INFLUENCE OF CRYSTALLOGRAPHIC TEXTURE OF TMCP PIPE STEEL ON THE NATURE OF DEFORMATION AND FRACTURE DURING TENSILE TESTING

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RESEARCH METHODS

The study was conducted on the specimens of 06Mn2MoNb low-carbon, low-alloy pipe steel (~ 0.05 wt.% C, ≤ 2.0 wt.% Mn, ~ 0.2 wt.% Mo, ~ 0.05 wt.% Nb, balance Fe and unavoidable impurities) designed for production of X70, X80 large diameter pipes. The specimens corresponded to the thickness of the plates 26–27 mm – that had been processed at 5000 Mill according to three modes with different finish-rolling temperatures (I – 920 °C, II – 844 °C, III – 760 °C).

The specimens for mechanical testing were cut out transversely to the rolling direction (RD) from the central areas of the plates, 11–13 mm from their surfaces. Standardized fivefold cylindrical specimens with 5 mm reduced section were tested according to ASTM E8/E8M-21. Tensile testing was carried out on Instron 3382 universal testing machine at 5 mm/s test speed at room temperature. Stain curves were analyzed according to the method described in [1].

Metallographic samples were prepared across the thickness of each specimen. Sample surface preparation for EBSD was carried out on a Struers LaboPol-5 grinding and polishing machine with a Struers LaboForce-1 device for a semi-automatic preparation of 1–3 samples. An electrolytic polishing of the samples in a solution of 15 % $HClO_4$ (perchlotic acid), 85 % CH_3COOH (acetic acid) was preformed after the grinding at 21 V voltage.

Electron microscopy study of the structure was carried out on a Tescan Mira 3 microscope with an auto-emission cathode with an accelerating voltage of 20 kV. EBSD HKL Inca system with Oxford Instruments analyzer was used to determine orientations of individual grains (crystallites). Step size was 0.1 µm. Orientation estimation inaccuracy did not exceed ± 1° (± 0.6° on average).

A coordinate system (X, Y, Z) with its axes coherent with the rolling direction (X║RD), the normal to the rolling plane (Y║ND) and with the direction perpendicular to them (Z║TD) was used in both the structural studies and the textural analysis. Z axis also coincided with the normal to the surface of the metallographic samples. The three chosen directions formed the vector right-handed triplet.

TABLE 1. Mechanical properties of the steel specimens obtained by means of tensile testing

Mode	YS, MPa	UTS, MPa	BS, MPa	UE, %	LE, %	Elongation, %
I	445 ± 11	560 ± 18	290 ± 4	12.5 ± 0.8	17.5 ± 1.0	30.0 ± 1.0
II	515 ± 9	610 ± 12	310 ± 5	9.0 ± 0.7	14.0 ± 0.7	23.0 ± 1.0
III	545 ± 9	620 ± 10	275 ± 4	9.0 ± 0.7	15.0 ± 0.8	24.0 ± 0.6

CONCLUSION

This paper describes the effect of the crystallographic texture of pipe steel processed by TMCP on the deformation and fracture during tensile testing. Elongated ferrite grains with {001} plane (plane along which cleavage in α-Fe proceeds) parallel to the pipe axis may occur depending on the temperature of the final isothermal rolling of high-strength low-alloy steel sheets.

The anisotropy of structural changes and shape of the samples during their fracture is associated with the pronounced crystallographic texture. The more scattered texture observed for final controlled rolling temperature of 920 °C demonstrates a greater necking isotropy.

ACKNOWLEDGMENTS

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[1] Erpalov, M.V., Khotinov, V.A., 2020. Optical method to study post-necking material behavior. AIP Conference Proceedings 2288, 030007.

