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Study of Texture and Warm Flow Stress of a Microalloyed Steel Due to Static Softening During Hot Deformation

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1- Introduction

Nowadays, thermomechanical processing is extensively used to improve mechanical properties of metals and alloys. In this process, plastic deformation is implied on austenite phase. As a result, the internal energy of work hardened material rises due to increase of dislocation density and crystal defects. Simultaneously, restoration processes including recovery and recrystallization occur at high temperatures and compete with work hardening effects and decrease internal energy of austenite. Therefore, the extent of flow stress of material is a function of softening fraction arises during and after hot deformation.

The stress relaxation test is an effective technique to investigate microstructural evolution after hot deformation such as static recovery and recrystallization. The recrystallization kinetics of a Nb micro-alloyed steel and a plain carbon steel after hot deformation have been evaluated by Zhang et al. [5]. They have accomplished that Nb in solid solution increases the value of apparent activation energy of static recrystallization significantly.

The objective of present paper is a comparative study of the static recovery and recrystallization and the effects of precipitates and thermomechanical parameters on the flow stress behavior of V–Nb–Ti microalloyed steel.

2- Experimental

The chemical composition of the microalloyed steel used in this research, used extensively in gas and oil industry, is listed in Table 1.

Table 1 The chemical composition of microalloyed steel used in this study (wt%)

C	S	P	Si	Mn	Nb	Ti	V	N	Fe
0.09	0.009	0.007	0.32	1.55	0.03	0.01	0.04	0.002	Bal.

In order to study the stress relaxation behavior of the steel, hot compression tests carried out using Gleeble 1500 thermo-mechanical simulator. The cylindrical hot compression specimens with 12 mm height and initial diameters of 10 mm were cut out from the steel plate with the axis parallel to the rolling direction. To do this, the specimens were reheated with 10°C/s to 1200°C, held for 5 min and cooled with 1°C/s to the prescribed deformation temperature, and then held for 3 min at this temperature before being subjected to hot compression. The tests were performed at temperatures of 850, 900, 950 and 1000˚C, annealing time of 0.05 to 1000s, strains of 0.04, 0.1, 0.25 and 0.4 and strain rates of 0.1 and 0.5 s^{-1}. During the hot compression test, stress relaxation was measured. The specimens were then water quenched immediately after deformation with cooling rate of 200°C/s and more to study microstructure evolution.

Hot compression samples quenched after relaxation, were sectioned and prepared for electron microscopy and electron backscattering diffraction (EBSD) observation to investigate the texture and microstructure. The normal of the observation plane was perpendicular to the sample axis. To do this, the JEOL JSM 6500F scanning electron microscopy was utilized.

3- Results and Discussion

The experimental stress relaxation data of hot compression tests at various temperatures are shown in Fig. 1. During hot deformation, the material is work-hardened and the flow stress increases. While the sample is held isothermally, the compressive stress is relaxed. In the beginning of restoration process, stress drops with a slower slope with logarithmic of time. Since dislocation annihilation occurs during static recovery which is the main softening mechanisms for the relaxation start times.

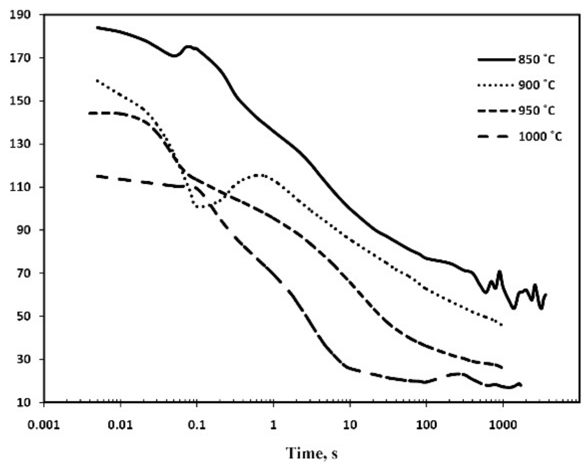

Fig. 1 Stress vs. log(time) curves for the isothermal relaxation of the steel at 850, 900, 950 and 1000 °C, strain rate 0.5 s-1 and strain of 0.25

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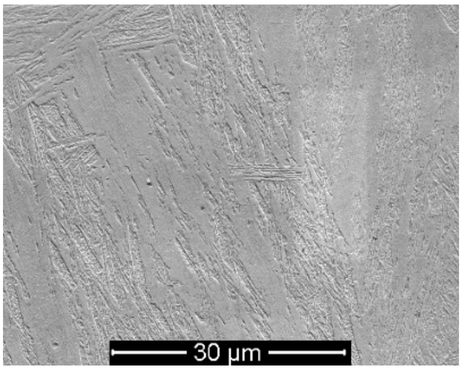
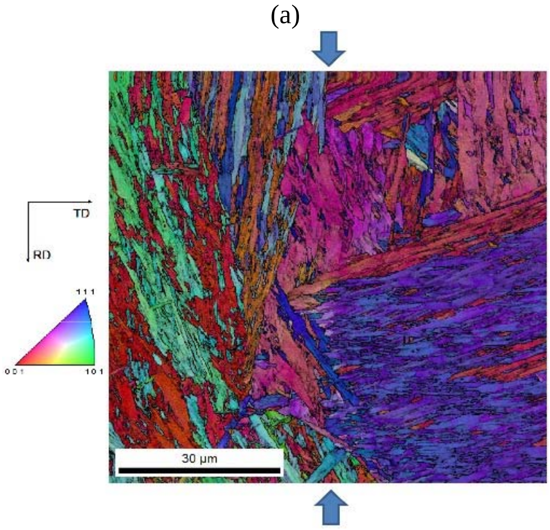
In the second part of the relaxation curve, due to recrystallization, the softening kinetics increases and stress falls rapidly. By increasing the holding time, the grain growth and creep occur after completion of recrystallization and it causes linear stress decrease as seen for deformation temperatures of 950 and 1000 °C in Fig. 1.

Fig. 2-a and Fig. 2-b display the scanning electron micrograph and the EBSD image of sample subjected to hot compression at 900 °C. The sample has a bainitic microstructure with the BCC texture at room temperature.

This texture is representative that the bainitic phase was originated from deformed but not recrystallized austenite. On the other hand, the EBSD image shows that in the above deformation condition the partial recrystallization happened.



(a)



(b)

Fig. 2 Scanning electron micrograph and EBSD image of sample hot compressed at 900 °C, strain 0.1, strain rate 0.5 s^{-1}

4- Conclusions

1- At 850 °C deformation, the strain induced precipitation starts just in the beginning of annealing time and retards the recrystallization. Therefore, the long annealing time is required for softening of material. However, at higher temperatures, first recrystallization starts and then the plateau occurs, afterwards recrystallization goes further.

2- Deformation rate influences on the first part of relaxation curve. On the other hands, it changes the internal energy of the deformed material before annealing starts.

3-The SEM and EBSD images show that the samples quenched following hot compression have a bainitic microstructure at room temperatures. The BCC texture confirms that the baintite phase was originated from deformed austenite.