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THE GEOMETRY OF STEAM GENERATOR TUBE AND ITS RELEVANCE TO THE OCCURRENCE OF STRESS CORROSION CRACKING IN OPERATING NUCLEAR POWER PLANTS

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INTRODUCTION

Occurrences of a stress corrosion cracking in the steam generator tubes of operating nuclear power plants are closely related to the residual stress existing in the local region of a geometric change, that is, expansion transition, u-bend, ding, dent, bulge, etc. Therefore, information on the location, type and quantitative size of a geometric anomaly existing in a tube is a prerequisite to the activity of a non destructive inspection for an alert detection of an earlier crack and the prediction of a further crack evolution [1].

This paper introduces a new diagnostic eddy current probe (D-probe) developed for the inspection of steam generator tubes, which has been equipped with the simultaneous dual functions of a crack detection and a quantitative 3-dimensional profile measurement.

In order to verify the performance of the D-probe including the accuracy of the profile measurement and a applicability of the probe to the plant inspection, the quantitatively measured profile data are compared with those from the laser profilometry (measurement resolution of 0.013mm) for the steam generator tube samples of geometric anomalies with various types and sizes, and the relationship between the tube geometry and the evolution of ID and OD side stress corrosion cracking at various tube locations of a steam generator is discussed with the results from the in-service inspections of operating nuclear power plants using a D-probe.

DIAGNOSTIC EDDY CURRENT PROBE (D-PROBE)

The D-Probe is a rotary type eddy current coil probe, developed by KAERI and designated as D- for its function of a diagnosis. It has three eddy current coil units(surface riding type plus-point and pancake coils for crack detection, and non-surface riding type shielded high frequency pancake coil for profile measurement), which are located at a circumference of the probe, as shown in Fig. 1. Consequently, it has simultaneous dual functions of a crack detection and sizing, and a 3-dimenstional quantitative profile measurement with a single pass of a probe movement into the steam generator tubes.

By comparing the eddy current data from the crack with those from the geometric changes, the relationship between the degradation and geometric changes can be revealed. Also, it supplies information on a tube location at which a cracking is most probable and thus, a more alert detection of an earlier crack and the resultant increase in the possibility of detection can be expected.

The prototype D-probe was manufactured to be compatible with the commercial eddy current test equipment (MIZ series digital data acquisition units) in cooperation with Zetec Inc.

ACCURACY OF 3-D PROFILE MEASUREMENT

A calibration standard tube containing 5 segments of uniform radial changes ranging from –0.35mm to +0.35mm was used for converting the value of the eddy current signal from the D-probe to the value of a radius. Tube samples with various geometric anomalies of a local dent, bulge and tube to tube sheet expansion were manufactured for use when comparing the accuracy of the quantitative size measurement by the D-probe with that by the laser profilometry.

Fig. 2 shows a result of the distribution map of the radius values measured along the angular and the axial directions of the tube sample with a single spot dent, by the laser (Fig.2-a) and the D-probe(2-b). The comparison of these two figures showed that almost the same results for a measurement were obtained and the maximum size of the dent evaluated in the radial direction was 0.35mm in both figures.

RELATIONSHIP BETWEEN GEOMETRY OF STEAM GENERATOR TUBE AND STRESS CORROSION CRACKING IN OPERTING NUCLEAR POWER PLANTS

The steam generator tubes in two Korean standard nuclear power plants have revealed a circumferential ODSCC and an IDSCC at the top of a tube sheet in separate operating plant, even though the steam generators of both plants have the same design, tubing material (alloy 600HTMA), expansion method (explosive) and operating condition. The dominance of an IDSCC or ODSCC may be controlled by the geometry of the expansion transition region, which governs the residual stress on the ID and OD surfaces of the steam generator tube, and thus the cracked tubes were diagnosed by applying a D-probe during the in-service inspection of each power plant.

