalities is low. Hence, a diagnosis method with high accuracy was being sought for. Recently, a study of using acoustic emission (AE) instead of vibration is being promoted; however, in reality, the technology is not prevailing because of lack of quantitative indices and high cost of device.

2.2.2 Needs of users

A study on the needs of users for improvement in an old-type, multi-function portable diagnosis device (ELESMART™) showed the following improvements in operability and function:

(1) Operability
① Stability under high ambient temperature
② Improved visibility in outdoor use
③ Enlarged display with the smallest possible body size
④ Longer service time

(2) Function
① Easy-to-understand diagnosis result
② Availability of new diagnosis technology

Among the above points, it is considered that the device has been improved to the level where needs from operability in (1) have been achieved because of the improved hardware capability, as shown in **Table 1**. Furthermore, on the enlarged display, three graphs analyzing frequency for comparison in precision analysis can be observed on a single display, and display capability has been improved to make analysis easier (**Fig. 2**).

2.3 Function and characteristics of developed device

Measurement functions of the developed device are shown in **Fig. 3**. Items in Gothic letters show new functions or improved functions, and functions of low-speed diagnosis, continuous monitoring, and chaos analysis among them are introduced.

2.3.1 Low-speed diagnosis

In Nippon Steel & Sumitomo Metal, for diagnosis of bearings running at general revolutions per minute, in order to enhance abnormality detection sensitivity by taking advantage of resonance frequency of an acceleration sensor, diagnosis is conducted in a frequency zone above 10 kHz. However, as in case of low-speed running, striking energy generated at the time of a rotating body hitting a flaw or the like on an outer ring is weaker than that generated in the case of conventional-speed running. In addition, vibration near a resonance point in the acceleration sensor becomes less; however, it is considered that vibration of a natural frequency specific to the bearing housing below 10 kHz becomes obvious.

Then, a low-speed diagnosis mode was developed, which includes a combination of the following three manners: selection of an optimum band pass filter depending on subject equipment, employment of an optimum acceleration sensor that covers resonance frequency in its frequency range, and securing time enough for data collection depending on number of revolutions. **Figure 4** shows the vibration wave forms caused by a flaw on an outer ring obtained with the conventional method and with the low-speed mode.

2.3.2 Continuous monitoring

One of the characteristics of the new functions is the continuous

Table 1 Comparison of basic specification

		ELESMART MCV-080	ELESMART X MCV-090
Basic structure	OS	Windows CE.NET	Windows CE.6.0
	Size	170(W) × 120(H) × 50(D)	165(W) × 119(H) × 40(D)
	Weight	750g including a battery	About 650g including a battery
Operating environment	Operating temperature	0 to 40 °C	−5 to 50 °C
	Dust-proof, waterproof	IP54 or equivalent	IP54 or equivalent
Operating time	Continuous usage	170 minutes	300 minutes
Storage capacity	Memory	Internal memory: 64 MB	Micro SD: 32 GB
LCD module	Screen size	4.7 inch	5.7 inch
	Number of dots	320 × 200	640 × 480
Touch panel	Touch-panel operation	One-touch mode	One-touch, two-touch, slide mode
Number of channels	BNC	1ch	2ch (option)
Internal gain	Vibration, sound	Maximum 40 dB	Maximum 50 dB
Type of probes	Standard sensor	Stick probe	Stick probe / magnet holder Exchangeable
LAN	Specifications	–	10BASE-T (option)

