Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

The Effect of Core Designs and Extrusion Speeds on the Coextruded Zr-U/Zr-Nb Fuel Rod

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I. Introduction

It is considerably required that the metallic fuel should have a metallic bond in the interface between fuel and clad for high power and high temperature operations[1]. For the present study, the coextrusion process was chosen as a fabrication method of Zr-U/Zr fuel rod. This process principally provides the metallurgical bonding between the fuel and cladding. To obtain the regular form of a core and cladding, we must consider how core design is optimal in this process because its design considerably affects the core metal flow during the coextrusion process.

In this study, the variety of the core designs and extrusion speeds is applied to coextrusion process. The goal of this study is to make the good manufacturing condition of metallic fuel rod consisted of Zr-U and Zr-Nb alloys. In order to analyze the effect of core designs on the dimension of a core and the thickness of a clad in this process, three conditions were applied. To control the length of the core in coextrusion rod, the different extrusion speeds were used.

2. Methods and Results

All Zr-U/Zr billets were coextruded on a 300-ton capacity horizontal extrusion press at high temperature. The billets composed of a copper can, Zr-U core and Zr-Nb alloy can were prepared. Both sides of the end of the billet were sealed by an electron beam welding method in a vacuum atmosphere. To obtain surface of extrusion rods in good condition, all Zr-U cores were machined owing to removal of the Zr-rich phase in the surface which caused crack and fracture of the clad during the extrusion process[2]. Coextrusion was carried out at press ram speeds of about from 12 to 22mm/sec. After coextrusion process the both sides of the Zr-U core in fuel rod decreased the dimension of cross section. We named this decreased region of the core the unevenness part which is measured by a standard, below about 80% of dimension. The unevenness parts were examined by means of gamma radiography films and conformed by measuring the cross section cut from the front and rear of a Zr-U core.

2.1 Core design

The three kinds of core designs were determined experimentally and compared against each other to investigate the effect on the unevenness part of the core in fabrication of the Zr-U/Zr-Nb clad composite as shown in Fig. 1. To optimize the condition of core dimension and unevenness part at the both front and rear of the fuel rods, Zr-U cores were machined before assembling the composite billet. The design of its billet is important owing to largely affecting the dimension of a core and the thickness of a clad after coextrusion process. The dimension of the core at around the end of fuel rod increased larger than that of the regular part when using the Zr-U core with cylinder type. Increase of core dimension results in decrease of clad thickness. Therefore to obtain regular size of the core and clad and also to meet the standard requirement, 4.1mm of core and 0.5mm of clad, the Zr-U core must be designed and machined specially. Fig 2 shows the cross section of the fuel rod consisted of Zr-Nb and Zr-U alloy.

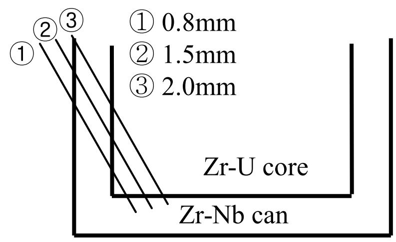

Fig. 1. Sketch of the Zr-U core machining the rear part in three ways

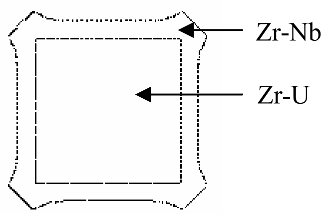

Fig. 2. The cross section of the Fuel rod after coextrusion process.

Fig. 3 shows the results of the size of core and clad around the end of extruded rods. Measurement of the clad thickness was complicated by variations in the regularity of the interface between the core and the clad. Average values were determined from measurements taken from a sample cut from the rear of core. Reading was made on a profile projector by translating the polished cross section. As shown in the Fig 3, of the three conditions the core machined with 75°, 1.5mm at the rear of the core is the most optimal. And also the sound thickness of the clad could be obtained with the same condition, as shown in Fig. 4. The core with 75°, 1.5mm was adequate to meet our standard of the clad thickness.

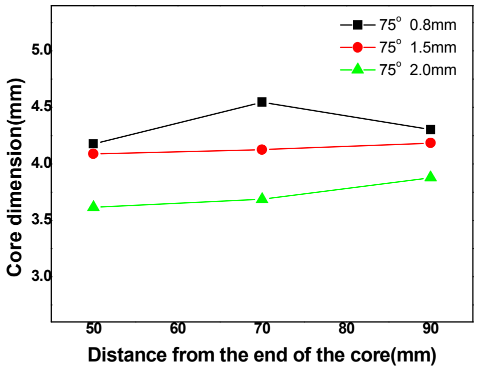

Fig.3. Core dimension of coextruded Zr-U/Zr rods as a function of distance from the end of the core for three regions.

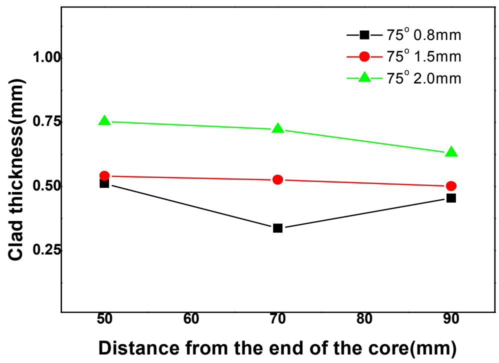

Fig. 4. Clad thickness of coextruded Zr-U/Zr rods as a function of distance from the end of the core for three regions.

2.2 Extrusion speed

Extrusion speed is an important factor in the coextrusion process because it is dependent on flow behavior of the material resulted in the length of an unevenness core in rods. The relationship between extrusion speed and the length of the unevenness core is shown in Fig. 5. It is evident from the figure that the unevenness part exists depending on the extrusion speed. As shown in the figure, the lengths of the core increased as the extrusion speed increased. Especially in over 20mm/sec of its speed the cores considerably increased. On the other hand, the unevenness part decreased as the extrusion speed decreased. It is considered that these results is complicated by the several factors, plasticity flow of the metal and the change resulted in friction with the die[3]. The more extrusion speed increase, the more the unevenness part appears severely.

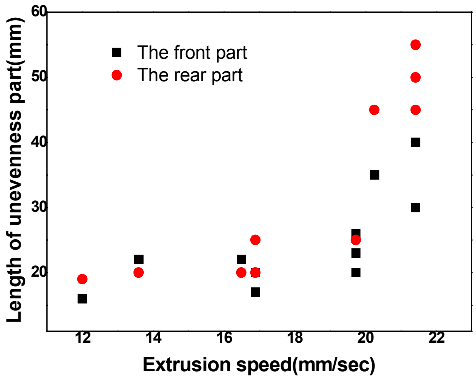

Fig. 5. Relationship between extrusion speed and the length of unevenness part of the Zr-U core.

3. Conclusion

In this study, we applied to the fabrication of Zr-U/Zr-Nb rod using a coextrusion process with the various core designs and under different extrusion speeds. We obtained a optimal Zr-U core design that results in sound core and clad thickness of the fuel rod. The effect of the extrusion speed on the length of the unevenness part was determined experimentally. The unevenness part of the Zr-U core increased as the extrusion speed increased. Especially in over 20mm/sec of its speed the cores considerably increased. It is considered that the result is related with the differences in material flow during the coextrusion process.

Acknowledgements

This study was supported by Ministry of Science & Technology (MOST), Korea government, through its National Nuclear Technology Program.

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