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Recovery and Recrystallization of Ferrite in Warm Forging of a Medium Carbon Steel

P. Zhao and J.D. Boyd

Dept. of Mech. Eng., Queen's University, Kingston, ON K7L 3N6, Canada

Warm forging produces high dimensional accuracy and enhanced mechanical properties [1-3]. When forging is carried out at temperatures below Ar_1, the transformed ferrite + pearlite is deformed, and the ferrite can be refined by recovery and recrystallization. The current research investigates microstructural evolution in a Nb-microalloyed medium-C steel, during warm forging. 35-mm diam. bars were forged to 12-mm thick plates, following the schedule given in Fig. 1. Samples were quenched immediately following the first 2 deformations ('1' and '2'), and the final plate was air cooled ('3').

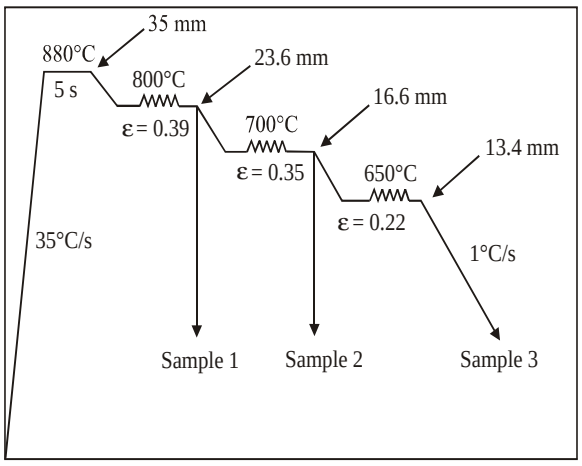
Sample 1 exhibits the elongated austenite grain structure produced by the first deformation (800°C). Sample 2 shows some transformed ferrite and pearlite. Grain boundary ferrite and a small amount of intragranular ferrite comprise 21% of the microstructure. The deformed ferrite recovers quickly and forms subgrains having a mean linear intercept of 0.46 ± 0.14 μm (Fig. 2). Some recrystallized ferrite grains are also observed in sample 2 (Fig. 3). The dimensions of these recrystallized grains are comparable to the subgrains in the recovered ferrite.

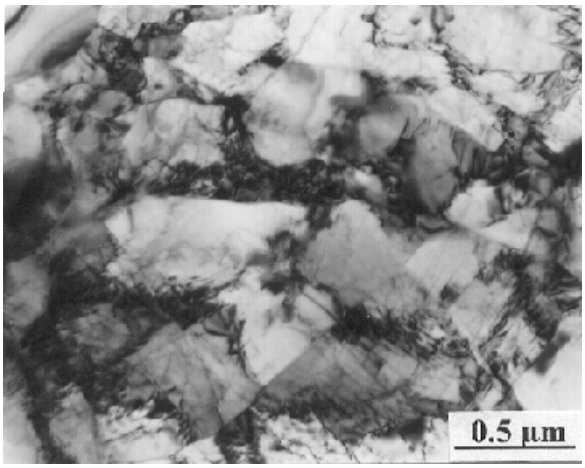
In sample 3, deformation at 650°C (below Ar_1) followed by air cooling produces elongated grain boundary ferrite and pearlite (Fig. 4). The mean dimensions of the elongated ferrite grains are length = 3.62 ± 2.01 μm and width = 1.33 ± 0.75 μm. Fig. 5 shows a typical area of recovered elongated grain boundary ferrite grains. The substructure comprises 0.73 ± 0.09 μm subgrains. It was confirmed by electron diffraction that the individual subgrains have small (< 10°) misorientations with respect to each other. Some areas of recrystallized ferrite are also observed in Sample 3 (Fig. 6). The mean linear intercept diameter of the recrystallized ferrite grains is 0.66 ± 0.27 μm, again comparable to the subgrain size.

