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Development of Transverse Tensile Testing Procedure of Pressure Tube in Hot Cell

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1. Introduction

Material surveillance of pressure tubes is a mandatory program under CSA N285.4 Section 12 [1]. The essential aspects of the pressure tube material surveillance program are the periodic removal of an in-service pressure tube followed by a series of standard tests. The test results are then compared both historical surveillance data and to predictive models to ensure the material is aging within known parameters.

In the present study, a procedure which describes how to prepare and conduct transverse tensile strength tests on Zr-Nb pressure tube material at room temperature and elevated temperatures was developed with an unirradiated tube specimens.

2. Methods and Results

The sample fabrication technique of the unirradiated pressure tube are recently developed to support the Wolsong unit 2 Pressure Tube Surveillance Project. For the tensile test specimen, the W-EDM in Fig. 1 will only be used fabricate the rough outline of specimens. The CNC mill in Fig. 2 will be used to mill the four surfaces of the specimen gauge length and the shoulder-loaded areas of the specimen to remove the heat affected zone from the W-EDM machining as shown in Fig. 3.

Fig. 1. W-EDM equipment to cut the outline of samples.

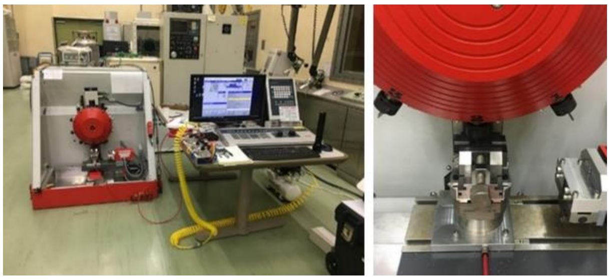

Fig. 2. CNC Mill equipment used to remove the heat affected zone from the W-EDM machining.

Once the specimens have been fabricated, all specimens shall be subjected to measurement of all specified dimensions with a calibration scale. Measured specimen dimensions shall be recorded as required. Then sample identification tracking procedure should be provided for all sampling materials to keep the traceability of samples prior to the testing and after fracture. In the present study, the laser engraved system was developed and applied to label ID on the specimen surfaces instead of a typical marking method in a hot cell with an ink felt marker as shown in Fig. 4.

Testing procedure should be applicable to both unirradiated and irradiated pressure tube material on transverse tensile specimens removed from Zr-Nb pressure tube sections. The applicable test temperature range is 25°C to 350°C.

The following equipment is required:

(a) Uniaxial loading machine in the hot cell interfaced with the computerized data acquisition and control system.

(b) Furnace and temperature controller.

(c) Calibrated imaging system or an imaging system with a gauge block of known dimension.

(d) Displacement measurement device of specimen gauge length change during the testing such as an extensometer.

Fig. 3. Fabricated transverse tensile testing specimens from an unirradiated pressure tube prior to CNC Mill (left) and after removal of a heat affected zone (right).

Fig. 4. Transverse tensile testing specimens with the identification number labelled by an ink felt marker (left) and by the ID laser engraved system (right).

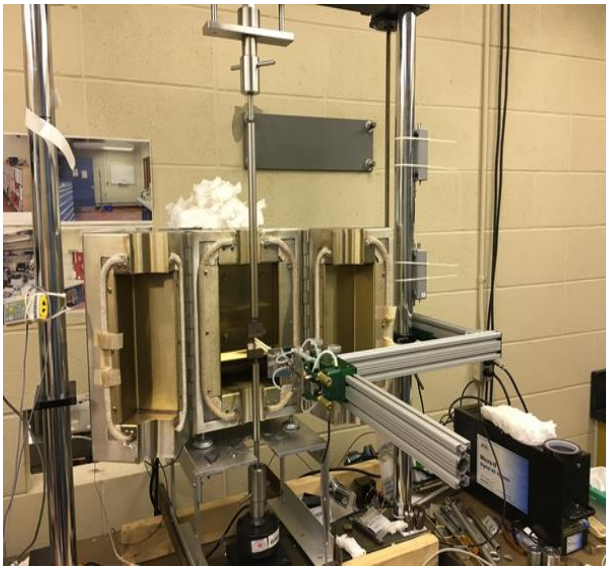

Fig. 5. Uniaxial loading machine with the furnace and the extensometer for the tensile testing.

