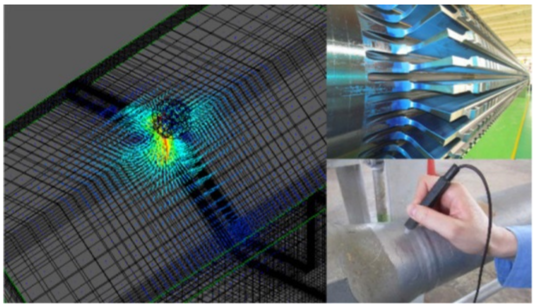
Inspection Service for Plant and Piping Equipment Utilizing Eddy Current Testing (ECT) in Lieu of Surface Inspection (MT/PT)



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Magnetic particle testing (MT) and Penetrant Testing (PT) are widely used for surface inspection of structures. However, they require time-consuming pretreatment work such as coating removal and liquid-proofing, and their detectability may be insufficient depending on the defect type and surface condition, so there is an issue of requiring shorter working time and higher detectability. To address this issue, Mitsubishi Heavy Industries, Ltd. (MHI) has developed an eddy current testing (ECT) service in lieu of MT and PT. This service improves the reliability of equipment and reduces inspection time and costs, thereby contributing to meeting the needs of customers.

1. Introduction

There are concerns that power plant equipment and outdoor piping facilities may suffer various types of damage due to aging deterioration, depending on their environment and operating conditions. So, in operating plants, it is important to understand such damage status of the facilities.

Nondestructive testing, which is used to understand the damage condition of equipment without destruction of objects, is believed to be an effective technology for detecting damage. In plant equipment and outdoor piping facilities, MT and PT are widely used as nondestructive testing methods to detect damage, mostly corrosion thinning and fatigue cracks on metal surfaces and welds. However, when the surface of the object has a coating or high-temperature oxide scale, blasting or grinding with a grinder is required, and these pretreatment operations are time-consuming. In addition, in order to perform MT/PT inspections of the rotor dovetail aera of plant generators, it is necessary to cure the rotor to prevent solvents (liquid proofing), which can be foreign substances if they enter the rotor, so time for the masking and the associated preparation and cleanup operations is also needed. Furthermore, at the Tanegashima Space Center, there is concern about corrosion of the outer surface of stainless steel high-pressure gas piping in the launch pad facility [(1)], and there is a need for inspection technology that can improve the efficiency of maintenance and inspection work time and detect minute defects.

On the other hand, in recent years, there is a strong need to improve plant availability, shorten regular inspection periods (processes), and reduce inspection costs, so the establishment of maintenance technology that can both improve reliability and reduce periods and costs is an issue for equipment with increased risk of damage. In addition, the Tanegashima Space Center launch pad facility has a high need for on-time launches, and reliable preventive maintenance of the launch pad facility is necessary [(1)].

This report introduces a highly efficient inspection service that utilizes ECT, which requires no pretreatment and has the same or better detectability than conventional MT and PT, to address issues of such conventional methods.

2. Features of developed probes and sample verification results

Figure 1 shows the principle of ECT. ECT is a method that generates eddy currents by

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bringing a coil to which an alternating current is applied into close proximity to a conductive test piece and detects defects on the surface of the test piece based on the changes in the eddy currents [2]. It is a detection method using electromagnetic induction, and can detect defects even when coating or scale is adhered to the surface.

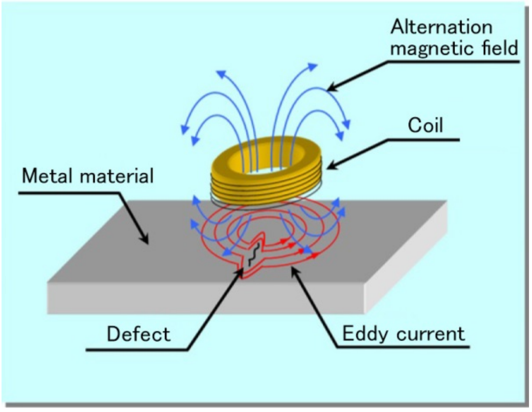

Figure 1 Principle of ECT

Figure 2 and **Figure 3** show the ECT probes MHI developed for use in ECT in lieu of MT/PT. We developed a pencil-type ECT probe [3] and an array ECT probe that can be equipped with multiple coils. First, the pencil ECT probe shown in Figure 2 consists of a pencil-shaped holding part and a small coil. The small coil is mounted on the tip of the sensor and embedded in a low-friction material. Defect detection is performed by bringing the tip of the sensor into direct contact with the area to be inspected. The pencil-type sensor is easy to hold and can perform inspections with relative ease.