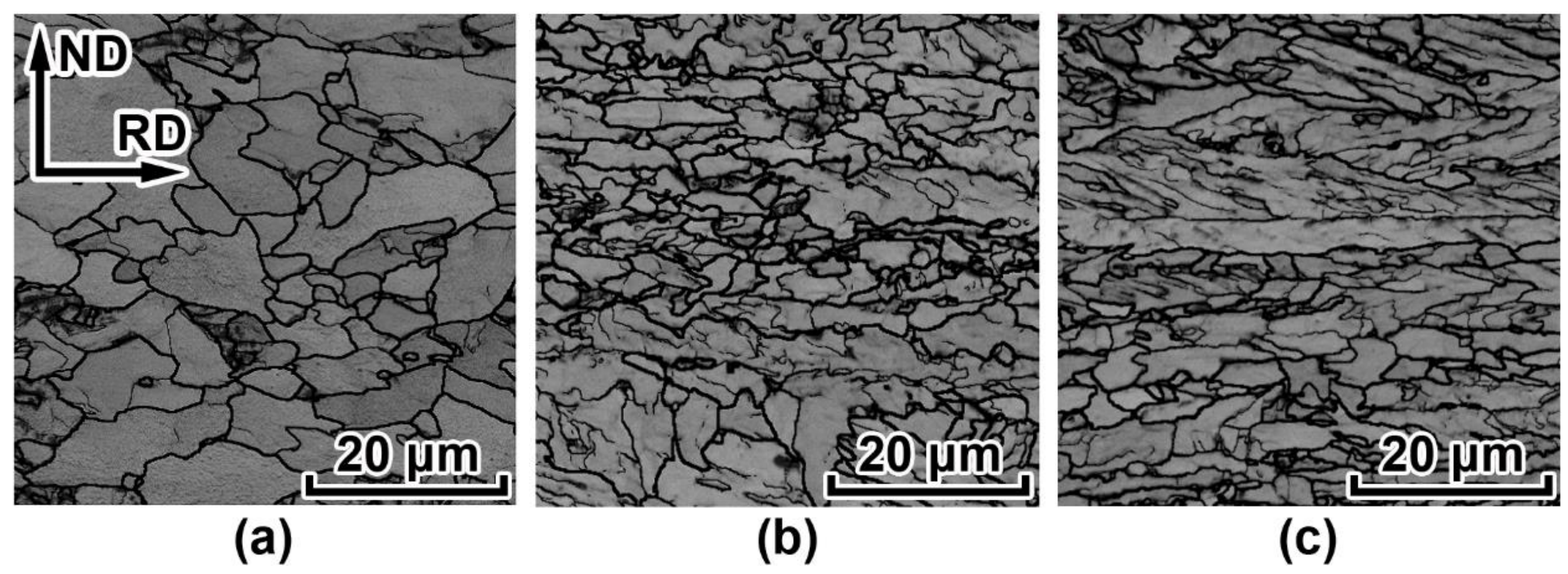

FIGURE 1. Microstructure (in the form of EBSD orientation maps) of the central areas of the 06Mn2MoNb steel plates after thermo-mechanical controlled processing according to different modes: a – I; b – II; c – III

