



Effects of mechanical force on grain structures of friction stir welded oxide dispersion strengthened ferritic steel



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ABSTRACT

The weldability of oxide dispersion strengthened (ODS) ferritic steels is a critical obstructive in the development and use of these steels. Friction stir welding has been considered to be a promising way to solve this problem. The main purpose of this work was to reveal the effects of mechanical force on grain structures of friction stir welded ODS ferritic steel. The grain appearances and the misorientation angles of grain boundaries in different welded zones were investigated by the electron backscatter diffraction (EBSD). Results showed that the mechanical force imposed by the stir tool can activate and promote the recrystallization characterized by the transformation of boundaries from LABs to HABs, and contribute to the grain refinement. The type of recrystallization in the stir zone can be classified as the continuous dynamic recrystallization (CDRX).

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1. Introduction

Oxide dispersion strengthened (ODS) ferritic steels are widely considered to be the promising candidate materials for structural materials of fusion reactors and cladding materials of advanced fast reactors [1–4]. However, the welding of ODS steels becomes a critical obstructive in the development and use of these steels. It has been found that conventional melting welding methods can disturb the fine dispersion of oxide particles in the alloy. As the excellent creep resistance and the neutron radiation resistance of ODS alloys are mainly due to the ultrafine oxide particles, conventional melting welding methods are not applicable and should be substituted by suitable welding methods [5–7]. The welding of ODS steels is an emerging issues. Till now, only little work has been focused on this field, and the potential welding methods have been limited to the special welding methods (e.g., diffusion bonding, rotary friction welding and friction stir welding) [5–9].

Friction stir welding (FSW), which is a solid state joining method and has no material melting phenomenon during the welding process, has been considered to be a promising way to weld ODS alloys, while preserving the advantageous microstructure [8,9].

Unlike other conventional welding methods, FSW is a complicated thermal–mechanical process. Frictional heat is generated between the stir tool and the material of the workpieces. This heat causes the workpieces to soften without reaching the melting point and allows the tool to traverse along the weld line. The resultant plasticized material is transferred around the stir tool and is forged together by the intimate contact of the stir tool. Obviously, the mechanical force of the stir tool, which could affect the microstructure and determine the properties of the joint, plays an indispensable and non-substitutable role during the whole FSW process.

So far, there has been only few works on FSW of ODS steels [5–10]. Particularly, no related research has been focused on the mechanical force of the stir tool in FS welded ODS steels. The present study aims to characterize the effects of the mechanical force on grain structures of friction stir welded ODS ferritic steel.

2. Experimental procedure

The material used in this investigation was a 15Cr-ODS ferritic steel with the composition tabulated in Table 1. This material was produced by mechanical alloying, where the Fe–15Cr powder was mixed with the Y₂O₃ powder by a high-energy attritor under an argon atmosphere. The resultant powder was subsequently consolidated by hot extrusion and forging at 1150 °C, then annealed at 1150 °C for 1 h. The plates were cut into specimens

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Table 1
Chemical compositions of the 15Cr-ODS ferritic steel (mass%).

Material	C	Cr	W	Ti	Y ₂ O ₃	Fe
15 Cr-ODS	0.02	14.9	1.9	0.2	0.34	Bal

with dimensions of $35 \times 10 \times 1.5$ mm, and then subjected to FSW in a butting configuration.

An ultra-temperature resistant tungsten-based stir tool was used in the welding process. The stir tool had shoulder diameter of 12 mm, pin diameter of 4 mm and 1.3 mm pin length. The rotation and traverse speeds used were 300 rpm and 50 mm/min,

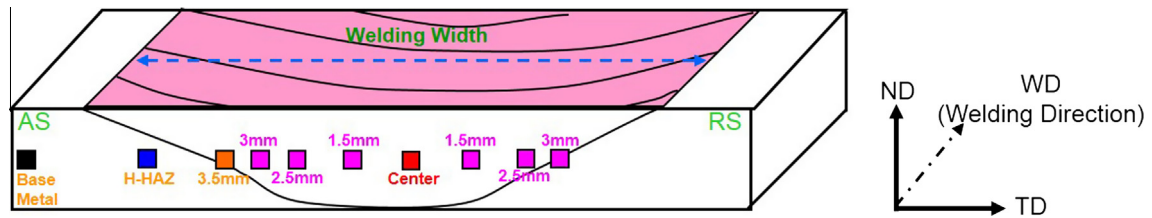


Fig. 1. Schematic diagram of the EBSD test positions.