Figure 2 Pencil ECT probe

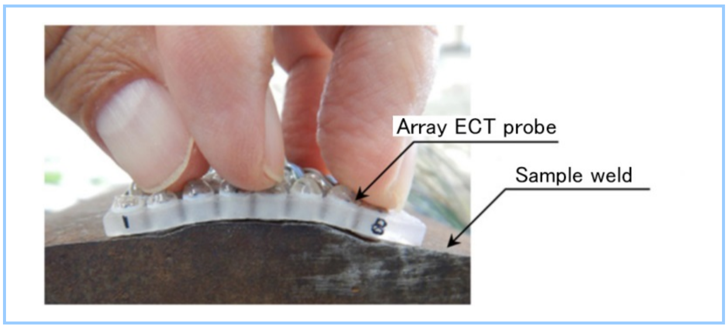

Figure 3 Array ECT probe

Next, the array ECT probe equipped with multiple coils shown in Figure 3 consists of multiple coils and has a structure in which the coils are inserted into a coil holder, which was produced by additive manufacturing using a flexible material. The probe is modularized and can be easily fitted to welds and various shapes by changing the size and shape of the coil holder produced by additive manufacturing. Furthermore, due to the array method, this probe can perform defect detection over a wide area at the same time, depending on the number of coils employed. **Figure 4** shows the results of a verification test of a sample plate weld using the developed array ECT probe.

This sample is prepared by overlapping and fillet welding plates, putting artificial defects of 2 mm and 4 mm in length on the weld line, and applying a coating of approximately 1 mm in thickness. The verification test results indicated that the probe could detect both defects with sufficient Signal Noise Ratio (SNR) and could perform inspections without removing the coatings.

Examples of inspection services using ECT in lieu of MT/PT with these developed ECT probes are described in Chapter 3 and Chapter 4.

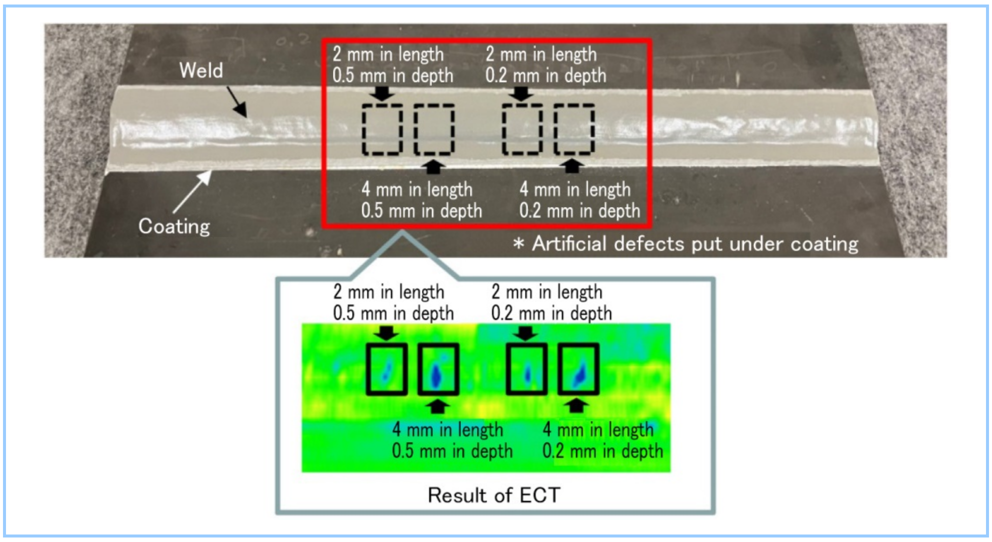

Figure 4 Verification test result of array ECT probe

3. Example of application to rotor/dovetail area of generator for power generation plant

3.1 Generator rotor dovetail inspection and ECT verification test results

Figure 5 shows a structural illustration of a generator rotor dovetail area and conventional inspection work. The surface of this area is inspected by MT/PT because of concerns about fatigue cracks caused by repeated contact of wedge angles during operation. However, since the MT/PT solvent is a foreign substance for the generator rotor, which is precision equipment, masking with tape is applied to the openings of the precision equipment at the time of inspection, and such incidental work other than inspection is time-consuming. In addition, inspection and repair of the rotor is often a critical process in the precision inspection of generators, and there is a need to shorten the lead time. In response, we are promoting the application of a solvent-free ECT method in lieu of the conventional MT/PT methods.

