Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Feasibility Study of Laser Cutting for Fabrication of Tensile Specimen

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1. Introduction

Mechanical properties of irradiated structural materials are of great importance for operation reliability in extended fuel burn-up and duration of fuel life. The specimen fabrication technique was established to machine the specimen from the irradiated materials. The wire cut EDM(electric discharge machine) was modified to fabricate the mechanical testing specimens from irradiated components and fuel claddings [1]. The oxide layer removal system was also developed because the oxide layer on the surface of the irradiated components and claddings interrupted the applying the electric current during the processing. However, zirconium oxide is protective against further corrosion as well as beneficial to mechanical strength for the tensile deformation of the cladding [2]. Thus, it is important to fabricate the irradiated specimens without removal of oxide layer on the surface of the irradiated structural components and claddings.

In the present study, laser cutting system was introduced to fabricate the various mechanical testing specimens from the unirradiated fuel cladding and the feasibility of the laser cutting system was studied for the fabrication of various types of irradiated specimens in a hot cell at IMEF (Irradiated Materials Examination Facility) of KAERI.

2. Methods and Results

The irradiated fuel assembly after 3-cycles operation in PWR was transferred from nuclear power plant to PIEF (Post Irradiation Examination Facility) of KAERI for the assessment of structural integrity.

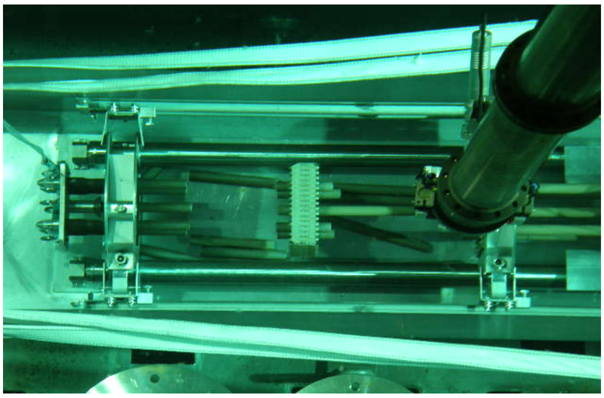

Fig. 1. Cutting machine to cut the guide thimbles and instrumentation tubes simultaneously at the both sides of a grid by using an abrasive wheels.

The fuel assembly was dismantled and cut by the underwater cutting machine at PIEF of KAERI as shown in Fig. 1 and the irradiated claddings were obtained for the fabrication of the mechanical testing specimens in the hot cell.

The irradiated specimens for the mechanical tests were made from fuel cladding, which was embrittled due to a neutron irradiation in a commercial nuclear power plant, by the wire cut EDM. The oxide layer removal system developed was applied to remove the oxide on the surface of the fuel cladding for the applying the electric current during the wire cut EDM processing as shown in Fig. 2.

Irradiated specimens for the tensile tests of the fuel cladding were fabricated by using the wire cut EDM as shown in Fig. 3. Fig. 4 shows specimens with two gauge sections machined in longitudinal and hoop directions from zircaloy-4 cladding.

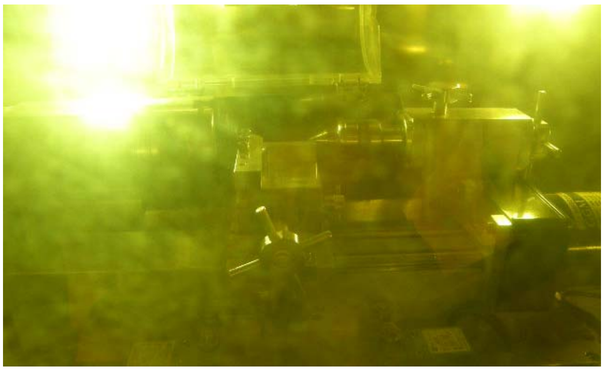

Fig. 2. Oxide layer removal system installed in a glove box.

