Concept of Atomized Metallic Fuel for SFR

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1. Introduction

Metallic fuel pin of U-Pu-Zr alloys for SFR has conventionally been fabricated by an injection casting method. U-Pu-Zr alloy melts are injected and cast into quartz tube molds during injection casting. Metallic fuel pins are collected by fracturing quartz tubes from the molds. Demolded quartz tubes are treated with radioactive wastes.

Atomized metallic fuel does not need these quartz molds during fabrication, as uranium alloys are prepared as a particle form. It is possible to reduce the formation of radioactive wastes by applying the fabrication process of a particulate metallic fuel. Metallic fuel having a fine microstructure, which originates from a rapid solidification effect during atomization process, results in a higher FG release rate during irradiation [1]. In the case of applying a new forming method such as vibro-compaction in Zr sheath, the sheath can act as a reliable FCCI (fuel/cladding chemical interaction) barrier and a re-constraint for external elongation. In addition, atomized fuel powder, dispersed in a Na liquid metal having a high thermal conductivity, may have a lower temperature distribution during irradiation.

In this study, the concept of a metallic fuel prepared by the atomization method will be explained, the characteristic of the U-10wt.%Zr powder, prepared by the centrifugal atomization method, will be investigated.

2. Concept of Atomized Metallic Fuel

Atomized metallic fuel for SFR, as shown in Fig. 1, is fabricated by charging fuel alloy particles into Zr sheath and filling it with liquid Na in the gap among cladding tube and fuel particles. Zr sheath is applied to prevent a fuel/cladding chemical interaction. From this point for view in reducing FCMI (fuel/cladding mechanical interaction) during an initial period of an irradiation, it is regarded that a smear density of 75% is appropriate for the metallic fuel pin. In order for a particulate packing density of about 75%, two kinds of fuel powders having different diameters at least needed to be mixed with each other. Atomized powder facilitates in the fabrication of a metallic fuel to controll the smear density. Fuel powder is fabricated by atomization process, which leads to a fine microstructure having a high fission gas release.

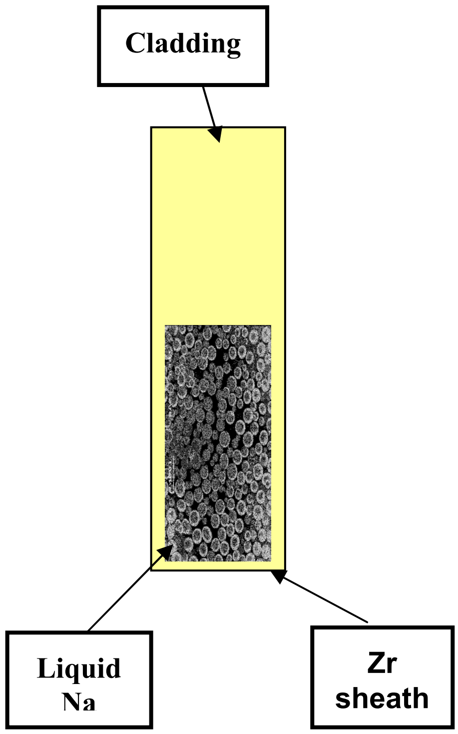

Fig. 1. Conceptual design of particulate metallic fuel.

3. Fabrication of Atomized Fuel Powder

3.1 Experimental procedure

A proportioned charge of depleted uranium lumps with a purity of 99.9% and zirconium sponges with a purity of 99.7% were induction-melted in a high-temperature-resistant ceramic crucible. The molten metal was fed through an orifice onto a rotating graphite disk in an argon atmosphere. In order to obtain the desired size distribution and shape, the atomization parameters were adjusted [2-3]. Powder size distribution of the atomized powder was classified by a sieve analysis. The morphology and microstructure of the powder according to the atomized particle size were characterized with a scanning electron microscope (SEM).

3.2 Results and discussion

The shape of the atomized U-10wt.%Zr alloy particles, as observed by the scanning electron microscope, is shown in Fig. 2.

