NON-DESTRUCTIVE OXIDE THICKNESS MEASUREMENT

FOR BWR FUEL RODS

~ DEVELOPMENT OF CRUD REMOVAL TECHNIQUE ~

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ABSTRACT

Eddy current test (ECT) is general PIE technique to measure the oxide thickness on the irradiated fuel rods. As a known issue about ECT measurement, the oxide thickness is overestimated compared with that by metallography on BWR type spent fuel rod.

It is suggested this overestimation is caused by the hard crud which is remained on the fuel rod even after the crud removal by the previous technique. Therefore, new crud removal technique was developed to remove the hard crud on the BWR fuel rod, and the effectiveness of that new technique was confirmed with the cold mock-up test and the hot-cell examination.

Both results indicate that the new crud removal technique can remove the hard crud remained on the BWR spent fuel rod and the oxide thickness could be measured precisely by ECT after that removal procedure. This report states the development of that new technique, the result of cold mock-up test to confirm its performance and the result of the hot-cell examination to confirm its effectiveness for BWR spent fuel rod.

Introduction

Oxide thickness measurements of irradiated fuel rods by eddy current test (ECT) method are generally applied for Post Irradiation Examination. On the procedure of oxide thickness measurement by ECT, the distance from metal layer of the cladding tube to the oxide outer surface should be measured accurately.

However, the oxide thickness of irradiated BWR type fuel rod measured by ECT is thicker than that by metallography. This phenomenon is caused by the deposition of the crud on the fuel rod surface during irradiation. The loose crud can be removed by cleaning process of fuel surface. However, the hard crud which interacted with oxide of the fuel rod is remained on the fuel surface. Therefore, the ECT coil could not contact the oxide surface. And the ECT coil is influenced by the magnetism of the hard crud.

For the precisely measurement of oxide thickness, the deposited crud should be removed away from the oxide surface. Therefore, new crud removal technique is developed.

The Development Of The Crud Removal Technique and the result of cold mock-up test

To measure the oxide thickness by ECT precisely, the new crud removal technique was developed and its effectiveness was confirmed on cold mock-up test. In this technique, it is important to remove only the hard crud without removing the oxide layer of cladding tube. The focused point of this development is the difference of hardness between these two materials. The oxide layer is composed of zirconium oxide, and the hard crud is mainly composed of iron oxide (Fe_2O_3 and Fe_3O_4), and the zirconium oxide is harder than the iron oxide. Therefore, the sponge brush containing fine ceramic particles was selected. And, it is confirmed in the cold mock-up test that the brush has the good performance to remove the only hard crud.

The procedure of the cold mock-up test is as follows:

1. Prepare two kinds of the sample tubes; one is stainless steel tube on which the iron oxide layer is formed to simulate the hard crud. Another is zircaloy cladding tubes on which the zirconium oxide layer is formed to simulate the oxide layer on the irradiated fuel.
2. Brush the sample surface with the sponge brush for approximately 20 minutes.
3. Observe the sample surface by visual, and the cross-section by SEM (Scanning Electron Microscope)

The result of visual observation and SEM observation are shown in Fig. 1 and Fig. 2. In Fig.1, the iron oxide layer formed on the stainless steel tube is removed after brushing and brushing area is clearly observed on sample surface. On the other hand, in Fig.2, the zirconium oxide layer formed on zircaloy tube is remained even after brushing and brushing area could not be observed on the sample surface. From these result, it is confirmed that the new removal tool can remove the iron oxide layer, which simulates the hard crud, without removing the oxide layer.

The Hot-Cell Examination Results

The hot-cell examinations are performed to verify the performance of the new crud removal tool and to confirm the effectiveness of developed technique for ECT using the spent fuel rod which was irradiated in the commercial reactor for 5 cycles.

To determine the best brushing time to remove only the hard crud from irradiated fuel cladding, the crud removal processes were performed on repeated occasions for a few minutes. After the each occasions, the oxide thickness was measured by ECT. The oxide thickness values were compared with the value by metallography. The crud removal processes were finished when the oxide thickness value reached to the value by metallography. After the all procedure, the removed crud powder was analyzed by EPMA to confirm the crud removal process had no effect to the oxide layer of cladding tube. The results of hot-cell examination are shown in following figures.

Figure 3 shows the relation between the oxide thickness by ECT and the time of crud removal process. The oxide thickness by metallography was indicated as broken line and was less than 10 μm for sample 1 and approximately 30μm for sample 2. Both oxide thickness by ECT decreased for 3 min, and after 7 min on removal process, both oxide thickness by ECT were reached to the thickness value by metallography.

