Introduction of a System for Detecting Abnormal Vibration in Shipboard Equipment

~The Potential of Abnormal Vibration Detection Systems for Preventive Maintenance~

1. Introduction

The Japanese economy is supported by import/export trade and international sea transport accounts for over 90% of total import/export cargo. Transport by shipping is an extremely important method for conducting international trade.

With the expanding global economy and borderlessness, it is becoming apparent that global risk is intricately interconnected. Sea transport businesses are always at the brink of danger and they aim to prevent serious accidents. To conduct safe transport while maintaining a transport schedule, not only maintenance management to safely operate vessels, but also various efforts towards safe operation of the vessel and marine environment maintenance are being taken.

The important basics for maintaining safe operation of vessels are appropriate monitoring by the navigation officers and selection of an optimal route taking weather and sea conditions into consideration. Important equipment for operation such as the main engine that propels the vessel, power generator and auxiliary engines such as various pumps, fans and motors are located in the engine room, which is monitored by the engineer who also manages preventive maintenance.

To prevent serious damages beforehand, the operational state of the various engines and equipment in the engine room are patrolled and inspected daily to discover any abnormalities, and early actions such as overhaul inspections are extremely important.

In previous times, only the bare minimum of monitoring devices for equipment installed on vessels were available and during the patrol to inspect the engine room, the five human senses were mainly relied upon to find problems.

Recently, with the improvement in technology for temperature, pressure and vibration sensors, systems that automatically monitor various inspection items and issue warning on abnormalities are installed, but the actual situation is that not all the small behavioral changes and abnormal vibrations of onboard equipment could be automatically monitored sufficiently.

In this report, we would like to introduce a portable system which detects abnormal vibrations that was developed together by MOL Techno-Trade, Ltd. and Valqua as a collaboration.

2. Efforts toward preventive maintenance of equipment

2-1) Monitoring of status of onboard equipment

The operational status such as the temperature, pressure, rotation rate, etc., of each part of major equipment onboard, such as the main engine, power generator, boiler, etc., are automatically monitored at all times. This is periodically recorded in the data logger installed in the engine control room, and when an abnormality is detected, a warning is issued regardless of the time, which automatically slows down or initiates an emergency shut-down, and for equipment with a back-up function, the substitute equipment will start automatically to avoid any operational disruptions or major equipment damage.

However, small rotating equipment and motors that run fans and pumps are not equipped with sensors to monitor their operational status. Overheating, abnormal sounds and vibrations due to wearing out of motor bearings are inspected by relying upon the five senses of the engineers during periodic patrols using touch and listening rods. If the discovery of abnormalities is delayed, this may lead to the burning of the motor due to damage to the bearing. The current situation is that preventive maintenance such as periodic opening maintenance based on operational time is conducted for main equipment onboard.

2-2) Use of big data onboard

Recently, the voluminous data obtained from status monitoring can be monitored around-the-clock on land by using a satellite link. Efforts towards improving safe operation are being conducted by combining this with weather and sea condition data, selection of an optimal route to decrease the burden on the vessel and propulsion engine, and utilization of optimal automatic navigation, etc.

Technical development on automatic operation of vehicles are being vigorously pursued by automobile manufacturers, and technical development of an autonomous navigation vessel (automated ship) has also started for ships. In the beginning of 2020, a test voyage to conduct actual validation is scheduled, so in addition to weather and sea condition information, various big data such as information on navigational meters (radar, collision prevention device, electronic marine maps) and status monitoring information within the engine room, etc. are becoming even more important elements to promote autonomous navigation.

However, currently, not all onboard equipment is automatically monitored and a tool that can measure the status of equipment, confirm the presence/absence of abnormalities, and make decisions is anticipated. In particular, for onboard equipment, different from equipment installed on ground, the location itself where the equipment is installed may rock or be affected by vibrations from other installed equipment and in this environment, it is very difficult to measure and monitor abnormal vibrations of the equipment itself. The newly developed "System to detect abnormal vibrations in marine equipment" considered such environment which such equipment is placed in, and does not require any conversion to be used for all onboard equipment. It is an easy-to-use monitoring tool that can conduct wireless distance vibration measurements of equipment installed in places that are dangerous or in high places where access is restricted, and it has noise-cancelling features that enables it to eliminate disturbance vibrations that are generated from equipment other than the measurement target and has an addition of a wireless detection feature. The system composition is anticipated to be used not only for onboard equipment in vessels, but also widely used for preventive maintenance of equipment used in the track & field industry and industrial plant related equipment.