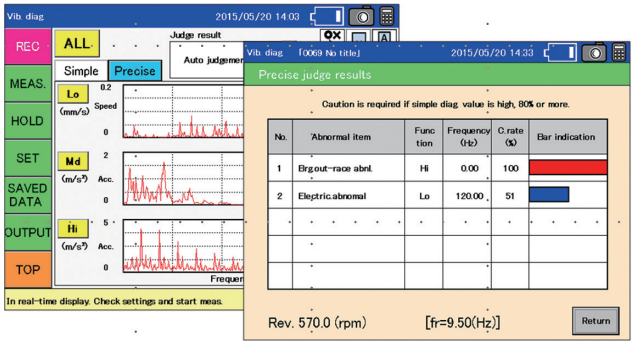

Fig. 2 Precision diagnosis and judgment screen example

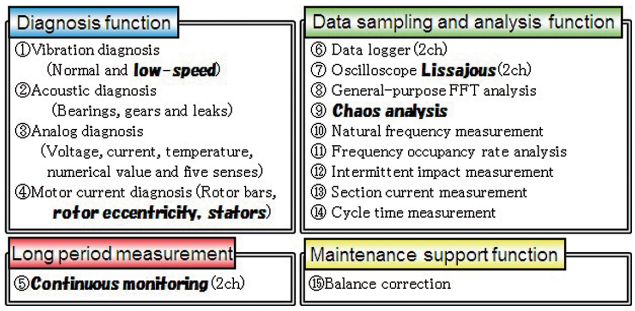

Fig. 3 Composition of functions

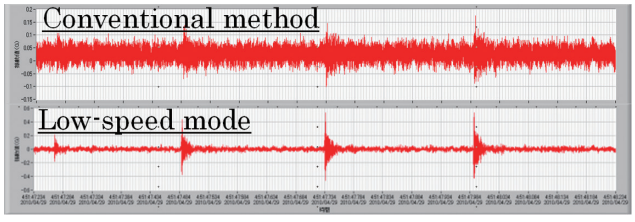

Fig. 4 Effect of the low-speed diagnostic mode

monitoring function. The system is considered to be applicable when needing concentrated monitoring until the next scheduled maintenance when a sign of abnormality is detected, estimating ef-

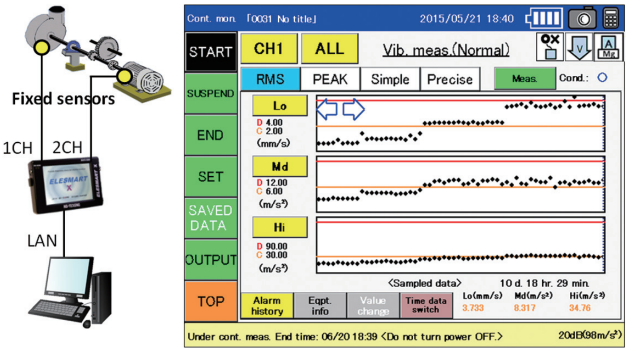

Fig. 5 Continuous monitoring system configuration and screen example

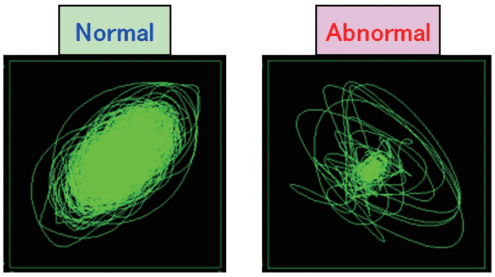

Fig. 6 Chaos diagnosis example (bearing vibration)

fects of installation of an online diagnosis system in advance, and so on. Continuous monitoring up to 31 days is possible, and monitoring not only at the machine side but also in a remote office room by a PC is possible when it is connected to a LAN system (**Fig. 5**).

2.3.3 Chaos analysis

"Chaos analysis" is the result of a challenge in the development of new technology. Chaos is defined as "a phenomenon of a system behaving in a very complicated, irregular, and unstable manner despite the fact that the said system is changing based on a firmly established rule and therefore making its state of affairs in long future utterly hard to be predicted."

