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# Effect of Fabrication Variables on Impact Energy in MA 316L and WET 316L ODS Stainless Steels

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## 1. Introduction

Oxide dispersion strengthened (ODS) steels have excellent high temperature mechanical properties due to the presence of thermally stable nano-scale oxides distributed in their matrix [1]. Therefore, ODS steels are being used for high temperature structural applications and ODS ferritic martensitic steels (FMS) have been considered as candidate cladding and structural materials for the Generation-IV fast reactors [2]. Generally, fabrication processes of ODS steels have incorporated a mechanical alloying (MA) process, in which repeated fracture and bonding of mixed powders occur by a high energy impact of steel balls [3]. On the other hand, it s possible to produce an ODS without MA process. AISI 316L-based austenitic ODS steels were fabricated by a wet mixing of metallic salts [4]. This method dispersed oxide particles by thermal decomposition of metallic salt during fabrication process. Austenitic ODS steel could be fabricated successfully by a wet-mixing process of 316L stainless steel powder in yttrium containing salt solution.

There are several fabrication variables to produce ODS alloys during their fabrication processes. The soundness of ODS is qualified by impact test easily. The effects of fabrication variable on impact energy in 316 ODS was examined systematically in this study.

## 2. Experimental procedures

Two kinds of 316L ODS alloy were produced by MA and WET method. Wet 316 ODS alloy is fabricated from a commercially available 316L powder and the other is a MA 316L ODS by using elemental powders without silicon. Both alloys are sintered by spark plasma sintered (SPS) machine at 950°C. One group of samples is hot rolled at 950 and 1150 °C, and the others are manufactured by a degassing and HIP. These are summarized in Table 1.

Microstructures of the specimens were observed by using a transmission electron microscopy (TEM) and optical microscope.

The impact energy was examined by a KLST specimen. The dimension of KLST specimen is shown in Fig. 1. The energy of hammer is 33.9J, and the distance of anvil is 20 mm. The tensile tests were carried out in RT. The fracture surface is compared macroscopically.

Table 1. Sintering and hot roll conditions for MA 316L ODS and WET 316L ODS.

| Alloys | Sintering Process | Hot Roll | Heat Treatment | Condition |
|---|---|---|---|---|
| MA 316 ODS | SPS | 950°C | X | A |
| | | 1150 °C | X | B |
| | | 950°C | 1150 °C-2H | C |
| | | 1150 °C | 1150 °C-2H | D |
| | SPS + HIP | 1250 °C | X | E |
| WET 316 ODS | SPS | 950°C | X | F |
| | | 1150 °C | 1150 °C-2H | G |
| | SPS + HIP | 1250 °C | X | H |

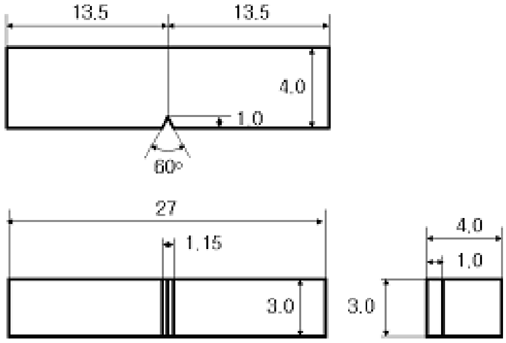

Fig. 1. Dimension of KLST impact specimen.

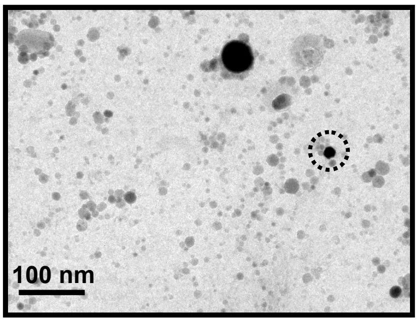

Fig. 2. TEM image of an austenitic ODS steel without silicon.