3. Summary of vibration detection maintenance system

3-1) Functions and characteristics of the vibration detection maintenance system

This system is currently undergoing validation on an actual vessel. As described above, it does not require conversion to monitor equipment status and it is currently undergoing validation as a system that can measure and monitor equipment vibration without being affected by vibrations due to rocking.

Figures1 and 2 show the external appearance of the vibration detection maintenance system and Table1 shows the major specifications of the main section of the system.

The sensor part for detecting vibration utilizes a fluorine resin and is intended to be used for locations with high temperatures such as pumps and has heat resistance in 100℃ environments. To enable easy installment regardless of the shape of equipment, it can be attached by tape and magnets.

The signal from the sensor is transmitted through the wireless dock and received by a tablet terminal located away from the equipment and whether there are abnormalities can be confirmed as chronological changes. It is also possible to directly connect the sensor and tablet with a cable for measurements.

On the functional side, it has a function that analyzes the pattern of rocking of the vessel and equipment and the amplitude as vibration frequency. It reduces the vibration effect (disturbance vibrations) by rocking of the vessel, and by distinguishing it from vibrations of the equipment itself, it conducts continuous vibration monitoring of the equipment.

Figure1 External appearance of the vibration detection maintenance system
Left : Tablet
Upper right : Sensor (Approximately 2cm square)
Bottom right : Wireless dock (amplifier)

Figure2 Thin film fluorine resin organic piezoelectric element

Table1 Major specifications of the main section of the system

Display section	10-inch tablet (touch panel)
Ch No.	4ch or 2ch / amplifier Max. 12ch (wireless connection with 4 amplifiers)
Output	SD card slot (SDHC compatible, Max. 32GB)
Water resistant	IP54 waterproof equivalent
Use range	−10℃ to 50℃ , under 90% RH (with no condensation)
Size and weight	40 (H) x275 (W) x188 (D) mm 1200g (includes Li-ion battery, 280g)
[Scheduled]	Radio Law approved (Europe, US, China, Japan) CE marking, WEEE directive Chinese version of RoHS

3-2) Examples of validation experiments on reduction of disturbance vibrations

A validation using experimental methods was tried regarding the effects (disturbance vibrations) due to the navigational environment of onboard measurements, such as the wind and waves at the time of operation.

A vibrator device was used as the source for disturbance vibrations, and the motor was setup on a vibrating platform to confirm whether it would be possible to distinguish between disturbance vibrations and motor vibrations. The vibrator device was i240SA3M (manufactured by IMV) using 5Hz, 5mmp-p conditions to vibrate in the z-axis direction (up and down vibrations). The motor was a Superline single-phase motor (SC-KR-100W-4P-100V) under the condition of 1720 rpm (28.7 Hz) and was installed and fixed so the motor rotational axis was perpendicular to the vibration direction. Measurement results are shown in Figures3 and 4.

According to Figure3, motor vibrations are affected by disturbance vibrations and compared to when the vibrator is turned off, the signal intensity at 5 Hz, which is the additional vibration conditions, increases and significantly changes (approximately 50 dB) in vibration level. On the other hand, if disturbance vibrations are reduced, the increase in vibration

