Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

A Study on Improving the Fuel Meat Homogeneity of U_3Si_2 Dispersed Fuel for Research Reactors

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1. Introduction

Plate-fuel, which consists of a thin fuel meat and aluminum alloy claddings on both side, is one of the most common type of nuclear fuel for research reactors. Normally, fuel meat has a structure of dispersed uranium alloy or compound with in aluminum matrix. Research reactors around the world were initially designed with highly enriched uranium (HEU) fuels containing more than 90% of ^{235}U such as U-Al alloy fuel. To support both U.S. government and international nuclear nonproliferation objectives, however, converting current research and test reactors from HEU fuel to low enriched uranium (LEU) with a ^{235}U content below 20% has been conducted [1]. As a result, existing HEU fuel system need to be modified for accommodating LEU. U-Mo alloys, U_3Si, U_3Si_2, UO_2, U_3O_8 are representative candidate materials proposed for LEU fuel of research reactors. Because the physical properties of these materials vary widely, it is necessary to conduct research to optimize the current nuclear fuel manufacturing process based on the specific characteristics of each candidate material.

This study focuses on describing the optimized manufacturing conditions for atomized U_3Si_2-dispersion plate fuel, with specific emphasis on the study's results related to improving the homogeneity of atomized U_3Si_2 within the fuel meat.

2. Methods and Results

In this section some of the details of fabrication process used for U_3Si_2 dispersed plate-fuel and parameters studied for optimizing fabrication process. The parameters include homogeneity of uranium distribution, fuel meat thickness, cladding thickness, microstructure of fuel meat were also descried. The effects of the process parameters on fuel meat behavior during fabrication also described.

2.1 Fabrication Process

Fig.1 shows a flow chart for fabrication process used for atomized U_3Si_2 dispersion plate fuel for research reactors. Instead of conventional process with crushed U_3Si_2 powders, spherical U_3Si_2 with centrifugal atomization technology was used. Fuel assembly which consists of picture frame containing fuel meat and clads is welded. It is then followed by hot and cold rolling processes, which have been widely adopted at many research reactor fuel fabricators around the world [2].

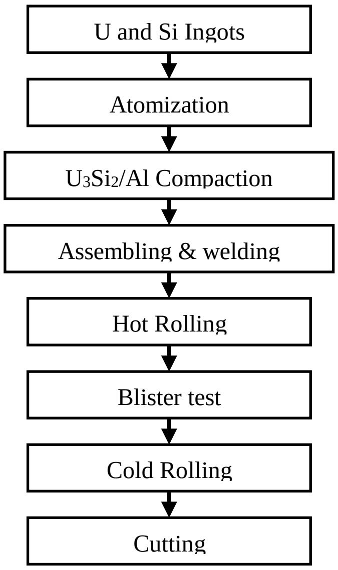

Fig. 1. A flow chart for fabrication of U_3Si_2 dispersion plate-fuel for research reactor.

2.2 Parameters for Inspection

Several important aspects of the U dispersed plate fuel were studied, which include such as homogeneity of uranium distribution, fuel meat thickness, cladding thickness, microstructure of fuel meat. Radiographs were taken and scanning electron microscopy (SEM) were used for microstructural analysis of fuel meat and its homogeneity.

2.3 Al Powders for Fuel Meat Mixture

The changes in various process parameters influence the quality and characteristics of the fuel meat during fabrication. In this experiment, the size of Al powders was varied and its influence on fuel meat compaction and homogeneity of uranium after rolling process.

Fig. 2. shows the SEM images of the pure aluminum powders with diameters. Fig. 2(a) shows crushed aluminum powders with mean diameter of 45 μm. Fig. 2(b) and (c) show atomized aluminum powders with mean diameters of 20 and 3 μm, respectively. The surface of the atomized powders [Fig. 2(b) and 2(c)]

