Effects of Surface Condition of Small Tensile Specimen for Evaluation of Irradiated Material on Tensile Properties of 316 Stainless Steel

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1. Introduction

In order to evaluate the integrity of nuclear reactor components, a mechanical test using standard test specimen is required. However, it is not always possible to use standard test specimens. So small specimens are often used when it is difficult to obtain standard test specimens, such as irradiation materials in the nuclear reactor components. In particular, handling of standard test specimens of irradiated materials is quite difficult. Even in the neutron irradiation test using a research reactor, small specimens are often used due to the limited space for irradiation test. In addition, in the case of manufacturing test specimens directly from irradiated components such as reactor vessels or internals, they are used to minimize radiation exposure.

There are many restrictions on the production of mechanical test specimens using irradiated materials in a hot cell. In general, rod-type specimens are used for tensile property evaluation. At this time, grinding is performed after machining the specimen in order to remove the surface stress caused by machining of the gauge part as much as possible. However, in order to manufacture a tensile specimen from an irradiated material, it is considering making a small plate-type specimen using wire-EDM(electric discharge machining) equipment. However, there is considerable difficulty in grinding process to remove the stress of the gauge part after machining.

In this study, the effect of the surface condition of small tensile specimens used to evaluate the tensile properties of irradiated materials on the tensile properties of 316 stainless steel was evaluated.

2. Experimental Procedure

316 stainless steel plate is used in this study and the chemical compositions provided by manufacturer are shown in Table 1. 35% cold-rolled material was used to simulate the irradiation embrittlement effect by neutrons along with as-received material. A small plate-type specimen as shown in Fig. 1 was used to evaluate the tensile properties. In order to examine the changes in the surface characteristics according to the processing method, the difference in surface condition and hardness of the finely polished specimen and the specimen processed by grinding or milling were compared. Tensile tests were carried out at room temperature using a universal testing machine (model MTS insight 50, MTS, USA) with a 5-ton capacity under a strain rate of 5.2×10^{-4}, according to ASTM E8M. The 0.2% offset stress method was used to determine the yield strength from the engineering stress-strain curves.

Table 1: Chemical compositions of 316 stainless steel

C	Si	Mn	Ni	Cr	Mo	Cu	Al	Fe
0.21	0.25	1.22	0.25	0.16	0.07	0.05	0.02	Bal.

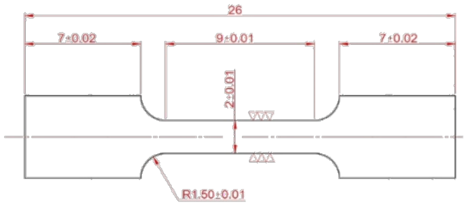

Fig. 1. Geometry and dimension of miniature tensile specimen for irradiated materials

3. Results

3.1. Microstructure

Figure 2 shows microstructure of as-received material and 35% cold work material. It was observed that the grains are elongated in the rolling direction by 35% cold working.

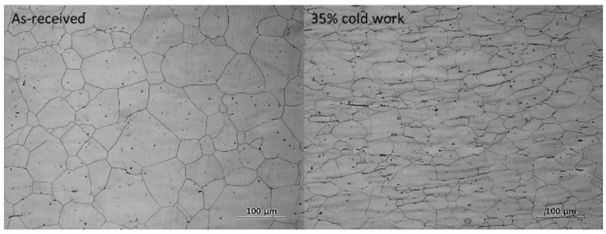

Fig. 2. Microstructure of as-received and 35% cold work materials

3.2. Surface observation

The photographs in Fig. 3 show the surface conditions of the milled, ground and polished specimens. And the sides of all specimens were processed with W-EDM. Table 2 shows the hardness measurement results according to each processing method. In the case of the as-received material, the fine polishing showed the lowest hardness, and the milling surface showed the highest hardness. As-received material is considered to increase the hardness of the surface even with a slight surface processing because the strength of the material itself is low. This increase in surface hardness is expected to affect the tensile properties evaluation using very small specimens. However, in the case of 35% cold working, the hardness of the material itself increased a lot due to the cold working, and the hardness of the finely polished specimen also increased more than twice as-received. However, the increase in hardness according to the surface processing was not noticeably as large as the as-received material. Therefore, it is expected that the effect on the tensile properties will not be significant.