## 3. Results and discussion

The Impact energy for MA 316 ODS alloys are compared according to fabrication conditions, in Fig. 3. The energy in A ~ D alloys made by SPS and hot roll process is relatively low, compared to the E alloy made by SPS and HIP and hot roll process. A great enhancement was observed by HIP process in E alloy. The process condition E improved the energy by 3 times.

The major difference in process condition between A ~ D alloy and E alloy is HIP process. This suggests that the soundness of ODS alloy is significantly enhanced by HIP and its related processes. It seems that the incompletely sintered boundary and the void in grain boundary is effectively removed by HIP process.

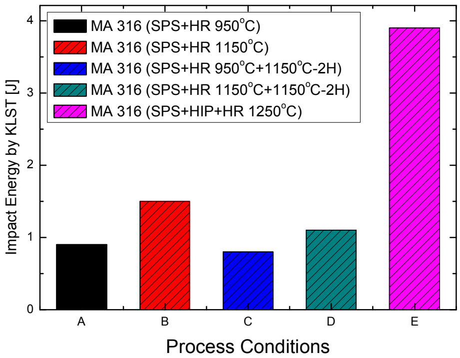

Fig. 3. Comparison of impact energy of MA 316 ODS alloys.

The energy of MA 316 and WET 316 ODS are compared in Fig. 4. As explained in Table 1, the energy of the F alloy hot rolled at 950°C is increased by a heat treatment of 1150 °C -2H (G alloy). This seems to be due to the enhancement of bonding between oxide and matrix by annealing treatment. The HIP process increases the energy by 0.5 J. This difference in effectiveness between MA 316 and WET 316 ODS of HIP can be attributed to the effectiveness of boundary compatibility enhancement.

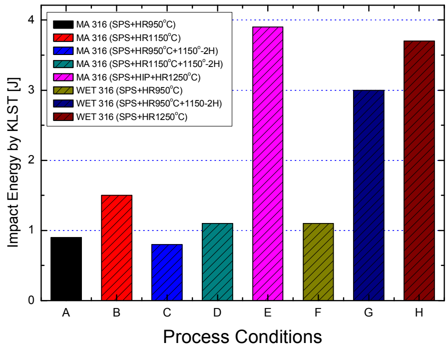

Fig. 4. Comparison of impact energy of MA 316 ODS and WET 316 ODS alloys.

The maximum energy of MA 316 and WET 316 ODS is similar in E and G alloy. This seems to be improved by a final heat treatment.

The tensile behavior at RT in MA 316 and WET 316 ODS alloy is compared in Fig. 5. The higher strength and the smaller elongation appeared in MA 316 ODS. The lower strength and the longer elongation is shown in WET 316 ODS. This seems to be due to difference in grain microstructure. The grain size is small and the distribution of oxide is relatively uniform in MA 316 ODS, compared to WET 316 ODS. It is well known that the area under the strain stress curve is representative of energy of materials. The impact energy of E and H is similar.

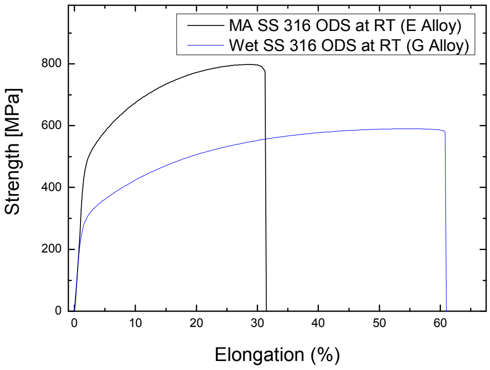

Fig. 5. Strain-Stress curves at RT in MA 316 ODS and Wet 316 ODS alloys.

## 4. Conclusions

The maximum energy of MA 316 and WET 316 ODS is similar, based on the examined process variables. However, the level of strength and elongation is significantly different. The effectiveness of application of HIP process is pronounced in MA 316 ODS alloy, compared to the WET 316 ODS. This is attributed the enhancement of compatibility and bond strength between oxide and matrix in MA 316 ODS.

## ACKNOWLEDGMENTS

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