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Effects of twin intersection on the tensile behavior in high nitrogen austenitic stainless steel

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ABSTRACT

The effects of microstructure evolution with different amount of cold compression on the mechanical behavior were investigated in high nitrogen austenitic stainless steel. Maximum tensile strength and 0.2% yield strength were increased with the increase of cold compression percent. Twin intersection in two different crystallographic orientations was observed when the specimen was cold-compressed more than 30%. Twin intersection resulted in the increase of strain hardening exponent and the reduction of strain at maximum tensile strength.

1. Introduction

The effects of nitrogen addition for steels lead to solid-solution hardening, grain size refinement, strong austenite stabilization, high corrosion resistance, and low tendency to form stress-induced martensite [1–3]. High nitrogen austenitic stainless steel has various engineering applications for non magnetic drill collar, retaining ring, and medical materials [4,5].

Many researchers have published that high nitrogen austenitic stainless steel has low stacking fault energy so that it has high tendency to form twins during cold deformation [6–10]. The generation and rearrangement of dislocation and twinning during cold deformation strengthen high nitrogen austenitic stainless steel [11]. Both dislocation slip and twinning are competitive deformation mechanisms in the steel. Twinning during cold deformation produces the orientation change of a plane which can provide a slip plane in a favorable orientation with respect to shear stress direction so that twinning can provide additional slip [12,13].

Many studies on microstructures and mechanical behavior have been published for high nitrogen austenitic stainless steels [6,8,11,14–16]. In spite of their works, there are still unclear in explaining the relation between mechanical behavior and microstructures when high nitrogen austenitic stainless steel is cold-compressed [17–19].

In this paper, the effect of cold compression percent on tensile behavior has been investigated in high nitrogen austenitic stainless steel. The tensile behavior and microstructures have been researched in the specimen cold-compressed from 0 to 50%. Twin intersection between primary twin and secondary twin was observed in the specimen cold-compressed over 30%. It reduced tensile strain at maximum tensile strength and enhanced strain hardening exponent.

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Table 1 – Chemical compositions of high nitrogen austenitic stainless steel.

Compositions	C	Si	Mn	Cr	V	N
wt.%	<0.08	0.2–0.6	18.0–18.7	18.0–20.0	<0.2	0.51

2. Experimental Procedure

Chemical composition of high nitrogen austenitic stainless steel in this study was listed in Table 1. The ingot of high nitrogen austenitic stainless steel was produced using pressurized vacuum induction melting (PVIM) method. The ingot was forged to a square bar of 60 × 120 ×800 mm in the temperature range from 950 to 1200 °C. The billet was solution heat treated at 1060 °C for 3 h followed by water quenching. It was machined to round bar shape of Dia. 50 × H. 45 mm, Dia. 50 × H. 50 mm, Dia. 50 × H. 57 mm, Dia. 50 × H. 66 mm, and Dia. 50 x× H. 80 mm for cold compression of 10, 20, 30, 40, and 50%, respectively. The specimens cold-compressed under a strain rate of 0.05 s^{-1} at room temperature were sectioned at the center line along the compression direction. The half part of the specimens was subjected to observe microstructure and the other part was machined to test tensile properties. Three tensile specimens machined from each cold-compressed specimen were tested at a strain rate of 2×10^{-3} s^{-1}. Microstructures of the cold-compressed specimens were observed using optical microscope (OM, ZEISS Axioplan) and transmission electron microscope (TEM, JEOL JEM-2100 F). Fracture surface was observed using scanning electron microscope (SEM, HITACHI S-3400 N).

3. Experimental Results

3.1. Microstructure

The specimens that were solid solution heat-treated at 1060 °C and then water-quenched consisted of full austenite structure as shown in Fig. 1(a). Annealing twins were observed in some grains and any precipitates were not observed at the grain boundaries and inside grains. The average grain size was about 170 μm. As shown in Fig. 1(b), 10% cold-compressed specimen

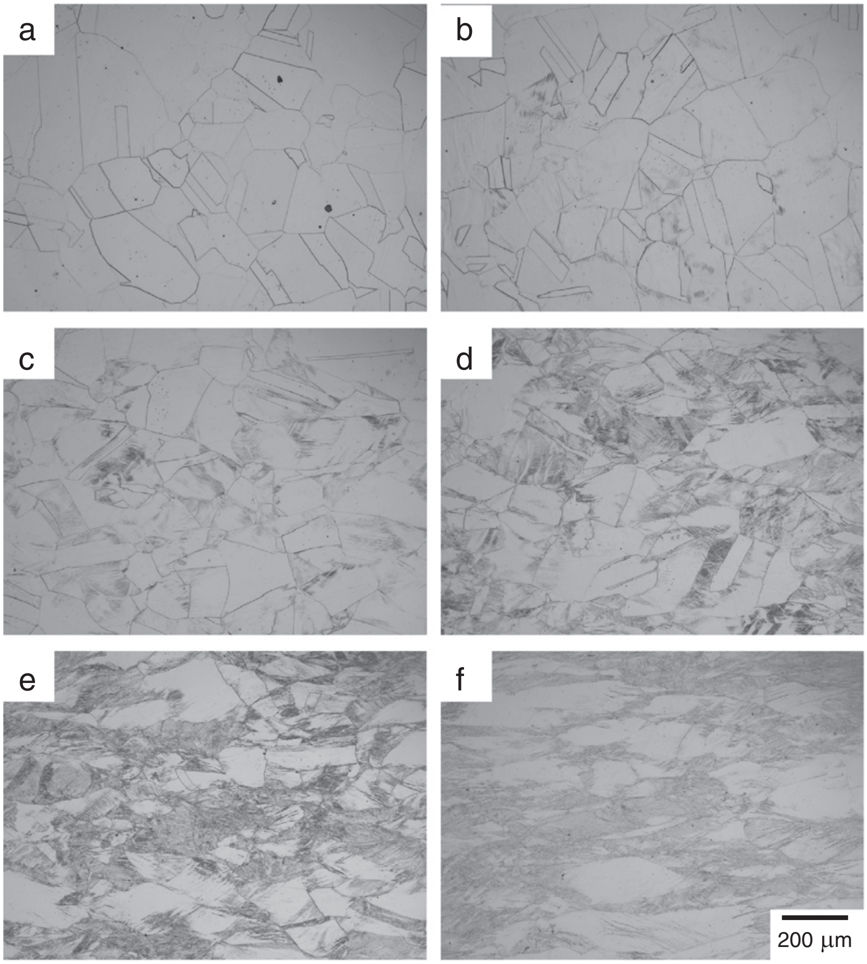

Fig. 1 – Optical microstructures of the cold-compressed specimens. (a) 0% cold compression, (b) 10% cold compression, (c) 20% cold compression, (d) 30% cold compression, (e) 40% cold compression, and (f) 50% cold compression.