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A Study on Mechanical behavior of Tensile Specimen Fabricated by Laser Cutting

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1. Introduction

The mechanical testing data are required for the assessment of dry storage of the spent nuclear fuel. Although the equipment and fabrication technique with the tube specimen was developed to machine the mechanical testing specimen from the irradiated fuel cladding and components using the wire cut EDM (electric discharge machine), it was necessary to find out an alternative method for machining irradiated specimens because of the oxide removal process, which might affect mechanical properties of the fabricated specimen, in the wire cut EDM [1].

Laser cutting system could be useful tools for material processing such as cutting in radioactive environment due to non-contact nature, ease in handling and the laser cutting process is most advantageous, offering the narrow kerf width and heat affected zone by using small beam spot diameter [2]. The feasibility of the laser cutting system was demonstrated for the fabrication of various types of the unirradiated cladding with and without oxide layer on the specimens [3].

In the present study, the dimensional measurement and tensile test were conducted to investigate the mechanical behavior of the axial tensile test specimens depending on the material processing methods in a hot cell at IMEF (Irradiated Materials Examination Facility) of KAERI.

Fig. 1. Laser cutting system and fabrication of the tensile testing specimens from the unirradiated fuel cladding.

2. Methods and Results

The axial tensile testing specimens are fabricated using the wire cut EDM and laser cutting process. The laser cutting system using Nd:YAG with fiber optic beam delivery was modified to fabricate the tube specimens.

2.1 Fabrication of the Tensile Test Specimens

In the present study, the commercial laser beam machining (LBM) system, model ALC-6000 of ATI, was selected and modified to demonstrate the laser cutting system. The laser cutting system used the Nd:YAG laser with the peak power of 500W and three-dimensional cutting method was introduced to fabricate the axial tension testing specimens from the unirradiated fuel cladding without oxide layer on the surface. Fig. 1 shows the demonstration of the laser cutting machine to evaluate the performance of the laser cutting process and the longitudinal tensile specimens were successfully fabricated from the zircaloy tube.

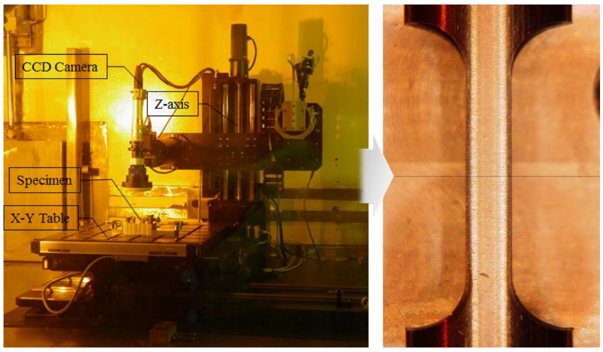

Fig. 2. Dimensional measurement set-up in a hot cell and the image of the specimen during the measurement.

Table I: Gage section width of the specimens depending on the processing type

Type	ID	Position	Gage section width (mm)
Wire EDM	1	1st	2.49
		2nd	2.50
	2	1st	2.49
		2nd	2.50
LBM	1	1st	2.44
		2nd	2.45
	2	1st	2.41
		2nd	2.44

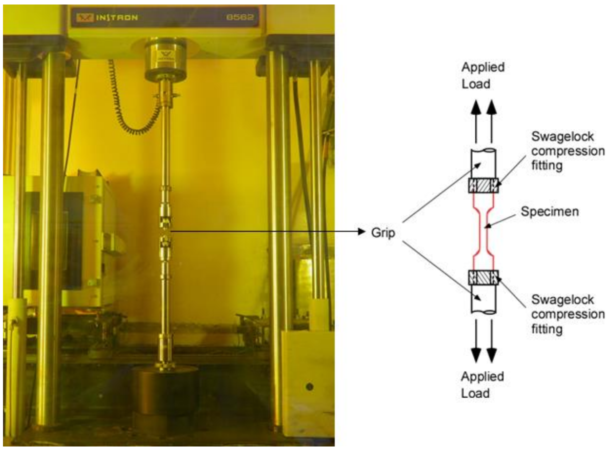

Fig. 3. Experimental set-up and schematic illustration for the tensile testing of the tube specimen in a hot cell.