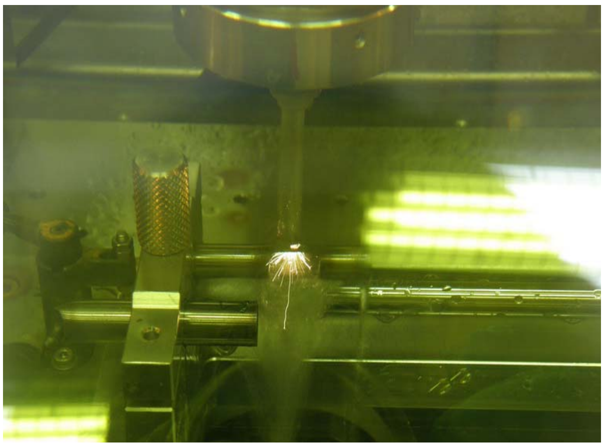

Fig. 3. Wire cut EDM processing for the fabrication of tensile specimens from the irradiated fuel cladding.

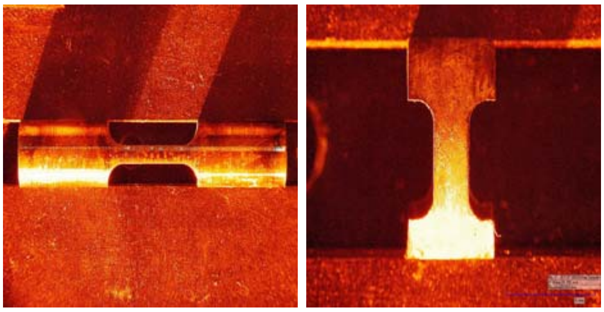

Fig. 4. Fabricated specimens from the irradiated fuel claddings by using the wire cut EDM for the tensile tests in longitudinal and hoop directions in the hot cell.

The wire cut EDM with the oxide layer removal system could be used for the fabrication of various types of irradiate specimens. However, zirconium oxide could be beneficial to mechanical strength for the tensile deformation of the cladding [2]. Thus, it is necessary to fabricate the mechanical testing specimens without removal of oxide layer on the surface of the irradiated components and cladding. 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 [3].

In the present study, laser cutting system using the Nd:YAG laser with the peak power of 500W was introduced to fabricate the various mechanical testing specimens from the unirradiated fuel cladding. The feasibility of the laser cutting system was studied for the fabrication of various types of irradiated specimens in the hot cell at IMEF of KAERI.

Fig. 5. Laser beam machining for the fabrication of tensile specimens from the unirradiated fuel cladding.

Fig. 6. Fabricated specimens from the unirradiated fuel claddings by using the laser beam machine for the tensile tests in longitudinal and hoop directions.

Figure 5 shows the laser beam machine to fabricate the specimens for the ring tensile test from the unirradiated cladding of zircaloy-4, which was hydrided and had a very thin oxide layer on the surface.

The Photograph of the tensile specimens in longitudinal and hoop directions is shown in Fig. 6. Hydrided cladding, which is dark one in Fig. 6, was prepared for the comparison with the wire cut EDM. It was impossible to machine the hydride cladding by using the wire cut EDM because of the oxide layer on the surface of the cladding while laser beam machining was successful as shown in Fig. 6.

Dimensions of specimens fabricated by the laser cutting system were compared with the design values for the as-received cladding, which is shiny one in Fig. 6. The values in gauge section were in agreement with an accuracy of 1% and 2% for the longitudinal and hoop direction specimens, respectively.

3. Conclusions

Laser beam machining system was introduced to fabricate the various mechanical testing specimens from the unirradiated fuel cladding and the dimensions were compared for the feasibility of the laser cutting system. The effect of surface oxide layer was also investigated for machining process of the zircaloy-4 fuel cladding and it was found that laser beam machining could be a useful tool to fabricate the specimens with surface oxide layer. This technique will be modified and developed for the fabrication of various types of irradiated specimens in the hot cell.

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