This test procedure follows the basic requirements of ASTM E8/E8M-16a [2] and ASTM E21-09 [3]. E8/E8M covers the tension testing of metallic materials at room temperature while E21 covers the tensile testing of a metallic material at elevated temperatures. Specifically, these methods define typical testing equipment and procedure for determination of yield strength, tensile strength and elongation as reference.

The transverse tensile specimen is illustrated in Figure 3. The specimen has an 8 mm gauge length and a 3 by 3 mm square cross-section in the gauge section. The specimen is extracted from the transverse direction of a pressure tube section with a nominal wall thickness of 4 mm. All surfaces in the gauge section of the specimen shall be milled as described.

As illustrated in Figure 3, the transverse tensile specimen is shoulder-loaded to perform the tensile test. An extensometer shall be used to measure the displacement of the gauge length. The test fixture shall be enclosed in the furnace for testing at elevated temperatures. Two thermocouples shall be attached to the top and bottom clevises to measure the test temperature during the heat-up and tensile testing.

The tests shall be carried out on a uniaxial loading machine that is interfaced with a computerized data acquisition and control system capable of monitoring and recording instantaneous data of applied load, stroke displacement, extensometer displacement and test temperature. A calibrated load cell, an extensometer and a thermometer with thermocouples shall be used for monitoring the specimen loading, displacement and temperatures.

The tensile tests shall be performed under displacement control at a nominal rate of 0.5 mm/min.

Based on the load vs extensometer displacement record, the engineering stress and engineering strain curve shall be determined for each test.

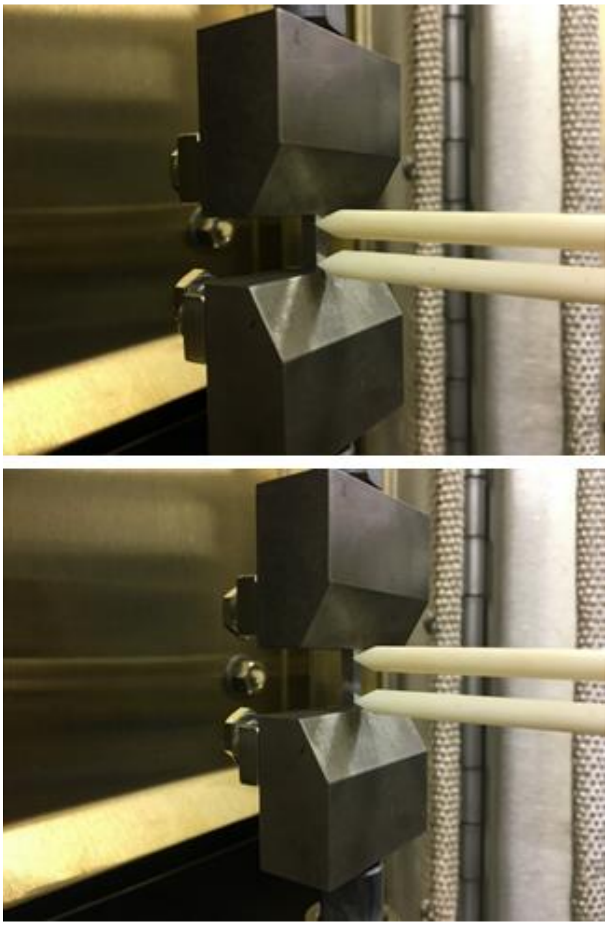

Fig. 6. Testing clevises, specimen and extensometer during the transverse tensile testing. Initiation of the testing (top) and the specimen necking (bottom).

The broken specimens shall be fitted together to measure the gauge mark distance after fracture. This information is needed to calculate the gauge section total percentage elongation.

3. Conclusions

In order to evaluate the transverse tensile strength of an irradiated pressure tube, the testing procedure and testing fixtures were developed using the unirradiated tube. This technique will be modified and developed further for the irradiated specimens in the hot cell.

REFERENCES

[1] Periodic Inspection of CANDU Nuclear Power Plants Components, A National Standard of Canada, CSA N285.4-14, May 2014.

[2] ASTM E8/E8M-16a, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International.

[3] ASTM E21-09, Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials, ASTM International.