A preliminary Formation Experiment on Monolithic U-Mo Plate Type Fuel With Arraying Very Large U-Mo Particle Available for High U-Density of More Than 8 g-U/cc

C.K. Kim, H.J. Ryu, S.J. Jang, S.J. Oh, and G.H.Choi*

Korea Atomic Energy Research Institute

Daedeokdaero 1045, Yuseong, Daejeon, 305-353, Korea

*Chungnam National University

220 Gungdong, Daejeon 305-764, Korea

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 U-Mo particle and Al matrix occurred in high-power-density of dispersion fuel [1].

Because the interaction product is low thermal conductivity and density, which are harmful effects for fuel performance, several attempts to avoid the above problems have been made such as (1) the decrease of contacting area between the fuel and Al matrix, (2) the increase of the alloy stability of the interaction phase through the addition of 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 operating parameters in 2006. A consideration was taken for an application of large particle to plate type fuel with a layer array. When the particles of spherical shape arrayed in closed packing way the equivalent U-density of fuel meat would approach to more than 8 g-U/cc. The interface temperature between U-Mo particle and 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 much 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 aluminum matrix so that a little of constraint force will act on the fuel particles from aluminum matrix. A kind of problem like debonding between U-Mo foil and Al cladding in monolithic U-Mo fuel under development could 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 atomization process is induced by disintegration of melt by centrifugal force. The melt droplet is affected by the tip speed of 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 in smaller size from 40 mm to 35 mm. The cooling gas was chosen as a gas having 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 fuel plate with one layer of arraying U-Mo large particle a mold was designed as shown Figure 1. The mold is composed of bottom and top caps and a tube between them. At 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 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 fitting to the tube and was pressed at 30 kgf/mm^2 by using hydraulic pressure. The pressed assembly was turned over and the bottom cap was removed. Then aluminum powder was put over the U-Mo particles. The bottom cap was assembled again and was pressed using hydraulic press. An annealing treatment was done for sintering aluminum powder at 430 °C and 10^{-3} torr for 6 hours.

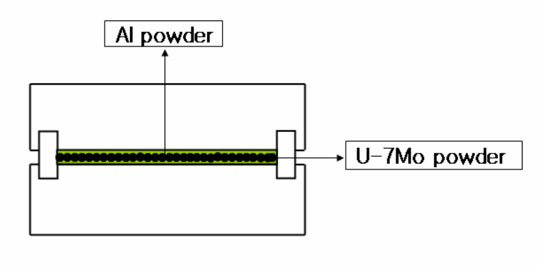

Fig. 1. Compacting Mold

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

3. Results and discussion

Fig.2 shows a morphology taken by optical microscope for a cross section of the specimen. Aluminum powder charged over U-Mo particles appeared to be consolidated without any difference between center part and side part of cap parts. U-Mo particles were mostly cut by cutting machine. A small part of U-Mo particles were pulled out during cutting work. The particles on the morphology were not closely arrayed. This phenomenon seems to happen due to a mismatch of the direction of close array and cutting direction. There would be another possibility from overall deformation by pressing on specimen.

For the space among closely arrayed U-Mo particles it was observed that aluminum powder was filled in the space and sintered soundly without any big voids. The pressure of 30 kgf /mm^2 is presumed to be enough for compacting Al powder among U-Mo particles. The interaction between U-Mo particles and aluminum powder was not observed on this optical observation. The annealing condition of 430 °C and 6 hours is considered not to cause any interaction.

From this result plate type fuel with arraying very large U-Mo particles is considered to be available. When perfect spherical U-Mo particles are arrayed with close-packed way the uranium density is calculated to be about 9.55 g-U/cc. If 8.5 g-U/cc is supposed as a target density, the two-dimensional fraction of particles in arraying U-Mo particles on the mold bottom will be about 89%. When the particle diameter is supposed as the thickness of fuel meat, U-Mo particles should be arrayed densely with more than 89 %.

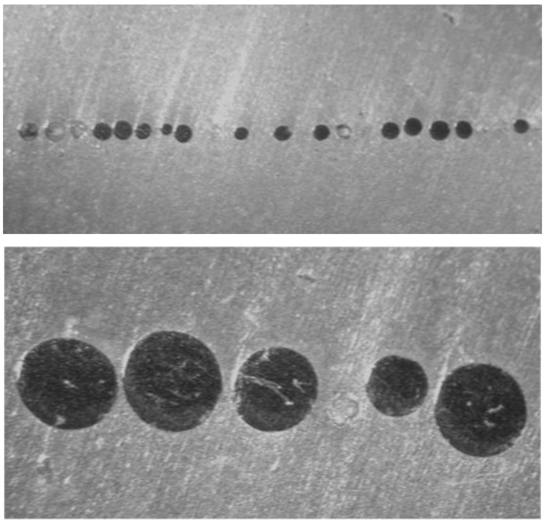

Fig. 2 Morphology of cross section of U-Mo particle arrayed fuel specimen

4. Summary

As an alterative way for obtaining U-high loading density a close array of spherical U-Mo particles with one layer was raised. A compaction and 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. Aluminum powder was filled in the space and sintered soundly without any big voids. The interaction between U-Mo particles and aluminum powder was not observed on this optical observation. The annealing condition of 430 °C and 6 hours is considered not to cause any interaction. 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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