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Rapid communication

Development of high strength and ductile ultra fine grained dual phase steel with nano sized carbide precipitates in a V–Nb microalloyed steel

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ABSTRACT

Ultrafine grained dual phase steel with yield strength of 865 MPa and tensile strength of 1640 MPa with a high work hardening rate and uniform elongation of 7% was produced by cold rolling and intercritical annealing. The fine scale Nb-V based carbides contributed to improving the strength and work hardening.

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1. Introduction

Dual phase steels (hard martensite embedded in a soft-matrix of ferrite) offer attractive properties such as continuous yielding, high work hardening rate, good uniform elongation and relatively high formability which are of considerable interest for applications in automotive industry [1–3]. However, further improvement in properties is essential in the competitive automotive industry. Among the different strengthening mechanisms, grain refinement is the only method to improve both strength and toughness simultaneously [4–9]. In the literature, number of different approaches have been proposed for producing ultrafine grained dual phase (ufg dp) steels. These can be classified as (a) intercritical annealing following cold/warm deformation of ferrite–pearlite microstructure [10,11] and (b) intercritical annealing following cold deformation of martensite [12]. The microstructure and properties of the ufg dp steels are strongly affected by the chemistry (especially the Mn content) of the steel [13]. Higher Mn content was shown to prevent grain growth during intercritical annealing (important for producing ufg microstructures) and also increases the hardenability [13]. However, the role of microalloying elements (V, Ti, and Nb) is not very clear though recent study on V containing steels indicate that they are beneficial [6]. In the present work cold rolling and intercritical annealing processing was used to develop ufg dp steel in low carbon microalloyed steel. The role of microalloying elements (V and Nb) on microstructure and mechanical properties of the ufg dp steels is discussed and we show that the microalloying elements contributed significantly to the strength and work hardening of the ufg dp steel.

2. Experimental procedure

Hot-rolled, V–Nb microalloyed steel (referred to as V–Nb MA in the paper) with the chemical composition of 0.12C, 1.43Mn, 0.25Si, 0.06V, 0.02Nb and 0.024N (wt. pct) was studied. The sample with size of $100 \times 40 \times 6$ mm^3 was austenized at 950 °C for 30 min and air cooled to room temperature. The normalized samples of V–Nb MA steel were cold rolled (~90% reduction in thickness, true strain of ~2.4) in a laboratory four-high rolling mill. The cold rolled strips were subjected to intercritical annealing (which involves heating and holding a temperature between the upper and lower critical temperatures to obtain partial austenitization) in salt bath at 760 °C for 2 min followed by quenching in water. Microstructural characterization was carried out using an FEI Inspect F Field emission scanning electron microscope (FESEM) and Philips CM-12 transmission electron microscope (TEM) operating at 120 kV. The ferrite grain size and martensite colony size were estimated from SEM micrographs using linear intercept method and the martensite volume fraction was evaluated using grid area method. Dislocation density measurements were performed on the bright field TEM micrographs (recorded in different tilting conditions) using the linear intercept method [14,15]. The precipitate volume fraction was also estimated using bright field TEM micrographs recorded from

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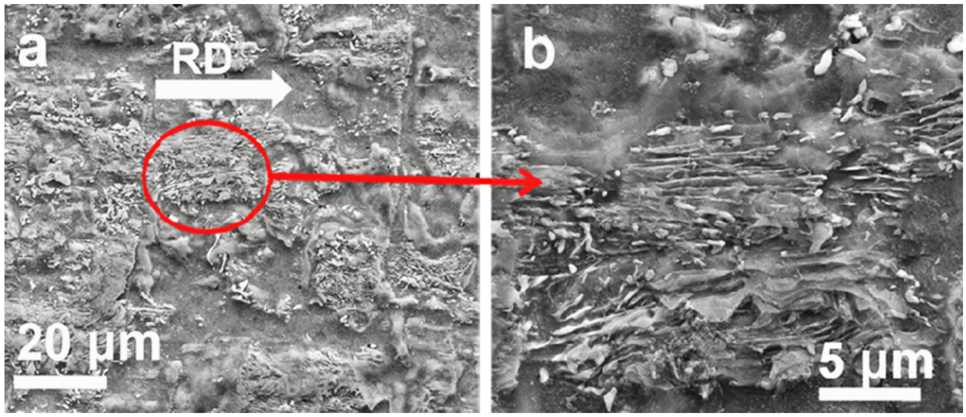

Fig. 1. Scanning electron micrographs of cold-rolled (to a true strain of 2.4) V–Nb microalloyed steel showing (a) fragmented pearlite colonies and (b) magnified image from circled region in (a) showing severely deformed pearlite.

