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Short Communication

An investigation to the microstructural evolution of Fe–29Mn–5Al dual-phase twinning-induced plasticity steel through annealing

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ABSTRACT

The potential effects of twinning induced plasticity have been taken into consideration to further improve the mechanical properties of advanced high-strength steels. Accordingly the high-Mn twinning-induced plasticity (TWIP) steels with austenite–ferrite dual-phase microstructure have been developed. In the present study, the influence of cold rolling and post-annealing treatments on the microstructural evolution and mechanical behavior of a group of dual-phase TWIP steel as a function of annealing time have been investigated. The mechanical behavior of processed materials has been examined through applying a set of low strain rate ($0.001\ s^{-1}$) compression tests at room temperature. The austenite recrystallization characteristics during various annealing conditions are explained through proper microstructural examinations. The results indicate that as the recrystallization proceeds with annealing time the related yield stress deceases. The rapid drop of yield stress in short annealing periods is related to the onset of recrystallization. The yield stress variation diminishes as the annealing duration increases. This is attributed to the formation of austenite side-plates which may balance the softening effects of restoration processes.

1. Introduction

Among the wide variety of steel grades, Fe–Mn–Al steels with low stacking fault energy (SFE) have gained much attention as a reliable address to the unsaturated demands of transportation industries. By adapting different concentrations of alloying elements (Mn, Al, Si), the transformation-induced plasticity (TRIP) and/or the twinning-induced plasticity (TWIP) effects may be stimulated. The microstructural changes during plastic deformation in TWIP steels involve twin formation due to low SFE [1,2]. A new type of dual-phase (ferrite–austenite) steels showing TWIP effects has been characterized by Shiekhelsouk et al. [3]. The presence of high Al content in these alloys increases the specific strength and stabilizes the ferrite phase. In addition, Al improves corrosion resistance of high Mn steels [4].

The possibility of developing Fe–Mn–Al alloys as the proper substitutes for conventional TWIP steels due to their lower density and better corrosion resistance has been received very good attention [3,5–7]. These alloys, depending on the alloying content, may be composed of BCC-ferrite and FCC-austenite. A two-phase material (like duplex stainless steel) is inhomogeneous, and each phase in the material would exhibit a different response to an applied strain or temperature variation. However, the information on the state of individual phases in dual-phase steels is relatively limited. In this regard a variety of phase transformations (e.g., Widmanstätten side-plate [8], massive [9], DO_3 phase [10] and 18R type martensitic phases [11]) have been reported within the original BCC phase during high-temperature annealing and subsequent quenching treatment. In the case of single phase TWIP steels, in addition to dynamic restoration processes [12,13], the microstructural variation during annealing treatment has been also characterized. Bracke et al. [14] have studied the texture evolution in austenite through recrystallization of single phase TWIP steel. In the other work, Bouaziz et al. [15] have exhibited the thermal stability of deformation twins (DTs) during recovery process. The latter resulted in the best combination of strength and ductility in a partially recrystallized structure [16]. More recently, Wang et al. [17] have reported the enhancement of stored energy and the subsequent recrystallization kinetics of cold worked TWIP steel through carbon addition.

Most of the recent studies on TWIP steels have dealt with investigating the twinning behavior and its effects on the related mechanical properties at room temperature. On the other hand, most of the studies on dual-phase Fe–Mn–Al alloys have focused on corrosion behavior, mechanical properties [18], microstructural evolution [19], and precipitation hardening [20] of the alloy without any evidence of TWIP effect. Accordingly, the present study has been conducted to investigate the mechanical behavior of a new dual-phase TWIP steel after cold rolling and post-annealing processes relying on the corresponding microstructural evolution and TWIP effects.

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