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Diffusion coefficients of H in Zirconium alloys at operating temperatures by neutron imaging

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Zirconium based alloys are widely used in the nuclear industry, mostly as tubes and claddings operating in high-pressure water at temperatures between 250℃-350℃. Hydrogen (H) or deuterium (D) ingress due to waterside corrosion, and subsequently precipitates as a brittle hydride phase. Degradation mechanisms involve the accumulation of these brittle hydrides at cold spots or crack tips, as a result of H diffusion in response to thermal and stress gradients, respectively. In both cases, the diffusion coefficient of H at operating temperatures determines the crack growth velocity. Here, we have adapted a traditional method to determine the diffusion coefficient of H in Zirconium based alloys, in order to apply it to smaller specimens and significantly reduce experimental times. The method involves the formation of a surface hydride layer on a small specimen machined out of a plate or tube, and the determination of the H concentration profile obtained after an annealing treatment at the temperature of interest. The innovation of the present work is the non-destructive determination of these low H concentration profiles by neutron imaging, achieving ~5 wt ppm H concentration and a spatial resolution of ~25 um x 5mm x 10 mm. Experiments have been performed on specimens produced from Zircaloy-2 and Zr2.5%Nb rolled plates having different metallurgical conditions. Diffusion coefficients have been measured along the rolling and transverse directions of the plates at temperatures of 250℃, 300℃, and 350℃. Zircaloy-2 results agree well with literature values within typical uncertainties reported in the literature (~30%), and presented little variation with direction and metallurgical condition. On the other hand, Zr2.5%Nb shows larger diffusion coefficients, with considerable variations depending on the metallurgical condition of the plate and the direction of H diffusion.

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