Figure 6 is a figure of an attractor, a qualitative index of state of chaos (a representation of the special feature of a wave form on a single space extracted by applying a special transformation proces-

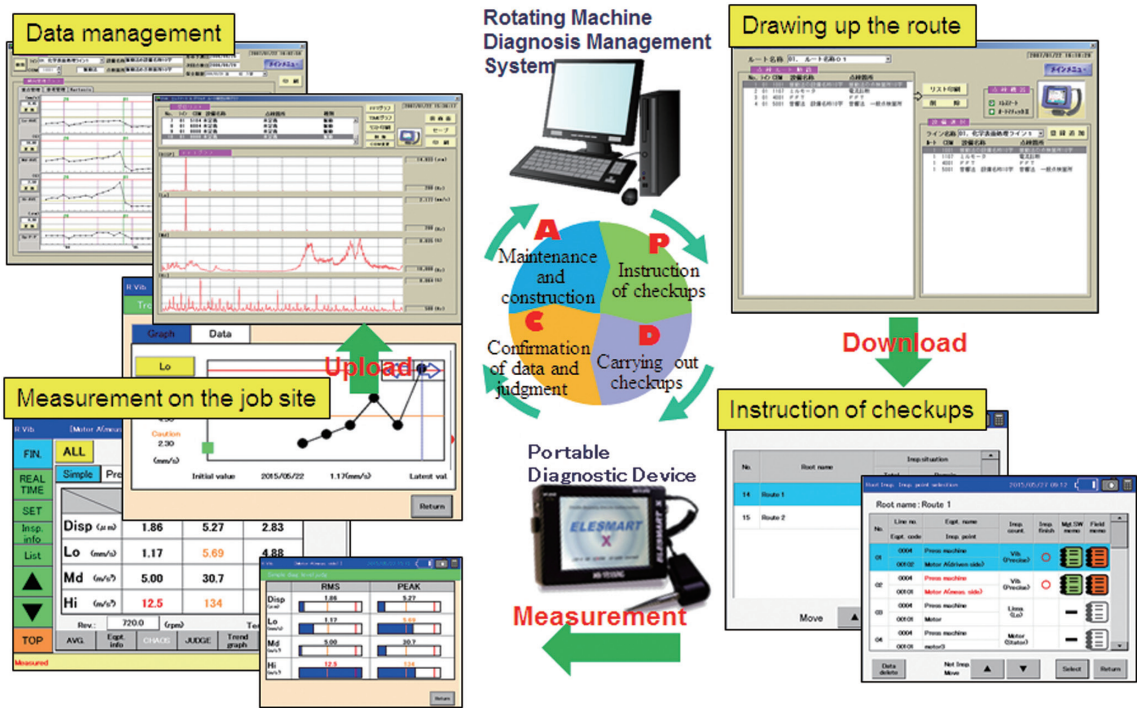

Fig. 7 Rotating machine diagnosis management system

sing to a time series signal), which enables visual evaluation of normal and/or abnormal states of equipment. Furthermore, trend management is made possible by utilizing quantitative indices such as Shannon's entropy, which shows the extent of scattering in an attractor figure, and Lyapunov exponents, which show the extent of instability of the path. By utilizing not only vibration but also other various types of signals, applications to diagnosis of operation can also be expected. Trial application results in certain users forwarded to us showed their appreciation that primary judgement of abnormality is possible even for maintenance personnel who do not have sufficient expertise in vibration diagnosis.

2.4 Diagnosis management system for rotating machine

In a multiple-function portable diagnosis device, not only storage of diagnosis data but also implementation of precision diagnosis is also possible with itself. However, to develop further sophistication of equipment management, linkage of a rotary machinery diagnosis management system to a PC processing software is desirable. Daily inspection is to be conducted on the basis of the inspection route and control criteria and the instruction downloaded from the PC. In case an abnormality is observed during the inspection, it is displayed in an easy-to-understand way, and past data can be referred to easily. After measurement, the data are uploaded to the PC and managed. By rotating the abovementioned PDCA circle of equipment management, further utilization of data becomes possible (**Fig. 7**). In Nippon Steel & Sumitomo Metal, this function is loaded to whole company equipment management system and is strengthening equipment management.