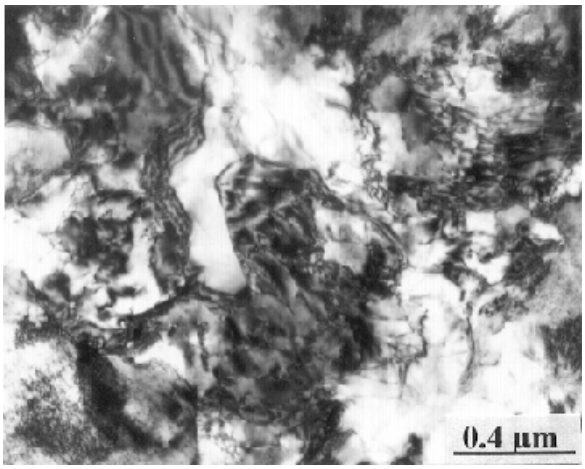
It is concluded that warm forging can produce significant microstructural refinement through the mechanisms of ferrite recovery and recrystallization. Sub-micron ferrite subgrains and recrystallized ferrite grains can be obtained.

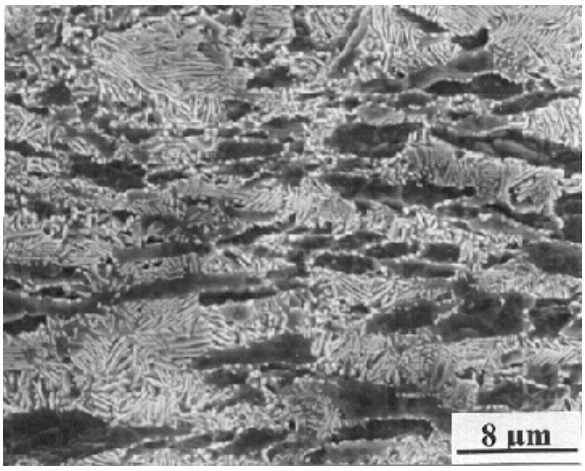
References

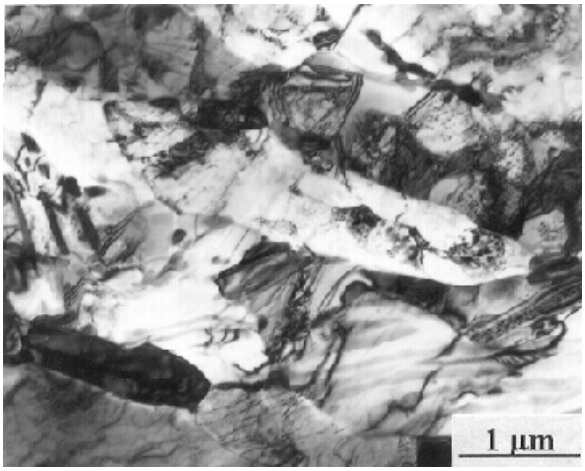
[1] S. Sheljaskov, *J. Mater. Processing Technol.* 46 (1994) 3.
[2] J. H. Reynolds et al, *Mater. Sci. Technol.* 4 (1988) 586.
[3] C. García-Mateo et al, *Iron & Steelmaker*. 27 (2000) 79.











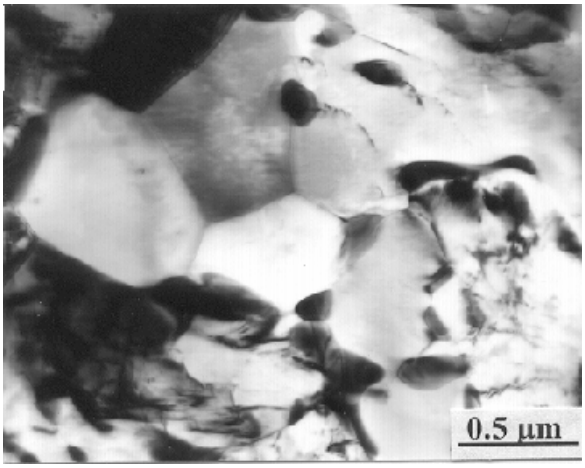


Figure 1 Experimental warm forging schedule.
Figure 2 Typical TEM microstructure of quenched sample 2.
Figure 3 Quenched sample 2, showing a recrystallized grain.
Figure 4 Typical SEM microstructure of air-cooled sample 3.
Figure 5 Typical TEM microstructure of air- cooled sample 3.
Figure 6 Air-cooled sample 3, showing a recrystallized area.

Fig. 1	Fig. 2
Fig. 3	Fig. 4
Fig. 5	Fig. 6

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