

Characteristics of MRPC Probe Eddy Current Signals in U-Bend Region of Steam Generator Tube

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1. Introduction

The u-bend regions of alloy 600 steam generator tubes in operating nuclear power plants are very susceptible to primary water stress corrosion cracking (PWSCC) due to the high residual stress developed by bending deformation and ovalized tube cross section. The smaller radius u-bend tube has higher tensile residual stress and vulnerability to cracking, and foreign operating power plants have experienced tube rupture events due to fast grown cracks in the smallest radius u-bend [1]. Therefore, small radius u-bend regions of steam generator tubes in operating plants are inspected periodically by using MRPC (Motorized Rotating Pancake Coil) eddy current probes. However, the cracks developed in u-bend region are hard to detect because of the large background noise signals from the tube geometry changes in wall thickness and ovality of tube cross section introduced by the bending process [2]. In this work, MRPC probe eddy current test signals in small radius u-bend regions of steam generator tubes are investigated using mock-up in order to scrutinize the characteristics of the eddy current background noise signals in u-bend region.

2. Methods and Results

2.1 Manufacturing of Mock-up

A mock-up of the smallest radius u-bend tube in steam generator of OPR-1000 was manufactured with alloy 600 tube of OD 3/4" and WT 0.042", by using a sliding bar type rotary bending tool as shown in Fig. 1. The value of u-bend radius is 3".



Fig. 1. Mock-up of the smallest radius u-bend tube.

In order to introduce small stress corrosion cracks in the early stage on the inner surface of u-bend region, solution of sodium tetrathionate ($\text{Na}_2\text{S}_4\text{O}_6$) was charged into the inside of u-bend tube intermittently, and changes of eddy current signals were examined at each interval.

2.2 Eddy Current Test

The u-bend mock-up tube was inspected by using a ZETEC MIZ-70 eddy current data acquisition system with a plus-point coil MRPC probe for small radius u-bend. A test frequency of 800 kHz was chosen considering the penetration depth of eddy current field. Compared to the frequency of around 300kHz used for general defect detection on both the tube inside and outside surfaces, the application of higher test frequency concentrate the eddy current field in the inner surface region so that any suspected crack signal on the inner surface of tube can be detected optimally. The c-scan graphs of vertical and horizontal component distributions of eddy current signals acquired from u-bend mock-up were analyzed respectively.

2.3 Results and Discussion

Fig. 2 shows the c-scan graphs of MRPC probe plus-point coil signals at 800kHz from the u-bend mock-up in as-bent condition. It is clearly observed that the background noise signals in both vertical and horizontal components increased drastically in the u-bend region. The pattern of noise signals was axial ridges along the span of u-bend, and the distribution of ridges were greatly different in vertical and horizontal signals. The circumferential locations of u-bend region, extrados and intrados, were analyzed and indicated in Fig. 2 as INT and EXT, respectively.

The distribution of background noise signals with axial ridge shape had no definite relation with tube circumferential locations, but only the peak of an axial ridge shape horizontal background noise signal was observed at the u-bend extrados position.

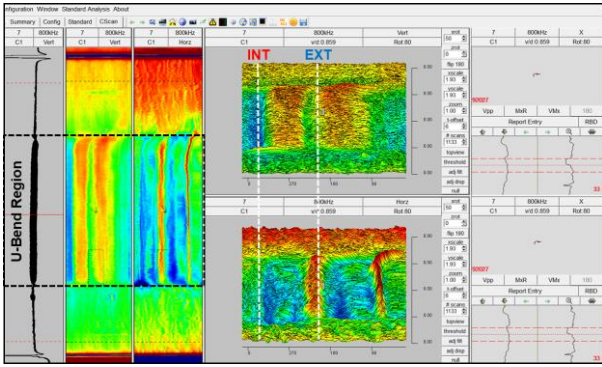


Fig. 2. MRPC probe plus-point coil eddy current signal from u-bend mock-up in as-bent condition.

Fig. 3 shows the c-scan graphs of MRPC probe plus-point coil signals at 800kHz from the u-bend mock-up in the condition where small cracks in the early stage have been developed through the exposure to the corrosive solution. C-scan graph of vertical component signals showed little change compared with the as-bent condition of Fig. 2, but horizontal component signals showed notable increase at the extrados and intrados positions. The increase of horizontal component signals at the extrados ranged from the beginning to the end of u-bend, but those at the intrados were confined to the apex region of u-bend. Through the destructive examination of the mock-up tube, the development of long axial cracks at the extrados and intrados were confirmed in accordance with the increase of the horizontal component signals.

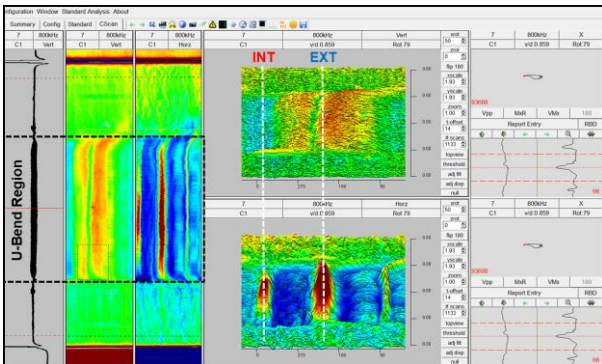


Fig. 3. MRPC probe plus-point coil eddy current signal from u-bend mock-up exposed to corrosive solution.

This result implies that small cracks in the early stage are more sensitively detectable in the horizontal component signals than in the vertical component signals. Also, it is found that the cracks are preferentially developed at the extrados and intrados positions. However, the observed change in the horizontal component signal distribution can be only identified through the careful comparison of two c-scan graph in Fig. 2 and 3, and it is impossible to notice the

increase of signals (crack evolution) from c-scan graph of Fig. 3 alone, due to the pre-existing high background noise signals.

In conclusion, it is hard to detect the small crack from the vertical component signal distribution due to the large background noise signals of axial ridge shape in the u-bend region, as well as the low signal sensitivity to the crack. However, the horizontal component signals are more sensitive to small crack in the early stage even though the considerable background noise signals of axial ridge shape are present in the u-bend region.

3. Conclusions

The background noises in both vertical and horizontal component of eddy current signals from MRPC probe plus-point coil increased drastically in the u-bend region. The distribution of background noise signals with axial ridge shape in both vertical and horizontal components had no definite relation with tube circumferential locations, but only the peak of a ridge shape horizontal background noise signal was observed at the u-bend extrados position. After exposure to the corrosive solution, cracks on the inner surface were developed preferentially at the extrados and intrados positions of u-bend. It is expected that small cracks in the early stage can be detected more sensitively in the horizontal component signals than in the vertical component signals.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (2017M2A8A4015158).

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