Recent studies on first generation indigenous Zr-2.5Nb pressure tube after 15.3 HOY

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1. Introduction

The first generation of indigenous Zr-2.5Nb pressure tubes were fabricated from double melted ingots using hot extrusions, two stage cold pilgering with intermediate annealing fabrication route. With time, the fabrication route has been changed from double melted to quadruple melted ingot and at present processing route follows forging and extrusion and single stage pilgering.

Many of the reactors are running with first generation Zr-2.5Nb pressure tubes and it becomes mandatory to estimate the toughness of the pressure tubes to understand the behavior of such tubes in the operating reactors. Due to irradiation, there is change in micro-structure, mechanical properties and corrosion behavior of the material. Being the primary pressure boundary material, the structural integrity of the operating pressure tubes is of vital importance. Strength increases and ductility and toughness decreases due to irradiation. Delayed hydride cracking (DHC) velocity, one of the most prominent crack growth mechanisms in operating pressure tubes, increases due to irradiation. The present paper deals with the estimation of fracture toughness and DHC velocity of the first generation indigenous Zr-2.5Nb pressure tube after 15.3 HOY.

2. Experimental

Fracture toughness of Q10 pressure tube from KAPS2, after around 15.3 HOY (Hot Operating Years), was evaluated using around 22.22 mm width DCT (Disc Compact Tension) specimens. 30 mm diameter disc coupons were trepanned from different regions of the pressure tube main body and rolled joint. Specimens were taken from (i) different distances within 300 mm from the hot end having Hydrogen equivalent (Heq) 20-40 wppm (ii) 1000 mm from the hot end (HE) and cold end (CE) of the pressure tube main body (MB) having maximum Heq 15 wppm and (iii) from the region of hot-end and cold-end rolled joint stubs having Heq 30-50 wppm. Fracture toughness tests were carried out at room temperature, 150^{o}C and 250^{o}C. One DCT specimen, from 200 mm from the hot end of the pressure tube, was used for delayed hydride crack (DHC) velocity estimation at 200^{o}C.

For DHC test the specimen was pre-cracked at room temperature, soaked at 2500C for one hour and then brought to test temperature of 200^{o}C and kept at test temperature for 26.5 hours.

3 Results and Discussion

Most of the room temperature fracture toughness tests have shown pop-in type failure of the specimen i.e sudden load drop and tests at 150°C and 250°C showed stable crack growth as shown in figure 1.

Characterisation of fracture toughness was done using Kq and J at maximum load (Jmax). A plot of all the fracture toughness values for generated on Q10 pressure tube main body and rolled joint stubs is shown in figure 2.

DHC velocity at 200°C has been found to be 1.5×10^{-8} m/s (0.054 mm/hr).

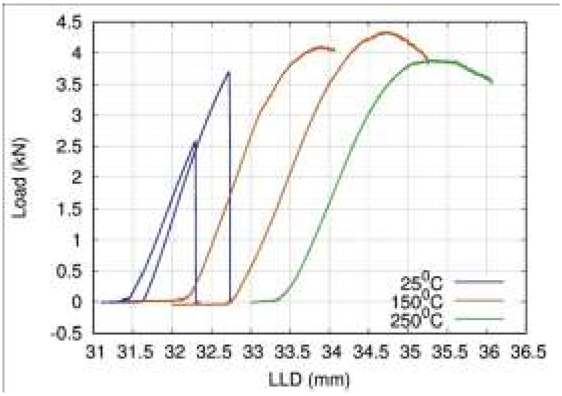

Figure 1. Load vs load line displacement (LLD) obtained for fracture toughness test specimens at different temperatures.

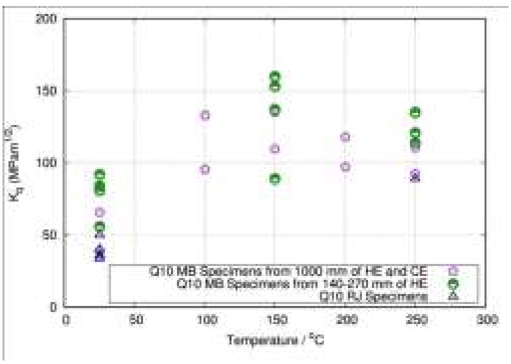

Figure 2: Fracture toughness of Q10 pressure tube main body (MB) and rolled joint (RJ) region after 15.3 HOY.

4. Conclusions

1. Fracture toughness and DHC velocity has been estimated using DCT specimens for one of the first generation indigenous Zr-2.5Nb pressure tube after in reactor operation of 15.3 HOY.
2. Fracture toughness was lower at room temperature but improved with higher test temperatures.
3. Rolled joint region showed lower bound toughness at all test temperatures.