Figure 4 shows the comparison between the oxide thickness by ECT before and after crud removal process. The vertical axis indicates the oxide thickness values by ECT and the horizontal one indicates the oxide thickness values by metallography. The circle indicates the oxide thickness by ECT before the crud removal and the cross indicates that after the crud removal. The oxide thickness by ECT was overestimated about 10-15 μm before the crud removal process, but after the removal process, the thickness values are almost same as the metallography data. From this result, it was confirmed that the oxide thickness could be measured precisely with ECT measurement using the new crud removal technique.

Figure 5 shows the result of EPMA analysis for the removed crud powder during brushing process. The vertical axis indicates the intensity of the characteristic X-ray, and the horizontal axis indicates the distribution of the X-ray energy. If the zirconium oxide layer was removed during the brushing process, the energy peak of Zr will be shown at 2.0 keV in this result. But only the peaks from crud are identified. Therefore, it was confirmed that the oxide layer on cladding tube was not removed during the rubbing process by new removal technique.

CONCLUSIONS

The new technique to remove the hard crud has been developed. From the confirmation tests, it was verified that the developed technique can remove the hard crud remained on the BWR spent fuel rod and oxide thickness could be measured precisely by ECT after that removal procedure. It is great advantage because the true oxide thickness which was only obtained by metallography previously could be measured by ECT method with the new crud removal technique.

References

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2. T. Miyashita, et al, 'Corrosion and Hydrogen Pick-Up Behaviors of Cladding and Structural Components in BWR High Burnup 9X9 Lead Use Assemblies,' 2007 LWR Fuel Performance Meeting/TopFuel, San Francisco.

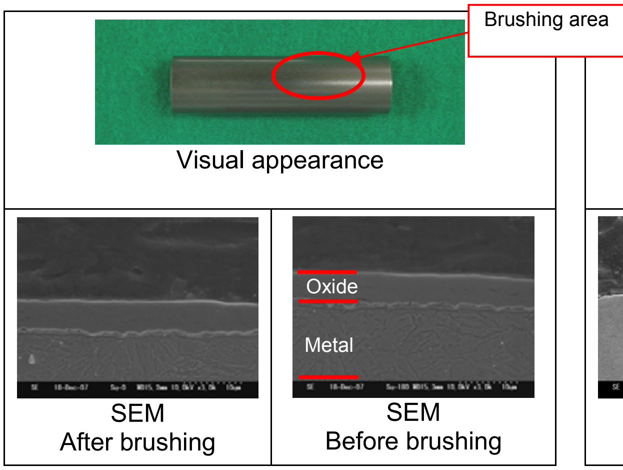


Fig. 1. Zry cladding appearance and SEM image for un-irradiated materials

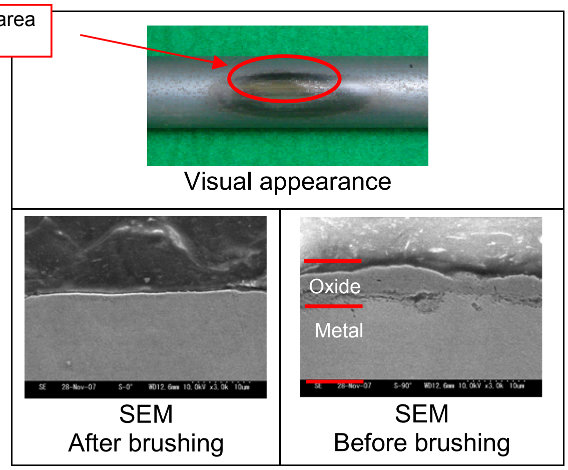


Fig. 2. SUS tube appearance and SEM image for un-irradiated materials

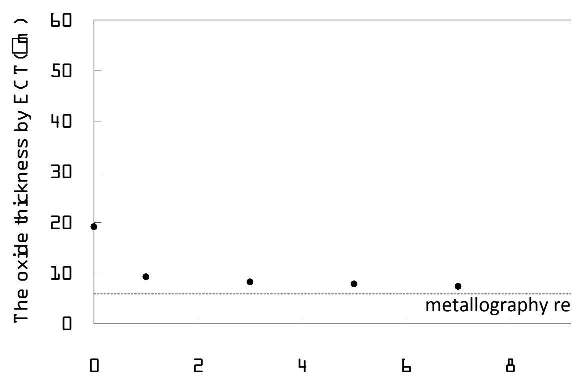
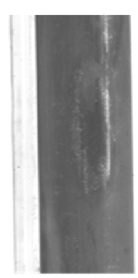
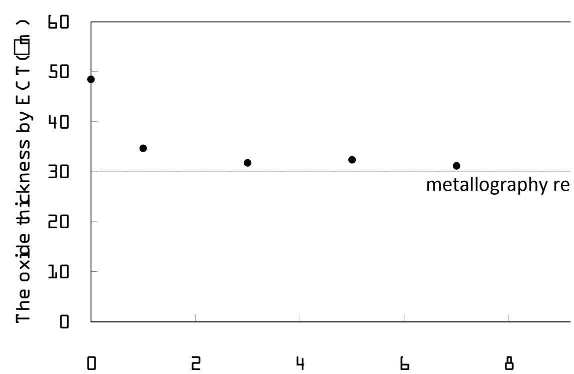
Sample No.	Visual appearance	Oxide thickness by ECT
1		
2		

