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# Experimental approach for adhesion strength of ATF cladding

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## 1. Introduction

After the Fukushima accident, the development of accident tolerant fuel (ATF) is a major concern in nuclear research fields at a present time. One of promising ATF concepts is the coated cladding, which take advantages such as high melting point, a high neutron economy, low tritium permeation rate, and oxidation resistance.

The quality of a coating depends on the quality of its adhesion bond strength between the coating and the underlying substrate. Therefore, it is essential to evaluate the adhesion properties of the coating. There are many available test methods for the evaluation of coatings adhesion bond strength [1, 2].

However, the facts that geometry of the coated cladding is cylindrical and the thickness of coating is very thin are unlikely to achieve good results from traditional test methods such as tensile or bending tests.

Considering these restrictions of the coated cladding, the scratch test is useful for evaluation of adhesion properties compared to other methods.

The purpose of the present study is to analyze the possibility of adhesion bond strength evaluation of ATF coated cladding by scratch testing on coatings cross sections [3].

## 2. Methods for adhesion test

Several methods have been proposed for measuring adhesion between the substrate and thin or thick coatings. Tensile test, e.g. ASTM C 633 or bending tests followed by metallography is traditionally used to evaluate adhesion strength of coatings. However, these methods are not applicable for ATF coated cladding due to their strong adhesion property between substrate and coating. Compression, flattening, and compression-shear tests were conducted to evaluate bonding properties of interface of Fe/Al clad tube and the test results were reasonable to judge adhesion properties of Fe/AL clad tube by explosive welding. However, these methods also have the drawback of requiring thick coating and then are not applicable for ATF coated cladding. Given these constraints to perform tests, the scratch testing is most useful test method for AFT coated cladding compared to other test methods. The scratch testing is one of widely used, fast, and effective methods to obtain the critical loads that are related to adhesion properties of coating. [4-6]

In this study, the scratch test apparatus was set up and the test was performed to analyze the possibility of adhesion properties of ATF coated cladding.

## 3. Experiment

### *2.1 Preparation of specimen*

Zircaloy-4 tube was used as a reference to the scratch testing. Cr-coated Zircaloy-4 tube by arc ion plating method and CrAl-coated Zircaloy-4 tube by plasma spray method were used as ATF coated cladding samples. The samples were cross-sectioned, embedded in a resin and then polished in a standard way. Test sample fixed to sample holder is shown in Fig. 1.

Fig. 1. Cross-sectioned test sample fixed to sample holder

### *2.2 Experiment procedure*

The scratch test apparatus used in the present study is shown in Fig. 2. First, the sample is brought into a fabricated sample holder horizontally. A Rockwell C diamond indenter having a tip radius of 0.2mm is fixed to the indenter holder. To carry out the scratch testing, constant normal force and indenter velocity should be set up in a controller. After that, the indenter approaches and presses down the surface of sample until the specified normal force in the controller is reached. The apparatus is thus ready to make a scratch and the indenter moves from substrate towards coating. During scratch tests, normal and tangential forces are measured and recorded by computer in Fig. 3.

The following test parameters were used to perform scratch test in the present study: constant load 10 kgf; indenter velocity 0.5mm/min and scratch length : 3.5mm.

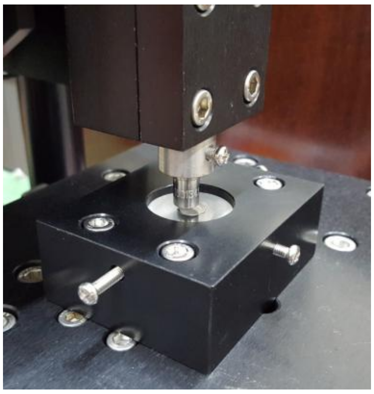

Fig. 2. The scratch test apparatus

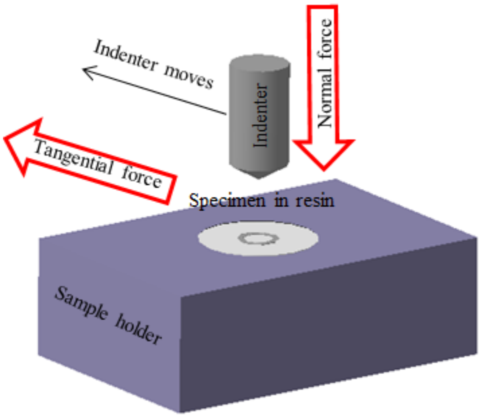


Fig. 3. Schematics of scratch testing

*2.3 Result*

Figure 4 shows the measured normal and tangential forces as a function of scratch length. The results showed that normal and tangential forces increased while indenter moved from resin toward cladding. Table 1 shows the comparison of results in normal and tangential forces about uncoated, plasma spray coated, and arc ion coated tube samples. It can be expected that the differences of measured result forces were caused by different adhesion properties between substrate and coatings.

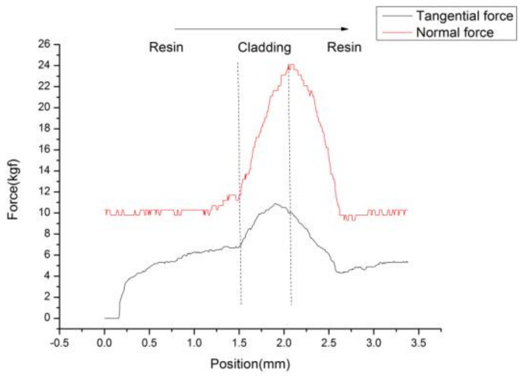


Fig. 4. Normal and tangential forces as a function of scratch length

Table 1: Comparison of test results in the maximum normal and tangential forces

| | Maximum Normal Force (kgf) | Maximum Tangential Force (kgf) |
|---|---|---|
| Uncoated Zircaloy (Ref) | 24 | 10 |
| CrAl Plasma Spray coating | 19 | 7 |
| Cr Arc ion coating | 27 | 11 |

## 3. Conclusions

Experimental approach for adhesion strength of ATF coated cladding was investigated in the present study. The scratch testing was chosen as a testing method. Uncoated zircaloy-4 tube was employed as a reference and plasma spray and arc ion coating were selected as a ATF coated claddings for comparison. As a result, adhesion strengths of specimens affect the measured normal and tangential forces. For the future, the test will be conducted for CrAl coated cladding by laser coating, which is the most promising ATF cladding. Computational analysis with finite element method will also be conducted to analyze a stress distribution in the cladding tube. After finding a load condition where adhesion failure in the experiment, FEM model will be developed in the same load condition and then the stress distribution will be analyzed.

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