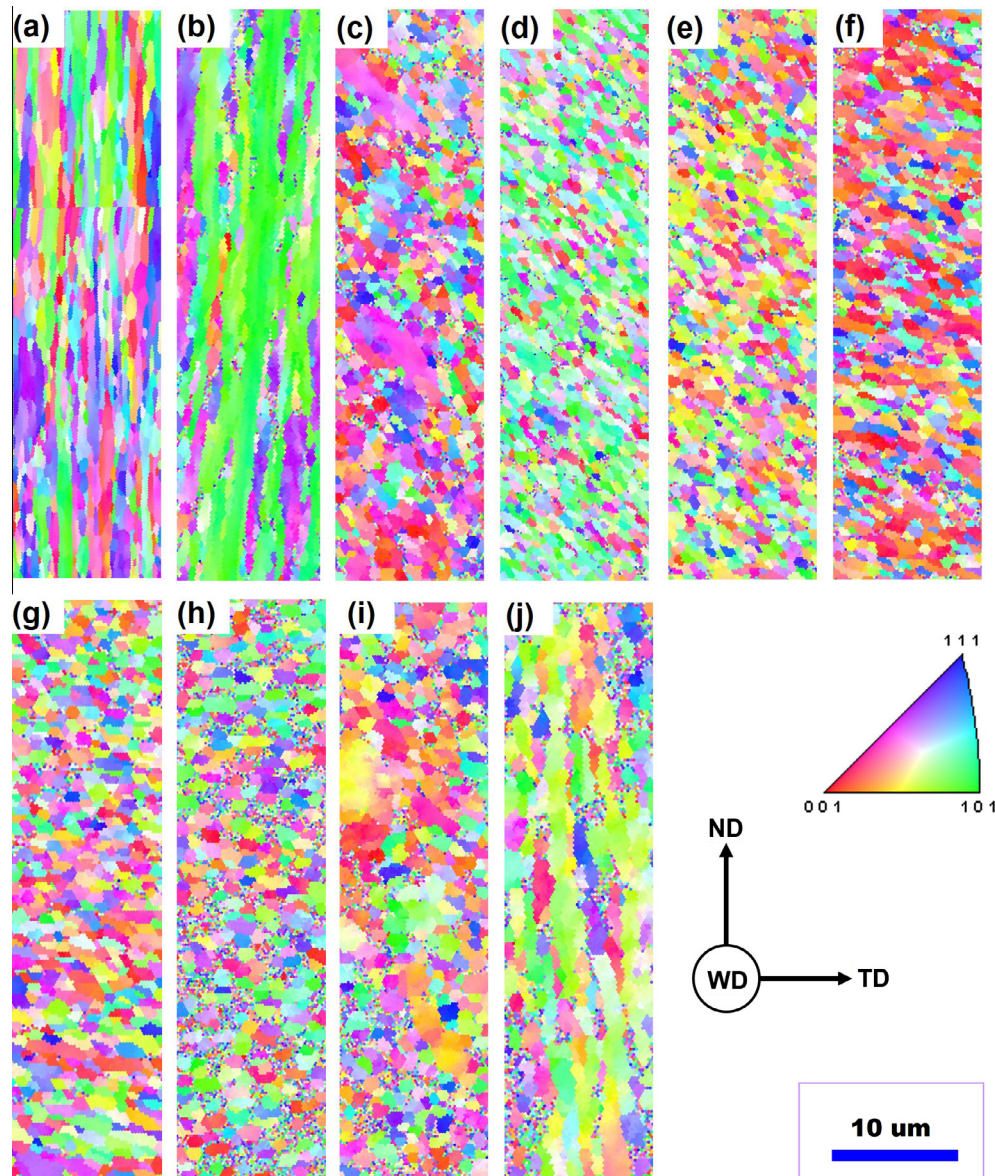


Fig. 2. Grain morphologies in different regions of the joint: (a) BM; (b) H-HAZ; (c) AS-3.5 mm; (d) AS-3 mm; (e) AS-2.5 mm; (f) AS-1.5 mm; (g) SZ center; (h) RS-1.5 mm; (i) RS-2.5 mm and (j) RS-3 mm.

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