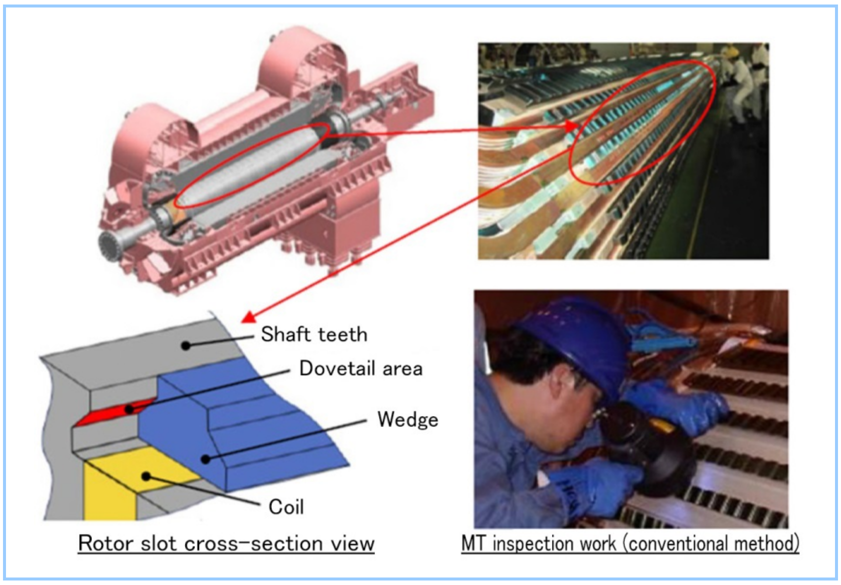

Figure 5 Structural illustration of generator rotor dovetail area and conventional inspection work

Figure 6 shows the ECT verification test work in the dovetail area of the actual rotor. The ECT probe shown in Chapter 2 is used and for the coil holder, additive manufacturing was used so as to fit the dovetail shape to improve its conformability to the dovetail surface. The dovetail section of the rotor was approximately 6 m in length and had 32 slots. The probe was placed in the dovetail area and scanning was performed manually in the axial direction of the rotor to check for cracks on the dovetail surface over its entire length.

Figure 7 shows the results of ECT and MT to evaluate the validity of the ECT. Crack signals were detected in two locations as a result of the ECT verification test, and MT was performed to evaluate the validity of the ECT results. As a result, 1.5-mm- and 2.5-mm-long magnetic powder patterns were detected at the locations where cracks were detected by ECT. This indicates that the actual cracks are detectable by ECT and that there are no problems with its detectability.