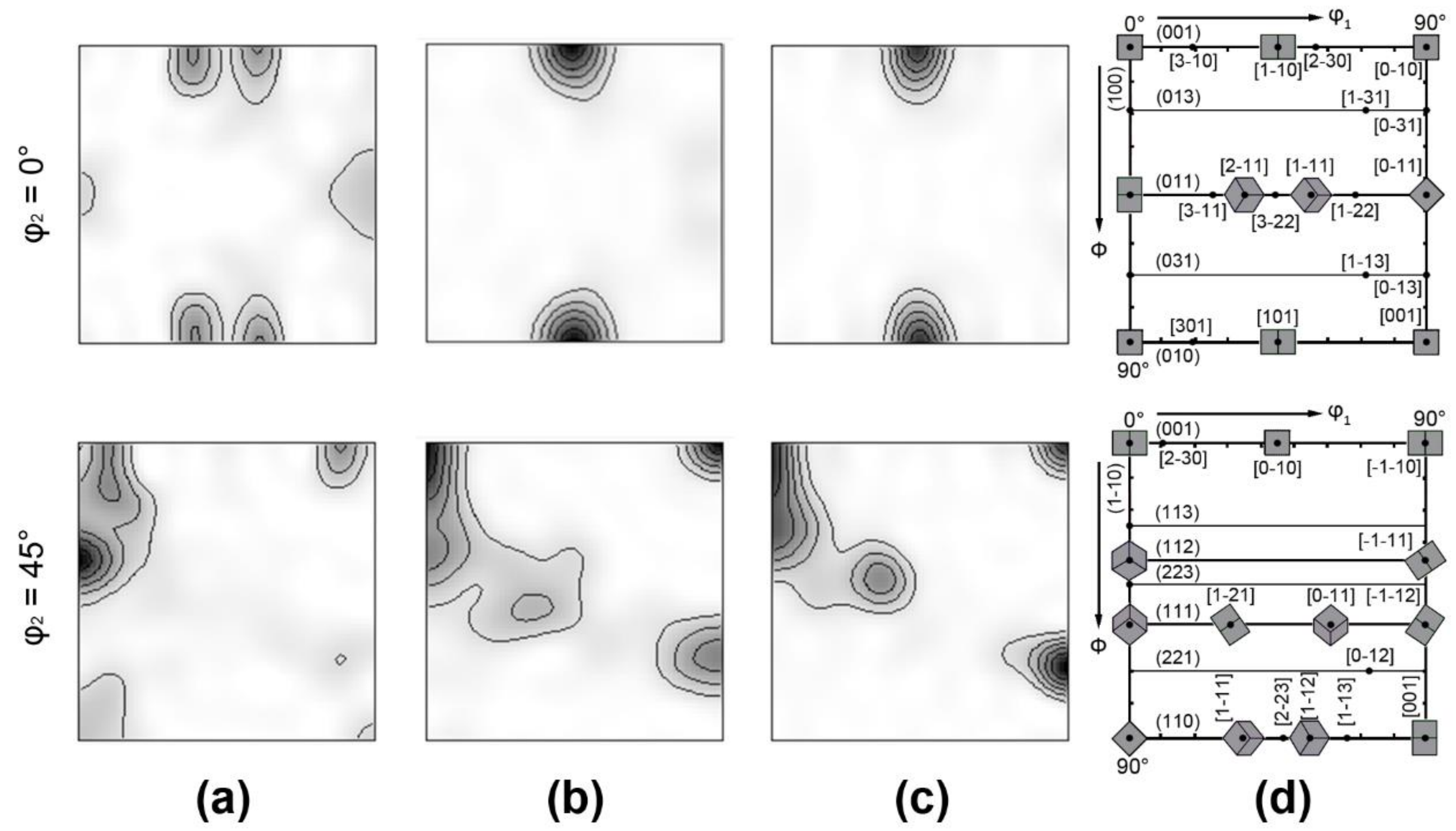

FIGURE 2. Texture of the central layers of the pipe steel plates in the form of cross-sections of orientation distribution functions obtained by means of EBSD at φ2 = 0°, φ2 = 45°: a-c – orientation distribution function in the form of distribution intensity of pole density after different modes (a – I, b – II, c – III); d – orientation distribution function standard grids with plotted ideal orientations in the form of crystal unit cells (view from TD)

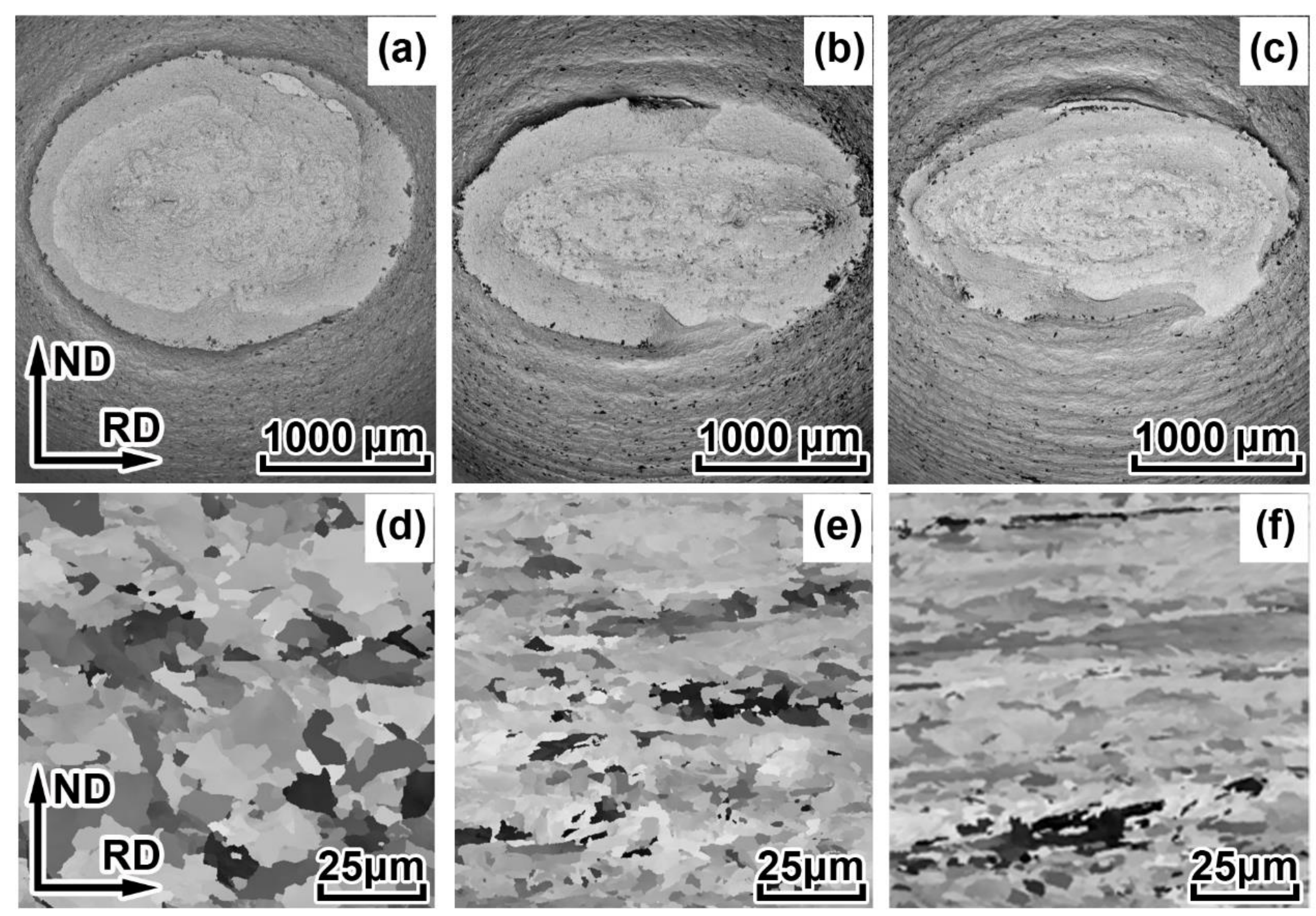

FIGURE 3. Fracture surfaces of cylindrical specimens after standard tensile testing (a-c) and plate central area microstructure in the form of EBSD orientation maps with highlighted <100> orientation orthogonal to the figure plane (d-f) of 06Mn2MoNb steel after different TMCP: a, d – after mode I; b, e – after mode II; c, f – after mode III

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