Fig. 3 shows a typical result from a tube with ODSCC. The c-scan graphs of matching pair for crack detection (plus-point coil signal) and profile measurement (shielded pancake coil signal) were shown with 3-dimensional profile illustrations. The tube was over-expanded and locally dented at the location just below the top of the tube sheet. The circumferential crack on the outer surface was developed at the transition regions of the protrusion, apart from the locations of dents.

Fig. 4 shows a typical result from a tube with IDSCC. The shape of expansion transition region was eccentric and the tube was locally dented at the location just below the top of the tube sheet. The circumferential crack on the inner surface was developed at the tube location facing the apex of dent.

These two results infer that the protrusion of expansion transition region causes build-up of tensile residual stress on the outer surfaces of a tube with subsequent ODSCC, and the denting of expansion transition region causes build-up of tensile residual stress on the inner surfaces of a tube facing the apex of dent with subsequent IDSCC, respectively.

CONCLUSION

A new diagnostic eddy current coil probe (D-probe) has been developed for a crack detection and a simultaneous quantitative measurement of 3-dimensional geometric changes in the steam generator tubes of nuclear power plants. The relationship between the geometry of expansion transition region of a tube and the development of ID/ODSCC in operating power plants could be diagnosed by using a D-probe.

ACKNOWLEDGMENTS

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REFERENCES

[1] MacDonald P.D, Shah V.N, Ward L.W, Ellison P.G., Steam generator tube failures, NUREG/CR-6345, Washington, DC: US NRC, 1996.

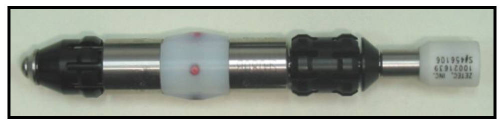

FIGURE 1: PHOTOGRAPH OF PROTOTYPE D-PROBE

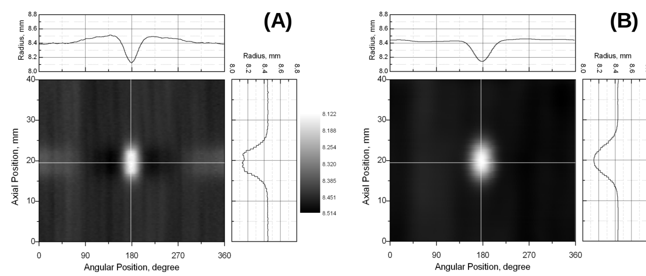

FIGURE 2: RADIUS DISTRIBUTION OF A TUBE WITH SINGLE SPOT DENT, (A) LASER AND (B) D-PROBE

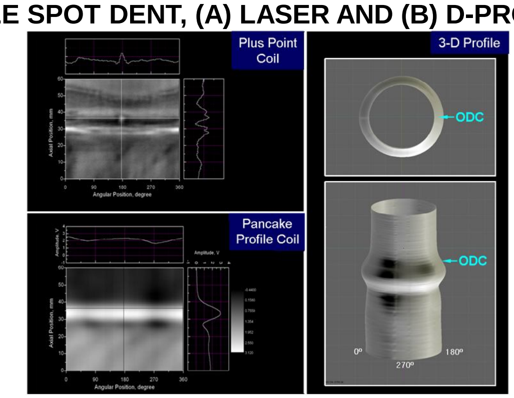

FIGURE 3: RESULT FROM A TUBE WITH ODSCC

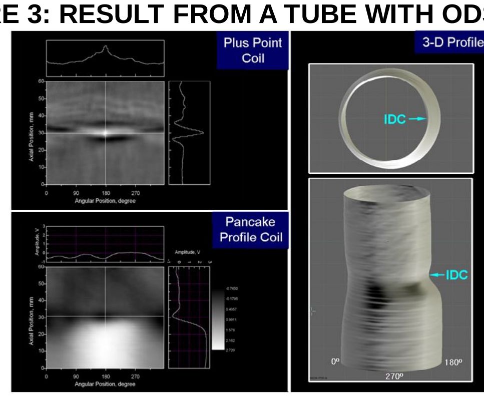

FIGURE 4: RESULT FROM A TUBE WITH IDSCC