An Investigation on Monolithic U-Mo Plate Type Fuel by a Pressure-Sintering Method

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1. Introduction

Previously the average particle diameter of U-Mo powder used for developing U-Mo dispersion fuel was about 50 μm. U-Mo/Al dispersion fuels were shown that an extensive interaction between the U-Mo particle and the Al matrix occurred in high-power-density of dispersion fuel [1].

Because the interaction product has a low thermal conductivity and density, which have harmful effects for fuel performance, several attempts to avoid the above problems have been made such as (1) the decrease of the contacting area between the fuel and Al matrix, (2) the increase of the alloy stability of the interaction phase through the addition of an additional alloying element, such as Si, Ti and Zr, into the Al matrix [2-4].

In KAERI U-Mo powder with very large particle size of more than 500 μm could be produced by rotating disk centrifugal atomization process through adjusting the operating parameters in 2006. A consideration was taken for an application of a large particle to plate type fuel with a layer array. When the particles of spherical shape arrayed in a closed packing way the equivalent U-density of fuel meat would approach to more than 8 g-U/cc. The interface temperature between the U-Mo particle and the Al matrix is expected to be low because aluminum with good thermal conductivity is connected from the interface to the cooling water without any thermal diffusion interruption. The temperature at the center of the large U-Mo particle is calculated to be not too high. When the heat flux and the particle diameter are supposed to be 560 W/cm^2 and 700 μm, the temperature difference was about 36 °C. In addition, the U-Mo particles are surrounded with an aluminum matrix so that a little of the constraint force will act on the fuel particles from the aluminum matrix. A problem like debonding between U-Mo foil and Al cladding in monolithic U-Mo fuel under development can be avoided. Some experiments related to the fabrication of large particle array fuel were carried out using surrogate material of depleted material. In this paper the results will be described.

2. Experimental

The particle formation in the atomization process is induced by disintegration of melt by centrifugal force. The melt droplet is affected by the tip speed of the rotating disk and the viscosity as well as the surface tension of the melt. In order to increase the droplet size, the revolution speed of the disk was lowered from about 30,000 rpm to 6,000 rpm. The disk diameter was adjusted from 40 mm to 35 mm. The cooling gas was chosen high thermal conductivity, which is helium. The obtained particles were distributed with about 38 wt.% of the powder fraction between 250 μm (60 mesh) and 710 μm (25 mesh) in diameter. In this experiment the size distribution of U-Mo powder was between 425 μm and 500 μm

In order to make a fuel plate with one layer of an arraying U-Mo large particle a mold was designed as shown Fig 1. The mold is composed of bottom and top caps and a tube between them and was designed so that it sintered under pressure. On the inside of caps there are round shape bulges for pressing aluminum powder. U-Mo particles are charged in the inside of the assembled die of the bottom die and tube. The spherical particles are easily arrayed at the bottom. After that aluminum powder was put over the arrayed U-Mo particles. Then top cap was assembled with a fitting to the tube and charged in the pressure-sintering chamber of the MTS. A pressure-sintering was done for 4 hours at 480 °C with a 2 ton pressing force.

In order to access the integrity of the sintered part the specimen was cut and examined by Optical microscope and SEM.

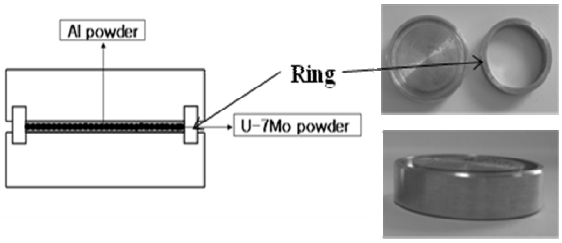

Fig. 1 Compacting Mold

3. Results and discussion

Fig 2 shows a morphology taken by SEM of a transverse section of the specimen. The spherical particles were almost closely packed. When a maximum particle size of 500 μm is supposed as a fuel meat thickness, the uranium density was calculated to be about 8.8 g-U/cc. When comparing it with the theoretical uranium density of a perfectly closed-arrayed layer, which is 9.86 g-U/cc, the compared fraction with the theoretical density corresponds to about 90 %.

The Interaction between the U-Mo particles and aluminum matrix occurred with a thickness of 5 to 10 μm in general as shown in Fig 3. From these results, the optimum sintering condition is presumed to be around 480 °C and 4 hours.

However, Fig 4 shows that aluminum powder was not filled into the gaps among the particles. This phenomenon seems to happen due to a small part of U-Mo particles were pulled out during cutting work.

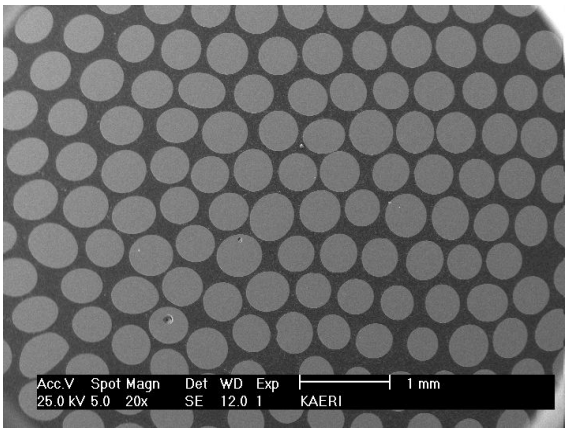

Fig. 2 Transverse section of pressure-sintered sample

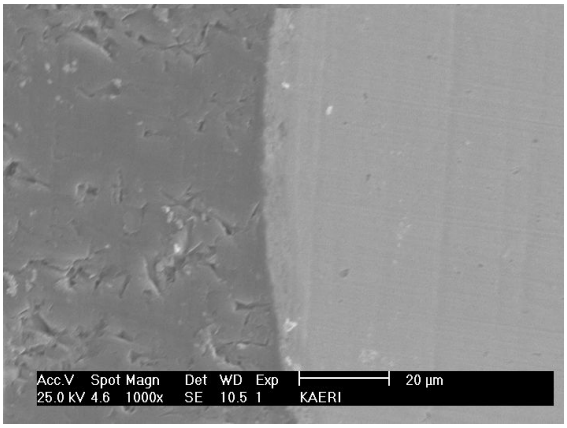

Fig. 3 Interaction between the U-Mo particles and the aluminum matrix

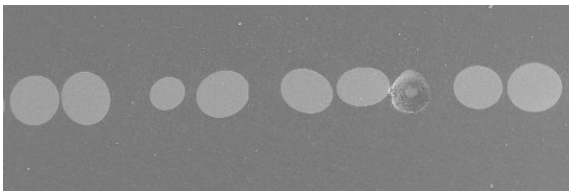

Fig. 4 Morphology of cross section of U-Mo particle arrayed fuel specimen

4. Summary

As an alternative way for obtaining U-high loading density a close array of spherical U-Mo particles with one layer was raised. A pressure-sintering method using a specially designed mold was applied to make an array fuel specimen successfully. Aluminum powder charged over U-Mo particles appeared to be consolidated without any difference between center part and side part of cap parts. The Interaction between the U-Mo particles and aluminum matrix occurred with a thickness of 5 to 10 μm. This arraying method is considered to be applicable to obtain up to 8.5 g-U/cc or even more.

Reference

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[4] J.M. Park et. al, Proceedings of the RERTR-2004 , Boston, Nov. 2005