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Fabrication of metal fuel pellet using powder metallurgy process

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1. Introduction

Metal fuels offer superior stability and economy compared to conventional nuclear fuels, owing to their high thermal conductivity and fissile density. However, to maintain an adequate thermal margin, the relatively low melting point of metal fuels necessitates efficient heat transfer within the fuel rod. This may require additional manufacturing processes, such as sodium bonding, which could potentially reduce the fuel fabrication yield. One approach to replacing sodium bonding is the use of porous fuel, which allows for the elimination of the fuel-cladding gap while maintaining a low smeared density. However, manufacturing such low-density fuel using conventional casting methods is challenging. Therefore, this study aimed to demonstrate the fabrication of U-10wt.%Zr nuclear fuel pellets using powder metallurgy techniques. The study analyzed the differences in density, microstructure, and phase composition between U-10Zr mixed nuclear fuel and U-10Zr alloyed nuclear fuel.

2. Methods

The U-10Zr mixed powder and U-10wt.%Zr alloyed powder were utilized to fabricate metal fuel pellet, respectively. The mixed powder was consisted of spherical metal fuel particles with ~48 um particle size and amorphous zirconium powder. For the alloyed powder, spherical U-10wt.%Zr alloy powder particles with an average particle size of 70 μm produced by centrifugal atomization were used. The compaction was performed under a pressure of approximately 100 kgf/mm², and PEG/PVA were employed as binders and Y_2O_3 was used as a compaction lubricant. The green pellets were sintered in a vacuum furnace at 970 °C, 1100 °C, and 1200 °C for 6 hours, respectively.

3. Results

The sintering process using mixed powder did not achieve sufficient densification at a 970 °C sintering temperaeture. For sintering temperature of 1100 °C , approximately 70%TD was achived, with a similar sintering density observed at 1200 °C (~68% TD). Insufficient alloying was observerd at 1200 °C sintering temperaeture, however, at higher temperatures, there is a potential risk of metallic uranium melting.

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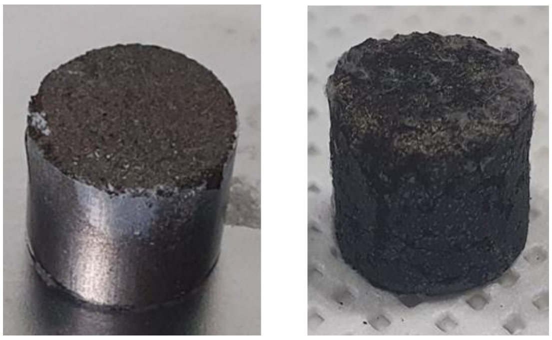

Fig. 1. Metal fuel pellet before sintering (left) and after sintering, using U-10Zr mixed powder.

For the alloyed powder, there were issues with green pellet compaction and handling, even with the use of binders. Nevertheless, through sintering at 1200 °C for 6 hours, a sintered pellets with 74% of the theoretical density was obtained. It is anticipated that higher sintering densities could be achieved by applying higher sintering temperatures.

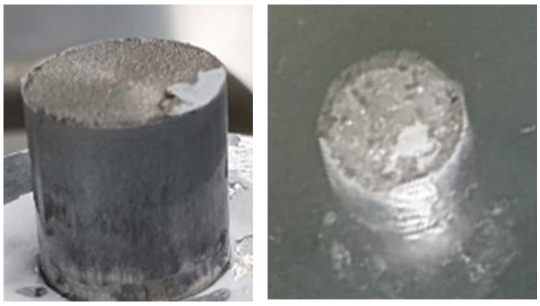

Fig. 2. Metal fuel pellet before sintering (left) and after sintering, using U-10Zr alloyed powder.

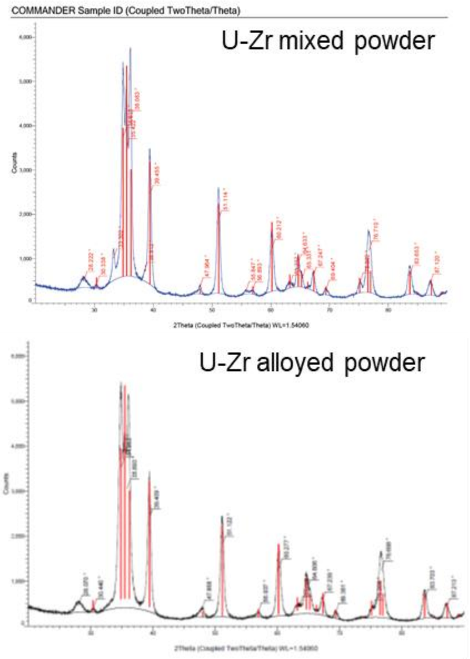

Fig. 3. XRD analysis on fabricated metal fuel pellets using U-Zr mixed powder and alloyed powder.

Acknowledgments

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