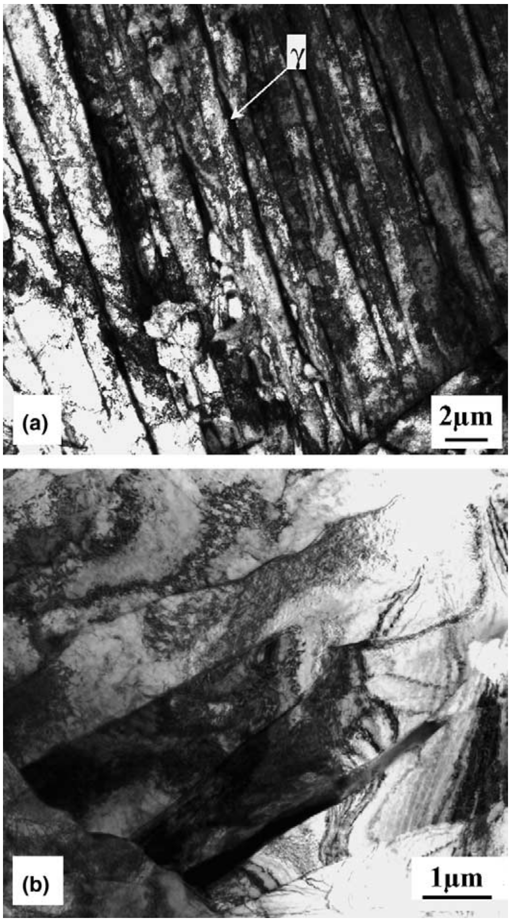

Fig. 1. Bright field TEM micrographs of (a) MI and (b) HI microstructures (thin foil observations).

lower cooling rate, bainite laths are thicker and lath boundaries are wavier for the HI microstructure than for the MI microstructure.

The austenite to bainitic ferrite orientation relationships were investigated using selected area diffraction patterns of bainite and of "blocky" retained austenite particles, which were easily found in the HI microstructure. The orientation relationships are close to the Kurdjumov–Sachs (KS) [15] (as in Fig. 2) or Nishiyama–Wassermann (NW) [16,17] orientation relationships, and always well within the Bain zone, i.e., within 10° from the $45°\langle 1\,0\,0\rangle_\gamma$ Bain orientation relationship.

The misorientation angle (in fact, the minimum misorientation angle) between parallel neighbouring bainitic laths was always low, i.e., between 0.5° and 9°, with a mean value of 3.5–4° (Table 2). Unlike in martensite [12], lower bainite [8], or even upper bainite in steels having higher carbon contents [18], parallel neighbouring laths were here always separated by low-angle boundaries. These groups of parallel laths will be denoted hereafter as "bainite groups". A few "covariant packets", consisting of morphologically parallel, but highly crystallographically misoriented bainite laths (as

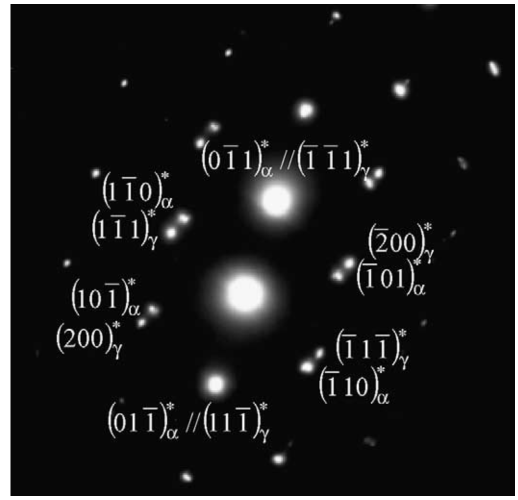

Fig. 2. Selected area diffraction pattern taken at the interface between retained austenite and bainite in the HI microstructure. The zone axis is $(0\,1\,1)^*_\gamma//(1\,1\,1)^*_\alpha$ in the reciprocal space.

Table 2
Metallurgical properties of the MI and HI microstructures

Cycle	MI	HI
Mean γ grain size (light microscopy) (μm)	56	76
Mean (%) M–A + carbides (light microscopy)	4.5	6.0
% Retained austenite (X-ray diffraction)	2.3 ± 0.5	4.0 ± 0.4
Mean crystallographic bainite packet size (EBSD) (μm)	12	15
Mean lath thickness (TEM) (μm)	0.9	1.3
Mean misorientation angle between neighbour laths (TEM)	$3.6 \pm 0.5°$	$3.9 \pm 0.5°$

reviewed by Kalwa et al. [19]) were also found. Thus, in both microstructures, bainite packets consist of "bainite groups" having close crystallographic orientations. These groups are the basic units of the bainite packets considered hereafter.

3.2. Bainite packet morphology

After interrupted heat treatments, a mixed bainite–martensite microstructure was obtained, with the martensite phase arising from the transformation of austenite upon quenching. The bainite and martensite phases could easily be distinguished from each other using light microscopy after 1% sodium disulphite etching (Fig. 3). The bainite transformation is very heterogeneous, at least from two-dimensional observations: some austenite grains are almost completely transformed while neighbour grains are still fully austenitic. Partially formed bainite packets (one of them is delimited with black lines in Fig. 3) consist of at least two interlocking sets of parallel features (one of them is