High Temperature Hoop Deformation of Zircaloy- 4 Nuclear Fuel Cladding using Advanced Expansion due to Compression Test

*Neli Nikolova[1], Huilong Yang[2] , Sho Kano[2] and Hiroaki Abe[1,2]
[1]Department of Nuclear Engineering and Management, Tokyo Univ.
[2]Nuclear Professional School, Tokyo Univ.

Abstract

The acquisition of hoop direction tensile properties is necessary for textured materials such as Zircaloy-4 used for nuclear fuel cladding tubes. The purpose of this study is to evaluate the deformation in the hoop direction of Zircaloy-4 at high temperature using a newly developed Advanced Expansion due to Compression (A-EDC) test. In this work, Zirclaoy-4 cladding tubes were tested at temperature ranging from room temperature up to 773 K. The stress-strain curves in hoop direction were derived and the effect of temperature on the tensile hoop properties was further investigated.

Keywords: Zircaloy-4 cladding, High temperature, Hoop mechanical properties, Advanced Expansion due to Compression

1. Introduction

During the fabrication process of nuclear fuel cladding tubes, Zircaloy-4 undergoes severe plastic deformation, which induces anisotropy in the mechanical properties. Though the mechanical properties of Zircaloy-4 in longitudinal direction are well investigated, there is limited data regarding the behavior of the material in hoop direction. Advanced Expansion due to Compression (A-EDC) is a mechanical testing method based on improvements on the conventional Expansion due to Compression test in which metallic inner pellet is axially compressed therefore radially expanding, causing equally distributed load on cladding specimen. Recently, A-EDC high temperature testing was made possible by using inner pellets with high temperature stability, which was used to study the temperature effect on the hoop properties of Zirclaoy-4 cladding tubes.

2. Experimental procedure

A cold-worked and stress-relieved Zircaloy-4 cladding tube ring-shaped specimen with height of 1 mm was used in this study. Bronze and stainless steel inner pellets with diameter of 8 mm and height of 8 mm were prepared for A-EDC test. The compression was done using Shimadzu AG-100KNX tester and the changes in the height and diameter of the inner pellet-ring specimen configuration were monitored by laser displacement meter Keyence TM-3000. Facture morphology microstructure of the tested specimens was observed by scanning electron microscope.

3. Conclusion

Zircaloy-4 ring specimens were successfully tested at different temperatures such as 298 K, 473 K, 573 K, 673 K and 773 K using bronze and/or stainless steel pellets. A-EDC test consists of two experiments: pellet only compression and compression with ring shaped specimen. By comparing A-EDC test and pellet deformation, the stress–strain curve of the hoop deformation of the ring-shaped specimen were derived, from which the tensile properties at hoop direction such as yield stress, tensile stress, and elongation were analyzed. In addition, the fracture morphology and area reduction ratio at fracture were analyzed. Evolution of crystallographic structure of Zircaloy-4 samples at various temperature will be further investigated using X-ray Diffraction. The effect of temperature on the hoop deformation up to 773 K will be systematically discussed in the presentation.