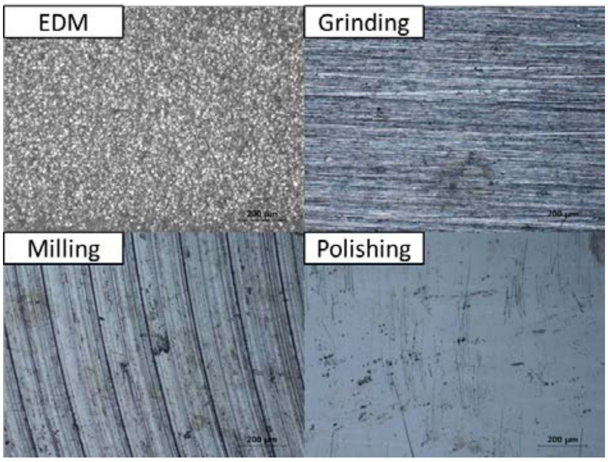

Fig. 3. Surface conditions of miniature tensile specimens with different surface processing method

Table 2: Hardness variation depending on surface processing method(Hv)

	As-received	35% cold work
W-EDM(side)	202	337
Milling(front)	229	326
Grinding(front)	187	329
Polishing(front)	142	317

3.3. Tensile properties

Figure 4 shows the stress-strain curves of as-received material and 35% cold work material according to three surface processing methods. It can be seen that the yield and tensile strength of the material greatly increased and the elongation decreased through cold working. There was no significant difference in yield strength in the specimens that were ground and finely polished, but when milled, the yield strength and tensile strength increased and the elongation decreased in both as-received and 35% cold work materials.. As a result of the experiment, it was found that the change in tensile properties by the surface processing method was not significant. However, it is expected that the change in tensile properties by the surface processing method will have a greater effect as the thickness of the specimen becomes thinner. In addition, in the case of the as-received material, which has a much lower strength compared to the 35% cold work material, it is considered that the effect will be more pronounced as the thickness of the specimen becomes thinner. In this regard, the evaluation of the effect of the surface finish according to the change in the thickness of the specimen is in progress.

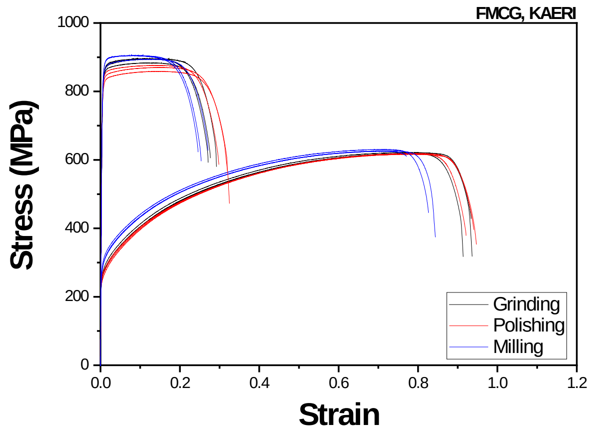

Fig. 4. Stress-strain curves of as-received material and 35% cold work material with different surface finishing method

4. Conclusion

The effect of the surface condition of the small plate-type specimen used in the tensile property evaluation of the irradiation material was investigated. In the case of as-received material with low strength, the change in hardness according to the surface processing method was larger than that of 35% cold-worked material. In the tensile properties, the strength increased and the elongation decreased in the milled specimen. As the thickness of the specimen becomes thinner, it is expected that the influence of the surface condition will be greater.

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