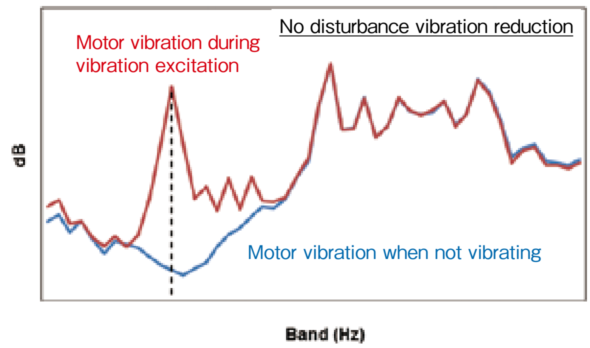

Figure3　Motor vibration band affected by vibrator vibrations

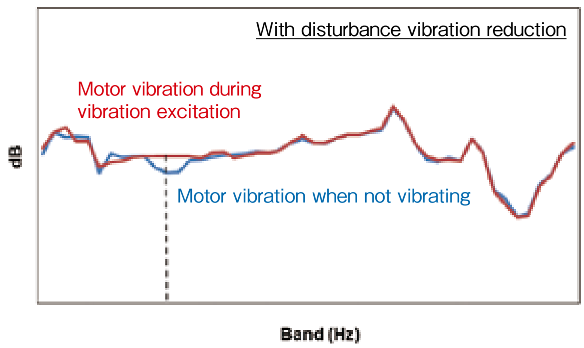

Figure4　Motor vibration band when effect of vibrator vibrations is reduced

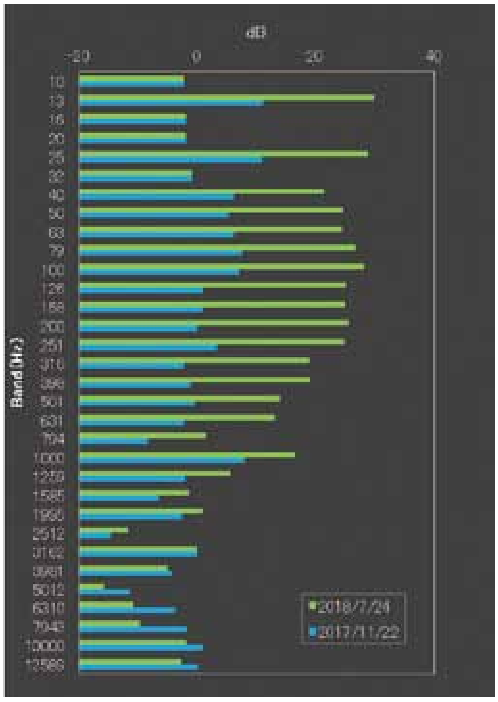

Figure5　An example of vibration measurement results on an actual vessel（seawater cooling pump）

intensity at 5 Hz was confirmed to be within 5 dB (Figure4) . Similarly, the results of the effect of disturbance vibrations were under 5 dB even if measurements were under the conditions such as when the additional vibration amplitude was changed（5 Hz: 5,7, 10mmp-p）or the additional vibration frequency was changed（75 Hz: 0.03, 0.05mmp-p, 200 Hz: 0.005, 0.007 mmp-p). This suggests the possibility of reducing the effect of waves during navigation.

3-3)Measurement example on an actual vessel

Figure5 shows an example of measurement results of a seawater cooling pump on a coastal tanker（Technostar）owned by MOL Techno-Trade, Ltd. Temporal changes in the signal intensity can be seen. Measurements are to be continued while considering the effect of disturbance vibrations in preparation for the main validation study.

4. Summary

With the developed system, it was possible to confirm reduction of disturbance vibrations in the validation study at the laboratory level. In addition, a difference in temporal signal intensity was confirmed by measurement on an actual vessel.

However, in actual navigation, it will be necessary to measure the vibration status with everchanging surroundings and environment, such as main power output, loading conditions that differ between outbound and inbound trips, operational status of auxiliary equipment, etc.

Aiming for the main validation study, while confirming and considering the effect of a wide variety of disturbance vibrations, detecting the status changes in equipment vibration and setting the appropriate cut-off value are our future challenges.

5. Conclusions

It is considered effective for vessels operating on sea away from land to conduct appropriate maintenance management that includes keeping track of defects and breakdown trends of individual equipment and stocking maintenance parts. By continuing our validation study, we would like to produce a system that visualizes the states that differ from the normal state and deliver a predictive maintenance effect that would contribute to safety and security throughout the whole industrial field regardless of land or sea.

Makoto Haneda
Managing Director
MOL Techno-Trade, Ltd.

Hisataka Sato
Corporate Research and Development Group
Product Development Division I

Tetsuya Komeda
Corporate Research and Development Group
Product Development Division I

Yasushi Aburatani
Corporate Research and Development Group
Advanced Technology Reseach Division