Contribution ID: **253** Type: **POSTER**

Development of Ultra Sub-size Tensile Specimen for Evaluation of Tensile Properties of Irradiated Materials

Tuesday, June 27, 2017 5:30 PM (1h 30m)

The idea of using small specimens for mechanical testing had actually originated in the nuclear industry to cater to the irradiation material testing and reactor surveillance programs. Small or miniaturized specimens ensure efficient use of available irradiation volume in nuclear reactors, reduce uncertainty in irradiation parameters due to flux and temperature variations and also reduce radiological hazard during testing.

A procedure for tensile testing employing a miniature tensile specimen called ultra sub-size (USS) tensile specimen carved out of a 10.0 mm diameter and 0.5mm thick disc sample has been developed and standardised. The geometry of the specimen was optimized using Finite Element Analysis (FEA) with the purpose of maintaining stress concentration in the fillet radius and gripping area equivalent to that in standard ASTM and sub-size tensile specimen. FEA was also employed to evaluate the allowable fabrication tolerances for gage width and thickness of USS by examining its effects on the stress strain curves obtained and comparing with that for standard ASTM and sub-size tensile specimens.

USS specimens along with ASTM standard and sub-size specimens were tested on a range of fast reactor structural materials for comparison of mechanical properties. Due to difficulty of employing extensometer on a small gage length of 3.0mm, digital image correlation (DIC) was employed for strain measurement. The strain obtained through DIC was co-related with that obtained from the cross-head displacement of the UTM. Online strain distribution was extracted from DIC images to study nature of strain distribution over the USS specimen during tensile test and was compared with that obtained from standard specimens. The results obtained from tensile testing of ultra sub-size specimen at ambient and elevated temperatures were found to be consistent and comparable with those obtained from standard specimens for a wide range of alloys examined. The scatter obtained in the UTS, yield strength and uniform strain values evaluated from USS specimen is comparable to that obtained from standard and sub-size samples. The uncertainty in the YS and UTS values from USS specimen were evaluated and compared with that of the ASTM standard and sub-size specimens. The results of this study show that USS tensile specimen geometry can be reliably employed for mechanical property evaluation of irradiated structural materials. Further efforts are required to formulate standards through round robin testing, before the technique can be deployed in the field.

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Session Classification: Poster Session 1

Track Classification: Track 5. Fast Reactor Materials (Fuels and Structures) and Technology