Fig. 3. Relation between the oxide thickness by ECT and the time of crud removal process

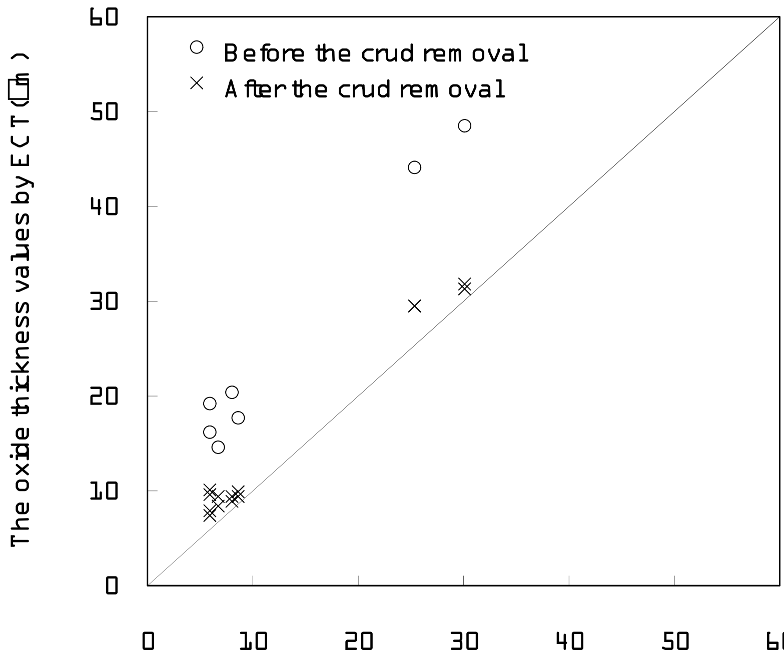


Fig. 4. Comparison between the oxide thickness by ECT before and after the crud removal process

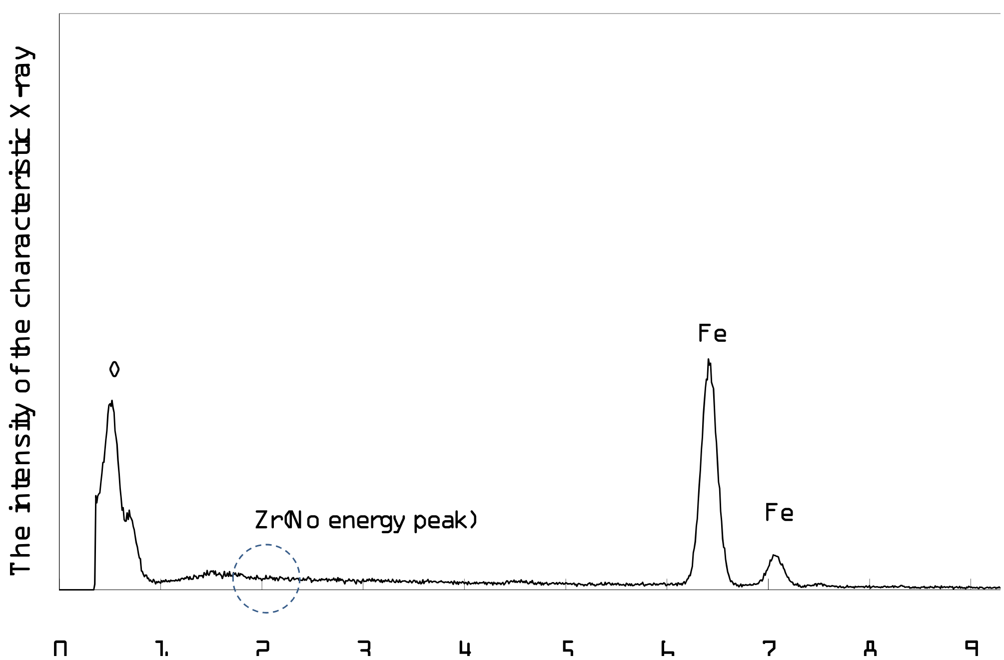


Fig. 5. The results of EPMA analysis for the removed crud powder