2.2Dimensional Measurement

Fig. 2 shows the dimensional measurement of a gage section width of the tensile specimen in a hot cell. A tensile specimen inspected by the ccd camera is moved using an x-y table so that the camera can take the images at two different edges of a gage section of the specimen. The displacement of the x-y table is measured using the linear scale, and then the coordinate values of it are converted to distance between two points by a dimensional measurement program.

Table 1 shows the difference of the gage section width depending on the processing type. The values of the gage section width of wire-EDM were in agreement with a design value of 2.5 mm. The values of laser beam machining were lower than those of wire-EDM, but an accuracy of each gage section width was less than 50 um. It would need trial and error to achieve the acceptable cutting quality of the specimen in the laser cutting system.

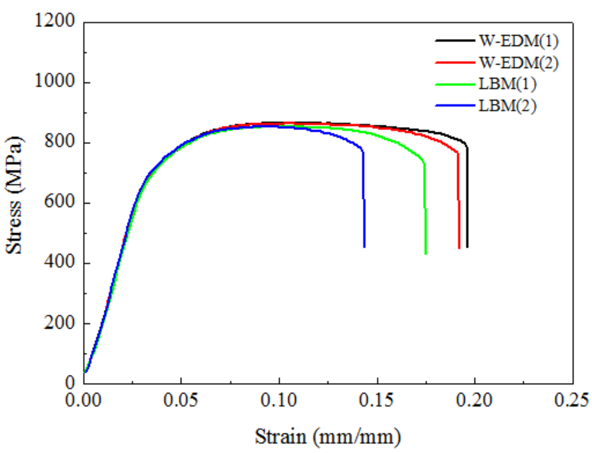

Fig. 4. Stress-strain curves for the tensile tests of the axial tensile specimens depending on the processing type.

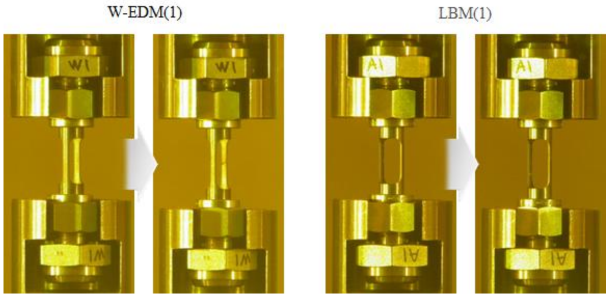

Fig. 5. Deformation behavior of the specimens at the initial and final status of the tensile tests.

2.3Tensile Testing

Fig. 3 shows the experimental set-up, and Fig. 4 and Fig. 5 show the results of the tensile test. Experiments were conducted using the universal testing machine (Instron 8562) at room temperature in a hot cell. Swagelok system was addressed as a grip to pull the specimens during the tensile testing prior to each test being performed. Following specimen placement and alignment on the tensile testing fixture, the testing machine crosshead was manually positioned to provide the preload (100 N) to the specimens. Bluehill software for Instron testing machine was commanded to execute the tensile test as a constant crosshead speed of 0.5 mm/min at room temperature. The elapsed time, displacement and load were collected during the tests and the data acquisition rate was 2Hz to ensure any small transient events were captured.

These curves show that the mechanical strength of the specimens by the laser cutting are similar, but the ductility decreased comparing to the specimens by the wire cut EDM, respectively.

3. Conclusions

Laser cutting system was used to fabricate the tensile test specimens, and the mechanical behavior was investigated using the dimensional measurement and tensile test. It was shown that the laser beam machining could be a useful tool to fabricate the specimens and this technique will be developed for the fabrication of various types of irradiated specimens in a hotcell.

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