3. Online Equipment Diagnosis System[4)]

3.1 History of development

An online equipment diagnosis system is a system that cautions the emergence of abnormality, mainly in a rotating machine such as a motor, pump, and blower, by automatically gathering data such as vibration values and temperatures through vibration sensors and temperature sensors mounted thereto and by judging the soundness of such data by referring to thresholds through a diagnosis device coupled with the PC. The system is used in various industries represented by iron and steel, cement, and paper manufacturing. Although the conventional system was improved whenever occasions called for and has continued to be standardized, because the system has been following the system environment and the file structure established at the time when the system was constructed, introduction of the most updated technology has become necessary to provide a system excellent in expressiveness and operability in the man-machine interface. On the other hand, to strengthen the data linkage to other systems, including equipment management system, alteration of data structure was indispensable.

Then, maintaining the then-existing basic equipment diagnosis function as it was, the supporting function that enables the utilization of diagnosis results in a more effective way by comparing the diagnosis data, which can be stored for a long term, with work and log records of maintenance has been strengthened. Furthermore, by establishing a web application software with improved expressiveness and operability, the system has been developed so that users can access their diagnosis result on their own business-use PCs.

3.2 Developed system

3.2.1 Operating environment

The old system was designed to store data such as vibration and temperature gathered by diagnosis devices in the form of a binary file in the terminal of a monitoring system and was a Windows®*2 application software, which displayed such data on the terminal or on other terminals after obtaining the data from the terminal via a

*2 Windows, Internet Explorer, SQL Server, and Visual Studio are the registered trademarks of US Microsoft Corp. in the USA and in other countries.

local network. This system had the following problems:

① As the execution of the application software was dependent on the OS made available at the time of the development, redevelopment had to be performed in accordance with the development of the OS.

② Installation of an exclusive application software to the respective terminal was required.

③ Data linkage to other systems lacked flexibility as the data were stored in a binary file form and preparation of a file for relaying to each of other systems was required.

The configuration of the new system is shown in **Fig. 8**. To solve the abovementioned problems, the new system was developed in the form of a web application software. The developed application software runs in a web server, and the clients' terminal can call for the equipment diagnosis screen by accessing the web server through Internet Explorer®*2. Furthermore, various data taken from the database and used in the system are stored in the database. With this, clients' terminals are not dependent upon the OS, and all clients' business PCs can be used without installing any exclusive application software. Furthermore, by utilizing the structure of the database, general versatility has been enhanced and a flexible link with other systems has been realized.

3.2.2 Introduction of new technology

Display of graphs becomes a technical problem when the system is operated on a web. In the general display on the web, numerical figures and graphs displayed on a screen are not continuously updated and only means of updating by users pushing the update button on the screen or periodically updating automatically by setting automatic updating are made available. On the other hand, in the equipment diagnosis system, the state of equipment is grasped through the display of the diagnosis result and analysis such as trend management graphs, frequency analysis result, and 3D trend management graphs. In doing so, to read the values of vibration and/or frequency at an arbitrary point, essentially required conditions in operability are the high responsiveness of a cursor to the manipulation of a mouse and real-time update of numerical figures.

Then, Flash®*3, one of the technologies used for displaying animation, was applied and display of a graph linked to a database was realized, responding to the manipulation of a mouse in a dynamic manner. Crucial issues to the development of the system were the establishment of interface between the database and Flash® and the practicability of performance. In the operation in the sequence of mouse manipulation → acquisition of data → drawing on a screen, how to shorten time was a subject of importance that needed to be studied. **Figure 9** shows an example of trend management graphs.

3.2.3 Enhancement of function

(1) Long-term preservation of individual data acquired in diagnosis and use as reference

In equipment diagnosis, subjects being monitored are normally motors, pumps, blowers, and so on and diagnosis lasts longer than several years before the equipment becomes deteriorated; therefore, acquired data (vibration, temperature, and so on) were managed by storage in the summarized form (average, maximum, minimum, P-P, and so on) for the periods of 1 h, 1 day, 1 month, and 2 years.

However, there were stronger requests for referring to data directly taken from similar troubles in the past when an equipment trouble occurred. Then, in the new system, along with the building of the database, the aim was to realize stress-free screen drawing processing for the storage of 10 years of vibration data acquired at a 10-min interval and analog data acquired at a 1-min interval.

