Development of Fabrication Technology of Annular Fuel by Hot Extrusion Method

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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 in INL seeks to investigate advanced fuel designs with the following features: decreased fuel smeared density (SD), venting of the fission gas to the sodium coolant, a uranium-molybdenum (U-Mo) based alloy fuel system, coating or liner on the cladding inner surface, and/or targeted fuel alloy additions to reduce FCCI, and an advanced fabrication method that includes consideration of annular fuel and co-extruded fuel and cladding [1]. From the experiment result in INL, annular fuel shows the possibility of the reduction of swelling effect and then prevention of the FCMI (Fuel Cladding Mechanical Interaction). 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. Result & Discussion

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. Fig. 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.

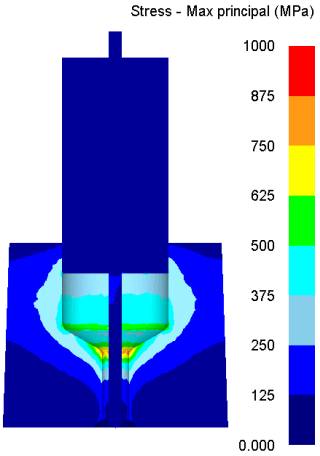

Fig. 1. Stress analysis of the extrusion mold.

Fig. 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.

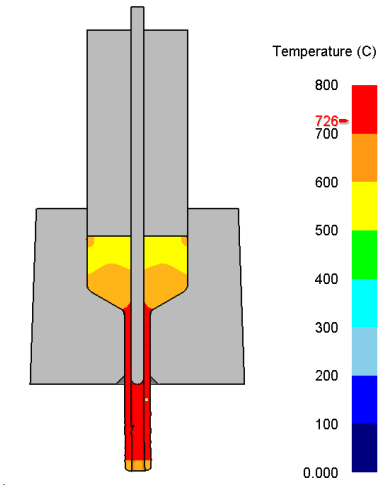

Fig. 2. Temperature analysis result of extrusion mold.

2.3 Production of annular simulated fuel shims

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 produce the annular simulated fuel slug, and the characteristics evaluation will be conducted and discussed.


Fig. 3. Sample Figure.

3. Conclusion

In this study, the prototype of annular fuel has been fabricated by using hot extrusion method. The mold for annular fuel was designed using Deform 3D, and the fabrication was successfully done by press extrusion method.

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