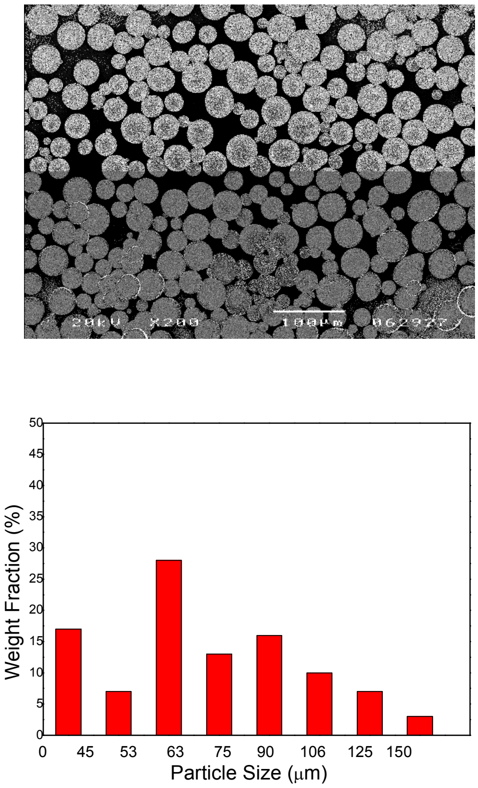

Fig. 2. Morphology (upper) and size distribution (lower) of U-10wt.%Zr powder fabricated by centrifugal atomization method.

Most of the particles have a smooth surface and generally near-perfect spherical shape with few attached satellites. The action of the surface tension force is thought to be the reason why atomized particles have a spherical shape [4-5]. The particles would have a tendency to form spherical shape under the action of surface tension force, when the disintegrated droplets maintain a liquid state for the time required for the formation of spherical particles. When the feeding rate of melt is small, the particle size distribution displays a bimodal distribution with the main and secondary particles. Champagne et al assumed that the bimodal particle size distribution was originated from the direct drop formation mode, which occurred at a relatively small rate of the melt feed in the rotating electrode process of iron, steel, copper, aluminum and zinc [5].

The cross-sectional micrograph of the atomized U-10wt.%Zr alloy particles, is illustrated in Fig. 3. It is seen that the microstructure of both types of atomized particles is polycrystalline, with many non-dendritic α-U grains below 3 ㎛ in size. U grains became finer by about twenty times, from about 40μm in a conventionally cast pin to about 2μm in an atomized powder. Metallic fuel having a fine-grained U phase enhances in a higher fission gas release rate during irradiation. U grains became finer from about 40μm in a conventionally cast pin to about 2μm in an atomized powder. Metallic fuel having a finer laminar structure also results in a higher fission gas release rate during an irradiation.

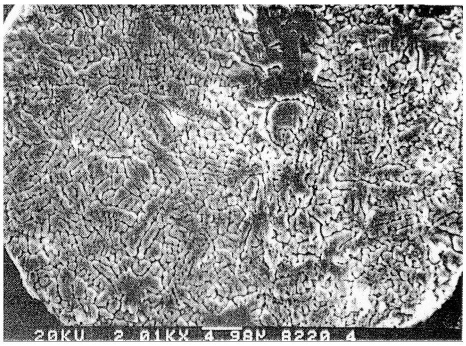

Fig 3. Microstructure of cross-section of centrifugally atomized U-10wt.%Zr powder (x2000).

4. Conclusions

Atomized particulate metallic fuel for SFR, which does not need quartz molds during fabrication was proposed. It is possible for atomized metallic fuel to reduce the formation of radioactive wastes, and to have a fine microstructure, resulting in a higher fission gas release rate during irradiation. In the case of applying the new forming method such as vibro-compaction in a Zr sheath, the sheath can act as reliable FCCI (fuel/cladding chemical interaction) barrier and a re-constraint for an external elongation. In addition, atomized fuel powder, dispersed in Na liquid metal having a high thermal conductivity, may have a lower temperature distribution during irradiation. It is also expected that a high-burn atomized powder fuel may be developed as a new metallic fuel having a higher FG release and a lower swelling rate.

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