was smoother than that of the crushed powder, but it

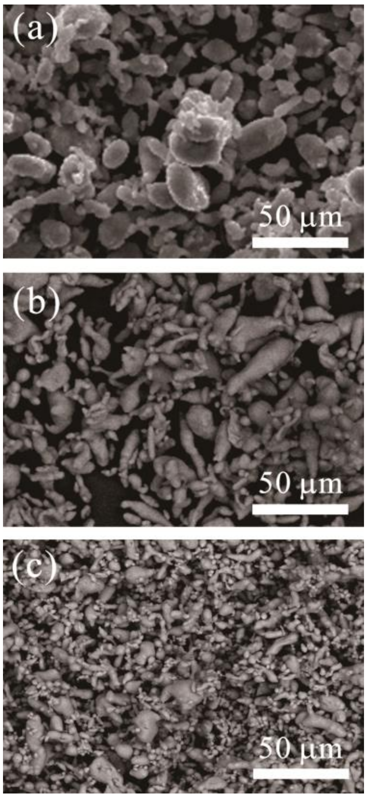

Fig. 2. SEM micrographs of Al powders used for compaction process of U_3Si_2/Al fuel meat having different mean diameter of (a) 45, (b) 20, (c) 3 μm, respectively

was not completely spherical. The fuel meat is made with centrifugally atomized U_3Si_2 powders and these pure al powders by powder metallurgy technique. Aluminum powders were sieved to a size less than 45 μm.

2.4 Al Powder and its Effect on Homogeneity of U

Ensuring the homogeneity of uranium in the fuel meat is very important for optimal performance of research reactor fuel. The homogeneity of the fuel meat is significantly improved as the size of the aluminum powder used decreases, as illustrated in Fig. 3. In the case of the sample made of the largest size, 45 μm aluminum powder, the agglomerated and low-density areas are clearly visible [Fig. 3 (c)].

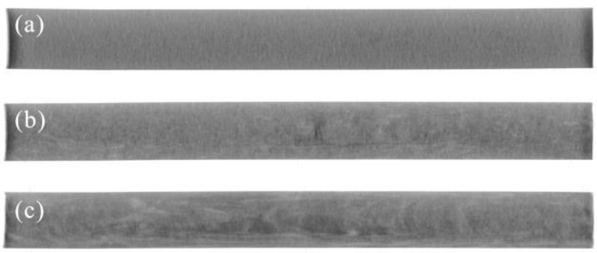

Fig. 3. Radiographs taken from the fuel meat region in rolled plate fuel samples fabricated with aluminum powder of mean diameters 45, 20, and 3 μm, respectively.

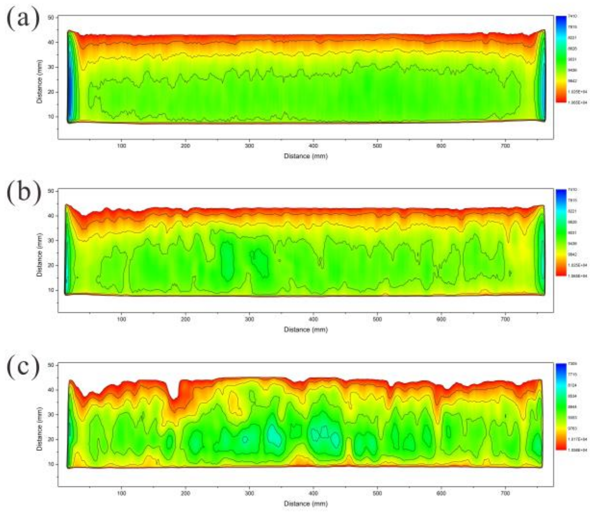

Fig. 4. Uranium homogeneity of fuel meat represented in color contours. (a), (b), and (c) shows the fuel meat region fabricated with aluminum powder of mean diameters 45, 20, and 3 μm, respectively.

The density of uranium in fuel meat can be quantified by analyzing the grayscale intensity of X-ray radiographs. Fig. 4 shows the color contour map generated from the grayscale analysis, where blue color represents high uranium concentration and red color represents low uranium concentration. These results also indicate that the homogeneity of uranium in the fuel meat varies significantly depending on the size of the aluminum powder used at compaction process.

3. Conclusions

Plate-type research reactor nuclear fuel was successfully fabricated with excellent homogeneity using U_3Si_2 powders with centrifugal atomization technology. Among various factors influencing the manufacturing process, the characteristics of aluminum powder used for compression manufacturing of fuel meat have been mainly studied. As a result, it was found that the average diameter of aluminum powder plays a significant role in improving uranium homogeneity in fuel meat.

REFERENCES

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