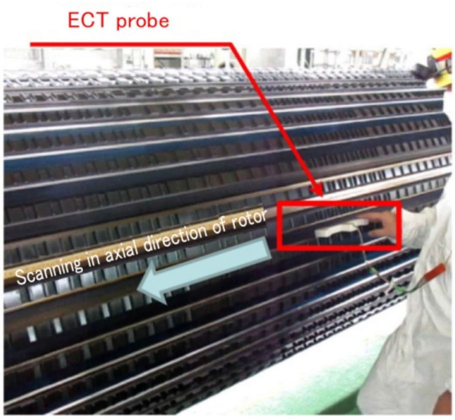

Figure 6 ECT verification test work in dovetail area of actual rotor

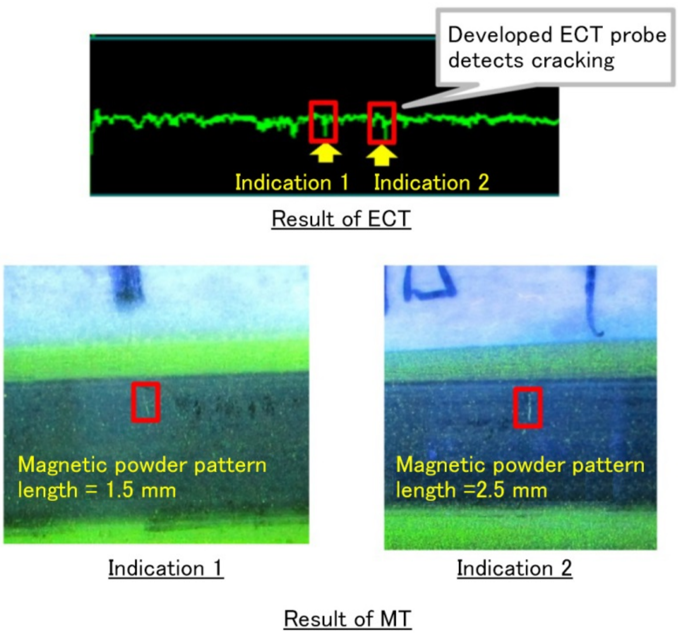

Figure 7 Results of ECT and MT

3.2 Services using this technology and value provided

Figure 8 compares the inspection flow and work time of the conventional method using MT/PT and the developed method using ECT. The comparison of work time was calculated based on the specifications of the generator rotor (total length: approximately 6 m, number of slots: 32) verified in Section 3.1. In the past, MT/PT was performed for the entire slot length, and so time for preliminary preparation and masking work was necessary, but the use of ECT reduces such work. By applying ECT, the work time is expected to be reduced by about 60%. This is largely due to the reduction in masking work time, but the inspection work itself can also be shortened. Consequently, the efficiency of the entire work operation was improved. In addition, since the inspection results are stored as digital data in the form of waveform information, they are easier to handle than conventional MT/PT records based on photographs or sketches, and can be compared and referenced with past records by creating a database. As such, the application of ECT is expected to bring about many advantages.

Based on the above results, we believe that providing our customers with inspection services using ECT in lieu of MT/PT for generator rotor dovetail areas will contribute to cost reductions through shorter working hours and shortening the process of precision inspections, which is the critical path. This technology is currently undergoing verification and preparation for application. We will bring this technology to the market as soon as possible to contribute to our customers' business.

