

Study of annular fuel fabrication technology in a viewpoint of microstructure

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1. Introduction

The motivation for innovative fuel development is the development of the advanced ultra-high burnup sodium-cooled fast reactor metallic fuel concepts. The fabrication experiment seeks to investigate advanced fuel designs with the following features: decreased fuel smeared density (SD), venting of the fission gas to the sodium coolant, reduce the FCCI (Fuel Cladding Chemical Interaction), and an advanced fabrication method that includes consideration of annular fuel and extrusion method. The one of most attractive advantage of extrusion method is save the process waste by omitting the sodium process. From the previous study, annular fuel shows the possibility of the reduction of swelling effect and then prevention of the FCMI (Fuel Cladding Mechanical Interaction) [1]. However, the fabrication technology of the annular fuel has not been developed yet. Therefore, KAERI has started to study the annular fuel fabrication method by using hot extrusion method. In this study, the prototype of annular fuel has been fabricated by using Cu billet. The design of billet and annular fuel has been determined, and then and design and material for the mold has been determined by using Deform 3D program. After the mold fabrication, the prototype annular fuel has been fabricated and its texture were examined by us EBSD (Electron Back Scatter Diffraction).

2. Methods and Results

2.1 Design of billet & annular fuel

The size of the billet and the fuel core specimens for the production of the annular simulated fuel shims were determined. In the case of the fuel padding, the annular shape having a diameter of 5 mm and a smear density of 75% was selected as a ring 10 mm in diameter. In the case of a billet, a diameter of 40 mm was selected by extrusion. The inside of the billet was designed to be easily manufactured into an annular shape by extruding holes of the same size as the annular fuel slug.

2.2 Design and manufacture of extrusion mold

A mold for extruding annular metal fuel shims was designed using Deform 3D analysis program. In this study, Cu which is similar to the dissolution condition of uranium was selected as the material for making the simulated annular metal fuel shims, Deform 3D was used to select the jig design suitable for extruding Cu and stress and temperature conditions. Figure 1 is an analysis of the stresses at each part generated during extrusion using Deform 3D. As a result of the analysis, it was confirmed that a stress of about 900 MPa was generated at the center portion, and a stress of about 1800 MPa was expected to occur when the actual extrusion was performed.

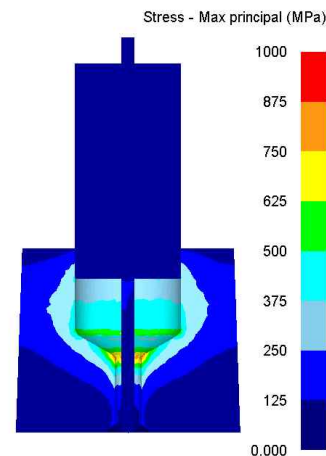


Fig. 1. Stress analysis of the extrusion mold.

Figure 2 shows the result of analyzing the temperature at each part during actual extrusion. The extrusion conditions were selected based on the extrusion of the annular simulated fuel core with Cu at a maximum temperature of 726 °C.

2.3 Preliminary fabrication of annular fuel

Based on the analysis results, the jig design was designed as shown in Fig. 2, and the mold was manufactured based on the design. In the simulated fuel core extrusion, a press machine capable of extruding a maximum of 200 tons was used, and the extrusion was performed by inserting the billet before extrusion into a mold set at 450°C after heating at 600°C. As a result of

the extrusion, it was possible to successfully fabricate the annular fuel.

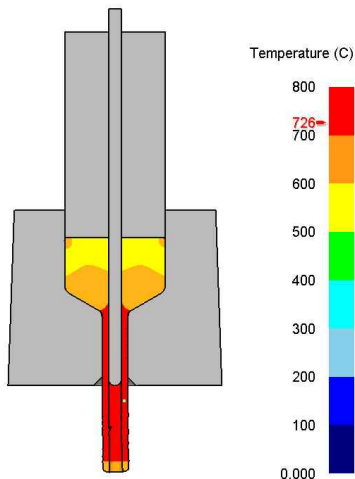


Fig. 2. Temperature analysis result of extrusion mold.

2.4 Microstructure analysis of annular fuel

In order to further analyze the microstructure of the extruded mock-up pellets, the microstructure distribution after extrusion was analyzed using Electro Back-Scattered Diffraction (EBSD). Cu has a phase centered cubic crystal structure (face centered cubic (FCC)) at room temperature. As shown in Fig. 3, Cu has a fine grain size of several μm to several tens of μm after extrusion. This tendency is different from that of an extruded structure exhibiting anisotropy along the machining direction. This is attributed to the fact that the microstructure of the billet formed in the initial machining already has a fine grain size.

2.5 Microstructure analysis of billet

In order to analyze the cause of the fine grains of the Cu annular fuel, the microstructure of the billet produced by the conventional machining is analyzed by EBSD. The texture of the treated billet was similar to that of the microstructure after extrusion, but it showed a tendency to have a grain size of at most 100 μm or more, which is relatively coarser than that of the extruded fuel core. Therefore, it is considered that the non-anisotropic crystal tendency analyzed after extrusion production is attributed to the fact that the crystal grains used in the processing billet are already small in size. In order to study the anisotropy control in

the extrusion process, it is judged to be appropriate. Therefore, in the future extrusion process research, the test will be carried out using the directly melt-cast billets.

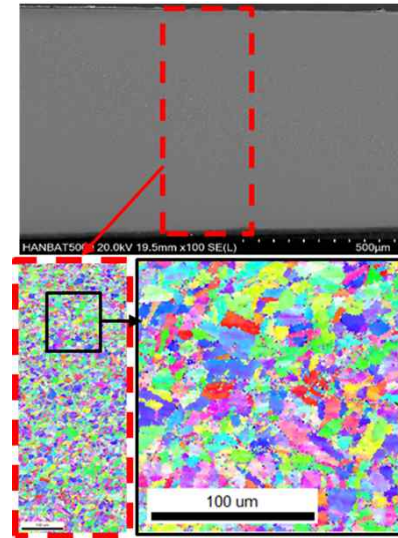


Fig. 3. Texture analysis annular fuel (L direction)

3. Conclusions

KAERI is developing the extrusion type metal fuel manufacturing technology as a part of the development of the original technology for the production of innovative metal fuel. In this study, the preliminary test of the extruded annular metal fuel and their properties were evaluated. In order to carry out the extrusion manufacturing test, the jig analysis and design for Cu and U were carried out, and the jig suitable for the extrusion manufacturing test was made by selecting the jig material. As a result, it was possible to successfully manufacture extrusion by utilizing billet heated at 700 °C and extrusion equipment of 200ton class. The fine size of grain after extrusion were observed due to its fine microstructure of billet, so it will be complemented by the production of billets through casting in the future.

Acknowledgement

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- [1] K. Marsden, "Report on Development of Concepts for the Advanced casting System in Support of the Deployment of a remotely Operable Research Scale Fuel Fabrication Facility for Metal Fuel", INL/EXT-07-12469, 2007.