(2) Strengthening of maintenance supporting function

With the conventional equipment diagnosis system, only diagnosis data could be confirmed, and to compare diagnosis data with maintenance action and results at the time, notes of maintenance personnel or trouble records had to be referred to. Then, in the new system, by realizing the comparison of the diagnosis result obtained through the equipment diagnosis system with the information of daily maintenance work, far more utilization of diagnosis results for maintenance work was intended. Following three are the major functions:

① Bulletin board function for sharing information of diagnosis results and for communication

② Arbitrary search function for extracting equipment with abnormality

③ Output function of comparison report for the day before maintenance and the day after maintenance

The first function is the display of a bulletin board at the top

*3 Flash Player is the trademark or the registered trademark of Adobe Systems in the USA and in other countries.

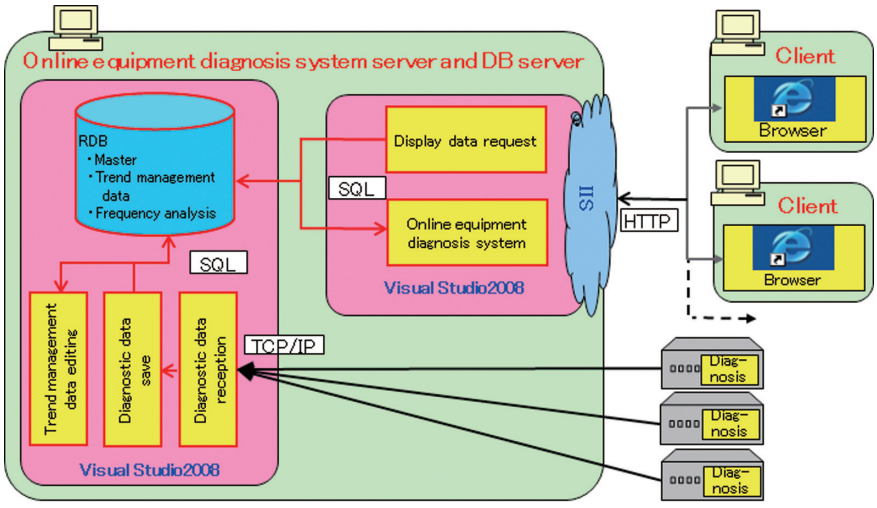

Fig. 8 Composition of online equipment diagnosis system

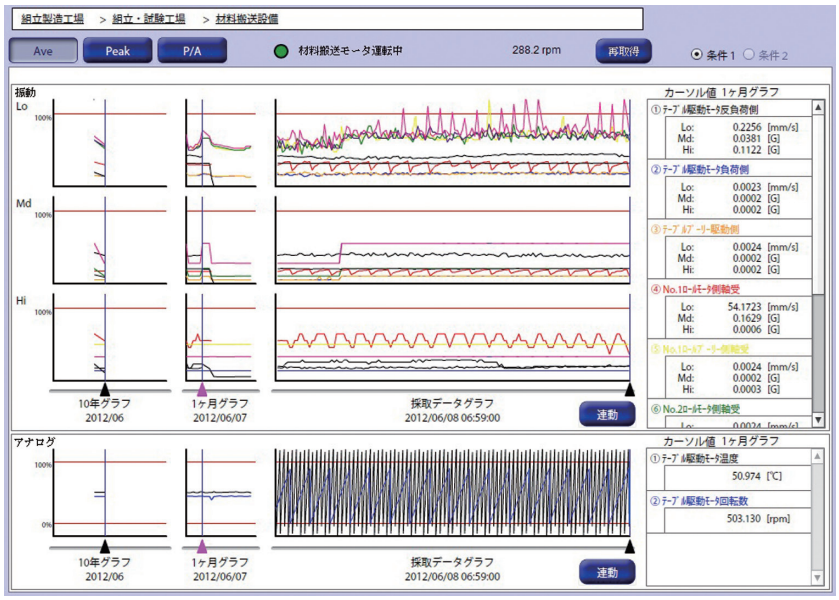

Fig. 9 Trend management graph (example)

Fig. 10 Bulletin board (example)

right position of the monitoring screen for daily use (**Fig. 10**). Signs of equipment abnormality obtained in the system, action taken, and so on are entered at every occasion when they are noticed so that such information is shared. Such information is filtered so as to be displayed specifically for the subject equipment shown on the screen, and upon reading the information, users can input latest information about the subject equipment so that useful information about the equipment is compiled and shared accordingly. Contribution to optimization of maintenance is expected as a result.

