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Analysis of Ultrasonic Inspection Defects of the High Density U3Si2 Fuel plate

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1. Introduction

For the LEU conversion of HEU using research reactors, high density fuel meat is mandatory to compensate the reduced U-235 enrichment. This calls for the development of 5.3gU/cc U3Si2 nuclear fuel plate consisted of high density U3Si2 atomized particle fuel dispersed in Al matrix. Increased fuel volume in the meat affects not only the fuel particle distribution, but also other fabrication defects. This paper reports the ultrasonic test (UT) data and analyses the root cause of the UT defects formed during the fabrication process.

2. Methods and Results

2.1 Foreign bodies

In the fuel plate fabrication method, U3Si2 fuel powder was blended with Al matrix powders. The mixture was placed inside the compaction mold and compacted by the press. Subsequently, the fuel core compacts were assembled with Al cladding components called a picture frame and cover plates. The components were pre-heated in a furnace at 500°C for 10 minutes to ensure the insertion of the compacts into the picture frame. During this process, there was a high chance of inclusion foreign matters either in the fueled zone or in the no-fueled zone. According to the fuel fabrication specification, foreign matters other than fuel particles in the non-fueled area are accepted under the condition of the acceptance standards. However, it is difficult to differentiate between the foreign body and the fuel particle by analyzing the UT inspection results. In this sense, KAERI intentionally injected foreign matters into the fuel pack assemblies, and subsequently made the assemblies into the fuel plate to perform the UT inspection.

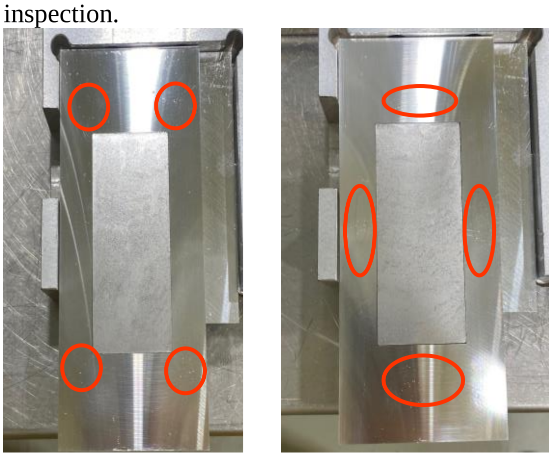

Fig. 1. Foreign bodies injected Al cladding components

2.2 Pitting

Each fuel plate is annealed at 500°C for longer than 1 hour to check non-bonding of the fuel plate after hot-rolling process. After cooling in air, non-bonded area can be visually confirmed by observing blisters, and any fuel plates containing blisters within the fueled zone of the plate are rejected. Only plates with blisters in the non-fueled area, and of a total area less than $1mm^2$ in the UT inspection can be offered for acceptance by concession. However, some of micro pores which is highly detrimental to the reactor during the irradiation is not visually observed even after high temperature annealing. It is also hard to discriminate between particles and micro pores by the UT inspection. For that reason, KAERI prepared dummy Al fuel plates by the same hot-rolling fabrication method, and made artificial pitting on the components as described in the Table 1. The UT inspection was performed on the micro pores in the dummy plates which were not shown in the visual inspection during blistering test. The diameter of the pitting was 1mm which is acceptance criterion of the UT inspection, and affection of the depth was analyzed.

Table 1: Diameter and depth of the holes.

No.	Diameter (mm)	Depth (mm)
1	1	4.28
2	1	3.21
3	1	2.68
4	1	2.14
5	1	1.61
6	1	1.07
7	1	0.54
8	1	0.32
9	1	0.11

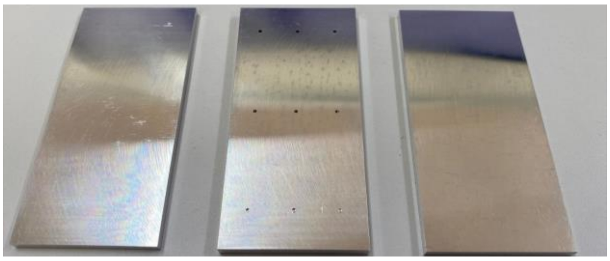
Fig. 2. Pitted Al components

2.3 Results

From the results of the UT inspection of the high density U3Si2 fuel plate, it showed that the defects can be categorized into the foreign body inclusion and micro pores as shown in Figure 3. Comparison analysis showed that each defect can be characterized by the contrast and the peak height.


Fig. 3. UT images of high density U3Si2 fuel plates

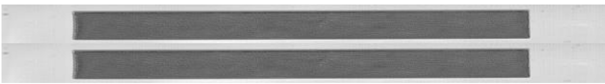
Fig. 4. UT images of foreign bodies injected high density U3Si2 fuel plates

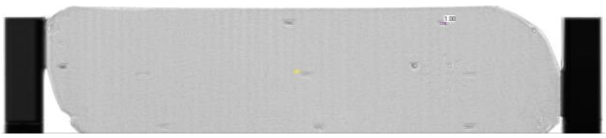
Fig. 5. UT images of the dummy Al plate with pitting

3. Conclusions

In this paper, it is confirmed that the inclusion of foreign bodies in the fuel pack assembly and micro pores generated during the hot-rolling process were one of the root causes of UT inspection defects. In depth study should be followed in the near future to improve the quality of the high density U3Si2 fuel plates.