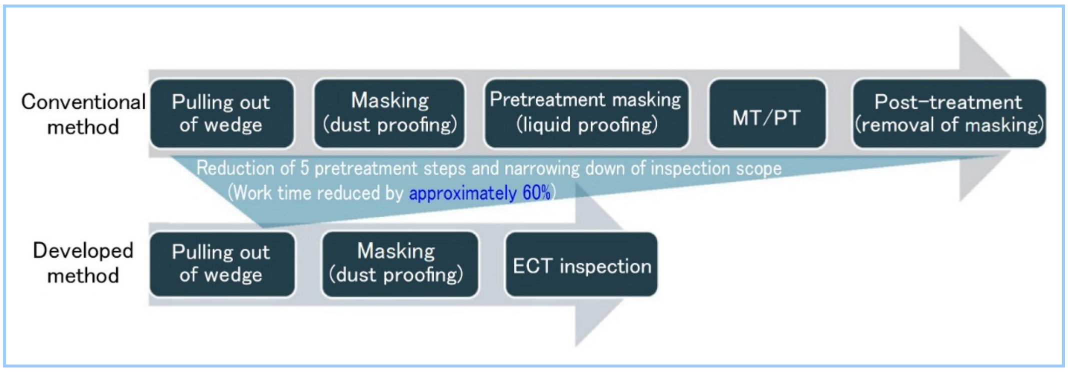

Figure 8 Comparison of inspection flow of conventional and developed methods

4. Example application to piping facilities of launch pad at Tanegashima Space Center

4.1 Application of ECT to launch pad at Tanegashima Space Center

The launch pad facility at the Tanegashima Space Center is the only launch facility in Japan for launching core launch vehicles such as the H-IIA. In recent years, the need for on-time launches and price competitiveness in the launch market has increased, and the importance of on-schedule launches has been growing [(1)]. On the other hand, stainless steel high-pressure gas piping for filled propellants such as hydrogen, oxygen and helium at the launch pad is the most important equipment indispensable for launches, but because these facilities are located outdoors and near the sea, there are concerns about corrosion thinning and intergranular cracking on the outer surface of the piping. As mentioned above, MT and PT are commonly used to inspect the outer surface of piping for corrosion and cracking, but due to its principle, MT cannot be applied to stainless steel, which is a nonmagnetic material. Although PT can detect corrosion thinning, its ability to detect minute cracks such as intergranular cracks is low, and the inspection is time-consuming because the permeation, development, observation, and post-treatment processes are required. Therefore, in cooperation with the Japan Aerospace Exploration Agency (JAXA), which manages and operates the launch pad facilities, MHI is promoting the application of ECT, which has high detectability of minute defects and does not require solvent treatment, for maintenance inspection of stainless steel high-pressure gas piping in the launch pad.

4.2 Example of ECT inspection of stainless steel high-pressure gas piping and value provided by this service

Figure 9 shows the ECT inspection work on the outer surface of stainless steel piping. The inspection flow consists of a visual inspection to select a rusting area that may be corroded, and then evaluation of the presence or absence of defects by applying ECT to the area. Because the stainless steel high-pressure gas piping in the launch pad is sometimes located in narrow areas due to facility constraints, a pencil-type ETC probe, which is compact and easy to scan, was used.

Figure 10 shows the ECT result of stainless steel high-pressure gas piping in the launch pad and the result of a cross-sectional survey of the area where defects were detected. The detection signal in ECT is displayed as a Lissajous waveform, which is pre-calibrated with an artificial defect so that the waveform changes in the direction of about a 135° phase angle in the second quadrant when a defect is detected. The ECT result showed that the waveform changed near a rusting area.

The result of the cross-sectional survey of the area where defects were detected by ECT showed that minute cracking was generated, which indicated that ECT is capable of detecting actual defects. The application of ECT eliminated the need for treatment with solvents and improved the inspection efficiency.

Based on the above results, by applying the ECT inspection service to the entire launch pad in lieu of PT, which is a conventional surface inspection method, it is possible to select replacement and repair points in the area where corrosion has occurred on stainless steel high-pressure gas piping prior to launch. This method enables more efficient preventive maintenance than ever before and will contribute to on-time launch.

Figure 9　ECT inspection work on outer surface of stainless steel piping

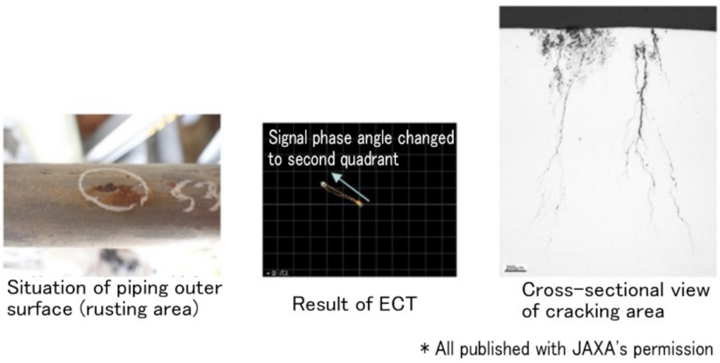

Figure 10　ECT inspection on outer surface of stainless steel piping

5. Conclusion

This report describes mainly application examples of the ECT inspection service in lieu of conventional MT/PT surface inspection methods. In addition to these application examples, this service can be applied to various plant and infrastructure structures where MT/PT is used, and we believe that it can meet the needs of our customers, such as improving the reliability of facilities and reducing inspection time and cost. We will continue to provide inspection services that our customers find valuable and contribute to their business.

References

(1) Misaki Adachi et. al, Risk Reduction Method by Maintaining Aging Stainless Steel Piping at Rocket Launch Pad, Proceedings of the 18th annual meeting of Japan Society of Maintenology, 2022, p291

(2) Eddy Current Testing II, The Japanese Society for Non-Destructive Inspection, p1-3

(3) Surface Defect Detection Technology Contributes to Shortening of Inspection Time, Mitsubishi Heavy Industries Technical Review, Special Edition: Mitsubishi Hitachi Power Systems, Vol.54 No.3 (2017), p59-61