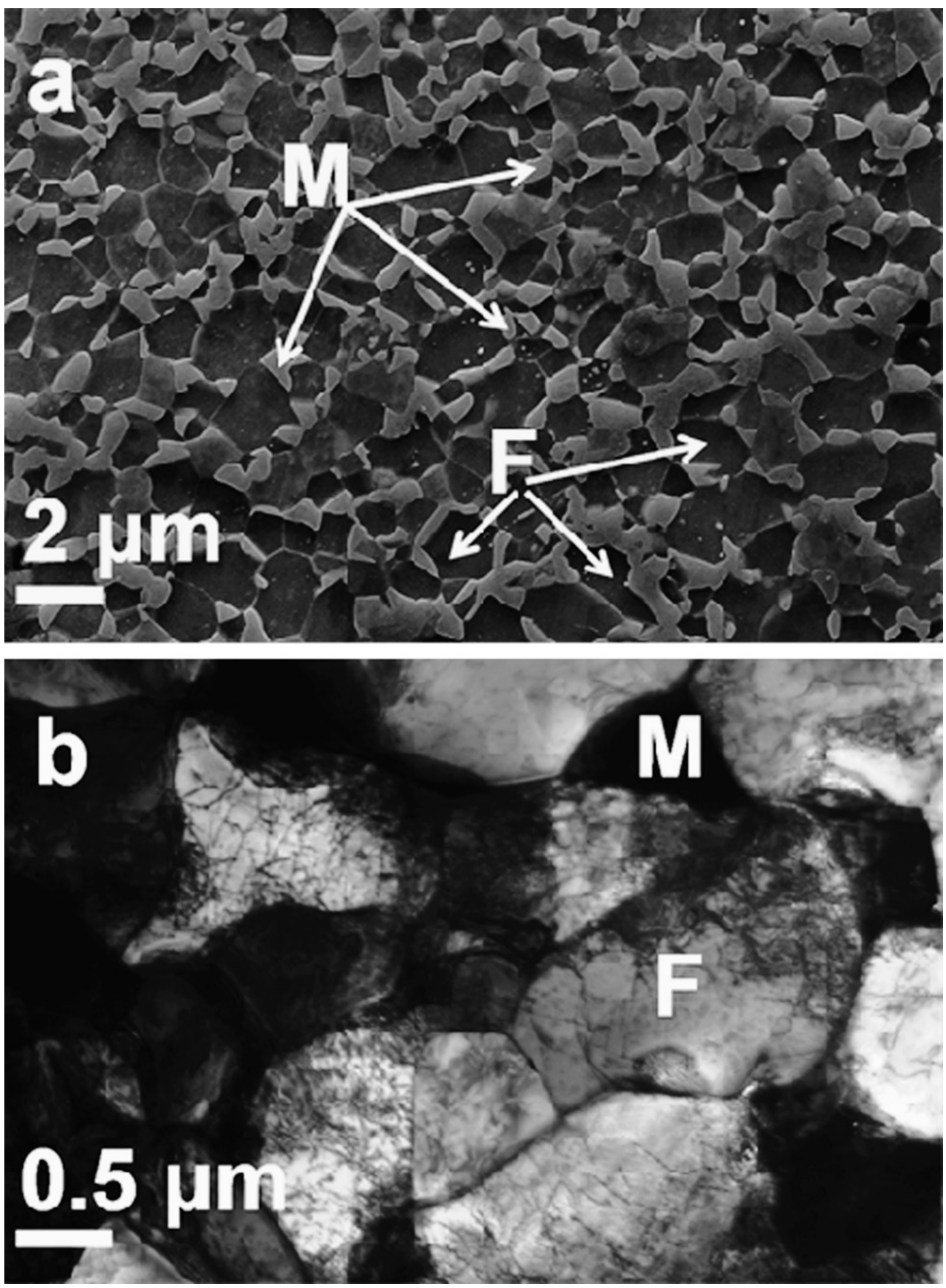

Fig. 2. (a) SEM micrograph showing fine grained ferrite and ufg martensite after intercritical annealing of the cold-rolled sample, (b) bright field TEM micrograph showing dislocation structures in the ferrite and block type of martensite. M: Martensite, F: Ferrite.

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