With regard to the second function, research function for extracting equipment implying abnormality was strengthened. So far, with regard to data values acquired, only caution/damage was reported on the basis of the judgement made for the two-step criterion. In the development, an abnormality extraction screen was loaded so that signs of abnormality could be extracted on the basis of users' own criteria of judgement by allowing the addition of a new extracting condition to the basic ones (**Fig. 11**). Such function is expected to be utilized in prioritizing subject equipment for maintenance within limited repair budget.

The third function is to strengthen report processing. Despite the fact that this is the paperless era, an inspection log and or the like is necessary in maintenance activities and in recording inspection results and reporting. In such inspection result reporting, the author considers that such information can be effectively utilized as material for grasping maintenance effects by output in the form of a report from the system of the diagnosis results of the days before and after of the maintenance day or as material for reporting equipment abnormality by output of a report of results of simplified and precision diagnoses over the abnormality (**Fig. 12**).

4. Conclusion

This article introduces the outline of the most updated multifunction portable diagnosis device and the online equipment diagnosis system among equipment diagnosis devices and systems that Nippon Steel & Sumitomo Metal group possesses.

The development of a diagnosis device and system owes much to sensor technology, analysis technology, and instrumentation technology, all of which progressing on a day-to-day basis. However,

Fig. 11 Abnormal extraction screen (example)

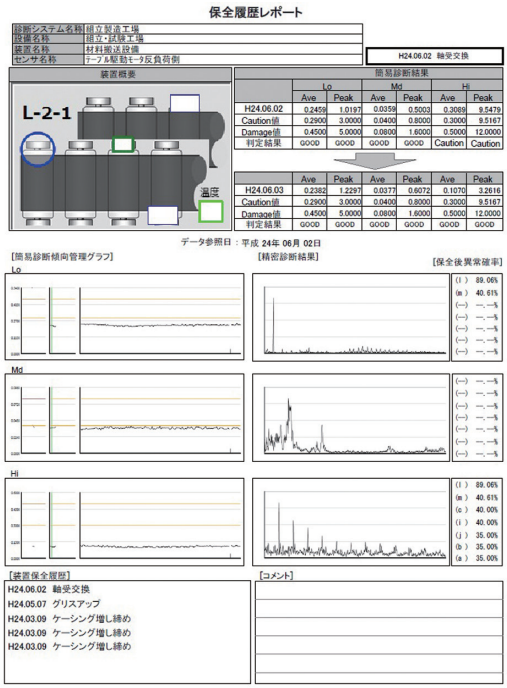

Fig. 12 Conservation history report (example)

the function of such equipment contributes to further enhancing diagnosis expertise of maintenance personnel and staff who are deeply knowledgeable about operation sites, and by not limiting itself to rotating machine diagnosis only, it can be further effectively used with the flexible idea of employing other diagnosis methods and analysis methods depending on equipment individuality.

From the viewpoint, the author is determined, as a matter of course, to continue to promote further enhancing function, operability, and performance of the equipment diagnosis device and equipment to contribute to stable operation as a supplier of diagnosis device and equipment and further as well as to make efforts to enhance the ability of preparing and proposing master plans from users' viewpoints.

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Tsunemi MURAYAMA
General Manager, Head of Sensing & Diagnosis Solution Department, Sensing & ICT Solution Division
Electrical Instrumentation & Systems Unit
Nippon Steel & Sumikin Texeng Co., Ltd.
1320-4 Otsuka, Maeda, Yahatahigashi-ku, Kitakyusyu City, Fukuoka Pref. 805-8555