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Evolution mechanism of grain refinement based on dynamic recrystallization in multiaxially forged austenite

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Abstract

Austenite grain refinement based on continuous dynamic recrystallization can be realized through multiaxial forging Fe–32%Ni alloy at 550 °C and 2×10^{-2} s^{-1}, which is generally considered not to take place. It not only greatly reinforces the recrystallization theory but also is of great directory significance to the development of new generation iron and steel materials. As a result, the evolution of the continuous dynamic recrystallization during multiaxial forging can be summarized as such a process that deformed bands crossing each other subdivide an austenite grain into several subgrains and these subgrains are gradually angled to new independent grains with their boundaries being transformed into big angle boundaries in subsequent deformation.

Keywords: Large strain and low temperature deformation; Multiaxial forged austenite; Continuous dynamic recrystallization; Grain refinement

1. Introduction

It is considered before that whole dynamic restoration process is controlled solely by dynamic recovery (DRV) and not by dynamic recrystallization (DRX) when metallic materials are deformed below 0.5 Tm (Tm is the melting point of the material). However, it was recently reported that continuous DRX could take place and the ultra grain refinement to submicro-size or nano-size level was achieved [1–15] within a lower temperature range of austenite state under a severe plastic deformation such as Equal Channal Angular Pressing, Accumulative Roll Bonding, etc. The DRX and ultra grain refinement produced at a large strain and a low temperature reinforces the recrystallization theory. Therefore, the study on DRX mechanism under such a large strain and low temperature deformation is of great value in theory. Additionally, a great improvement of mechanical properties [16] based on the ultra grain refinement is of great directory significance to the development of new generation iron and steel materials.

As a new approach to produce submicro- or nano-austenite structures, the large strain and low temperature deformation contains various processes such as Equal Channel Angular Pressing (ECAP) [7–9], Accumulative Roll Bonding (ARB) [3–8], Multiaxial Forging (MF) and Torsion under High Pressure (THP), etc. So far most of investigations have focused on behaviors of austenite deformed in ECAP or ARB, while microstructural evolutions of austenite deformed in other processes have received relatively less attention. The main thrust of this paper is principally concerned with elucidating the microstructural evolution and the DRX mechanism of multiaxially forged austenite.

2. Experimental material and procedure

Fe–32%Ni alloy was used for the experiment with its chemical composition shown in Table 1. The material fits for the

Table 1
Chemical composition of the material used for experiment in weight percent

C	Si	Mn	P	S	Ni	Al	N	O
0.007	0.01	0.04	0.005	0.0006	32.4	0.022	0.00074	0.020

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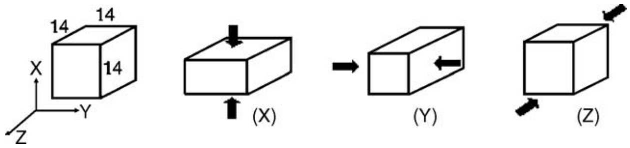

Fig. 1. Schematic diagram of multiaxial forging.

observation and investigation of deformed austenite microstructure, for its martensite starting temperature is below the room temperature so that it is fully in austenite state at ambient temperature.

The material was machined into four squares 14 mm long by 14 mm wide and 14 mm thick. These samples were annealed at 1200 °C for 60 min, giving an initially austenite

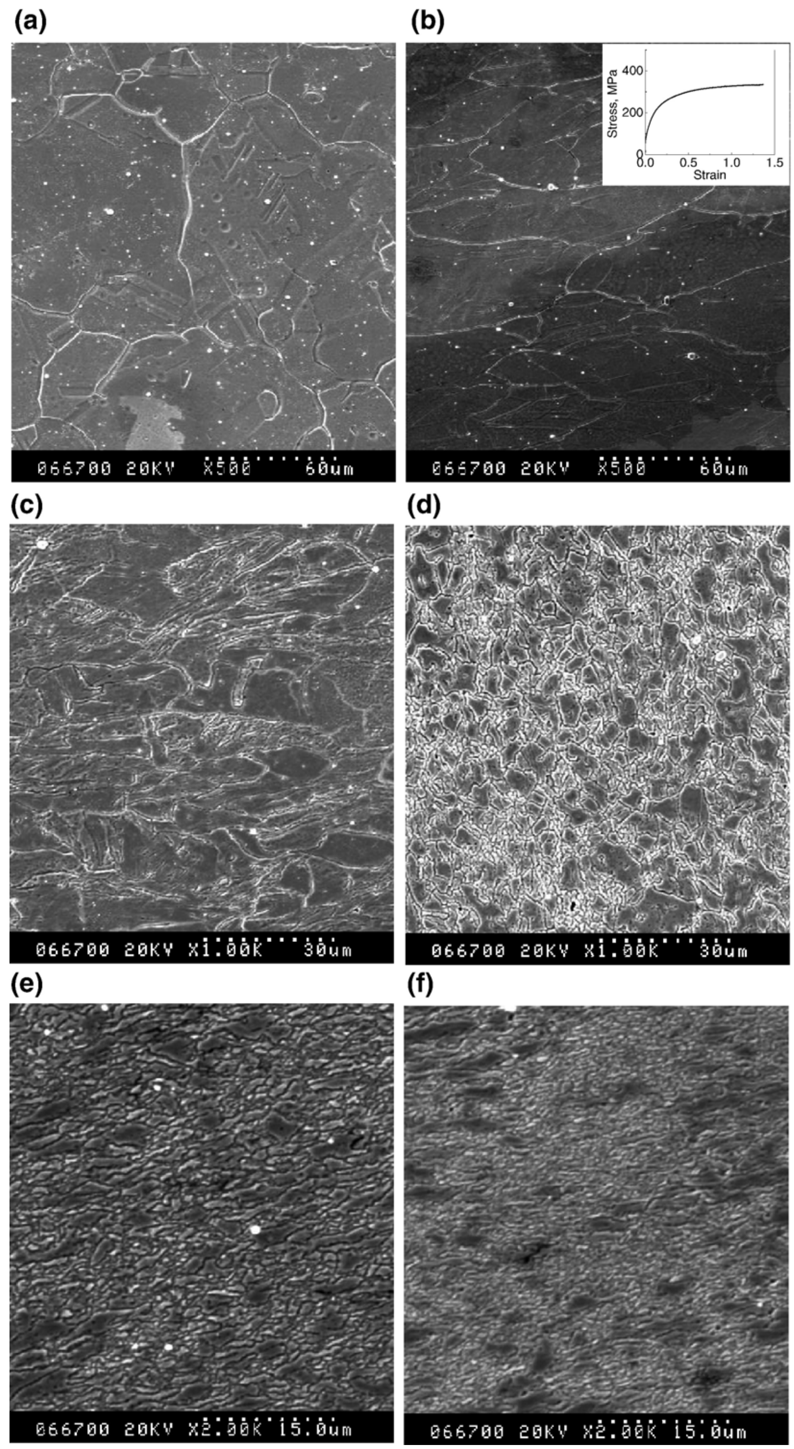

Fig. 2. SEM micrographs of multiaxially forged austenite. (a) Pass0, $\sum\varepsilon=0$ (b) Pass1, $\sum\varepsilon=0.6$, ×500; (c) Pass2, $\sum\varepsilon=1.3$ (d) Pass3, $\sum\varepsilon=1.6$, ×1000; (e) Pass12, $\sum\varepsilon=6.4$ (f) Pass15, $\sum\varepsilon=7.9$, ×2000.