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THERMO-KINETIC AUSTENITE TRANSFORMATION IN THIN-SHEET STEELS

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Abstract. In this contribution thermo-kinetic austenite transformation in high-strength thin-sheet steel at cooling rate of 0.05-5.0 K/s is studied. A transformation diagram has been constructed, steel structure formed after the disintegration under isothermal conditions at constant cooling and phase composition of the steel are given.

1. Introduction

Intermediate-alloy steels with 0.4-0.5 % carbon content are widely used in engineering in the state of quenching and tempering (high and low) with the ultimate strength of 1300-1800 MPa [1, 2]. The processing technique includes melting with out-of-furnace treatment and continuous casting, hot and cold rolling [3-6]. Technical requirements to the steel chemical composition [7], mechanical properties and full-scale testing results are achieved by controlling steel melting technology, pressure treatment and special thermo-mechanical treatment of armor structure details [8-10].

As that takes place, a complex of mechanical properties is determined by relations between number of phases (ferrite, perlite, bainite, martensite) formed in the process of quenching, their dispersibility, morphology and other factors of austenite transformation at constant cooling [3, 4, 6]. Great number of weak-controlled technological factors results in product operation efficiency instability and requires additional testing of full-scale samples and products in the production process for a product batch certification at delivery trials [2], when limited width details experience complicated stressed state caused by specificity of shock waves propagation [11]. The wide product mix causes various austenite transformation kinetics in the process of quenching, it is necessary not only for different products, but also for separate parts of a detail. It occurs because the transformation kinetics strongly depends on kinetics of the heat exchange with the cooling surroundings. Therefore, diagram of austenite thermo-kinetic transformation is constructed with the help of modern research equipment (dilatometry and microscopy), which help to increase reliability of analysis and prognostication of steel structure, mechanics and operational capability of details made of high-strength 0.4C-1,0Cr-1.0Ni-1,5Si-0.5Mo steel.

The present paper considers a steel containing (% mass.) 0.40C, 1.20Cr, 1.30Ni, 1.50Si, 0.45Mo. Parent sheets of 4-20-mm thickness were obtained by rolling a continuously cast bar of 200-mm thickness, tempered at 680 °C and 10 hours soaking. Rolling completion temperature was 900 °C, the sheet coiling was performed at 700 °C. Critical temperatures for the investigated steel are A_{c1}=720 °C, A_{c3}=820 °C.

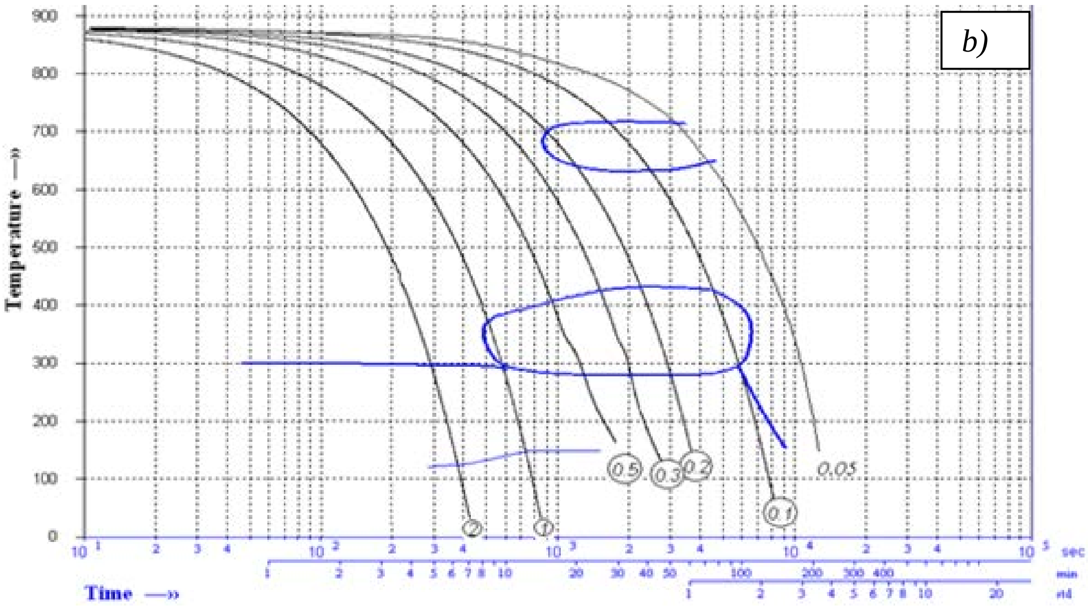

Fig. 2b. Thermo kinetic diagrams of various steel samples with close chemical compositions. Heating up to 880 ^{o}C. Cooling rate (from left to right): 2; 1; 0.5; 0.3; 0.2; 0.1; 0.05 degree per second.

The zone of ferrite-perlite structure (F) is limited with the cooling rate less than 0.2-0.5 K/s, and temperature 630-750 °C. The bainite, zone is limited with the cooling rates 1-3 K/s (from martensite side) and 0.1-0.05 K/s (from perlite, bainite side); temperatures 290-300 °C and 430-520 °C. Start of martensite transformation in the given steel occurs at about 300 °C temperature and at the cooling rate of 1-3 K/s. That indefiniteness of structural zones locations results in steel structural heterogeneity and spread of standard samples mechanical properties in the process of certification testing of full-scale products.

Structures of various phases corresponding to isothermal disintegration of steel austenite (Fig. 1) are presented in Fig. 3.

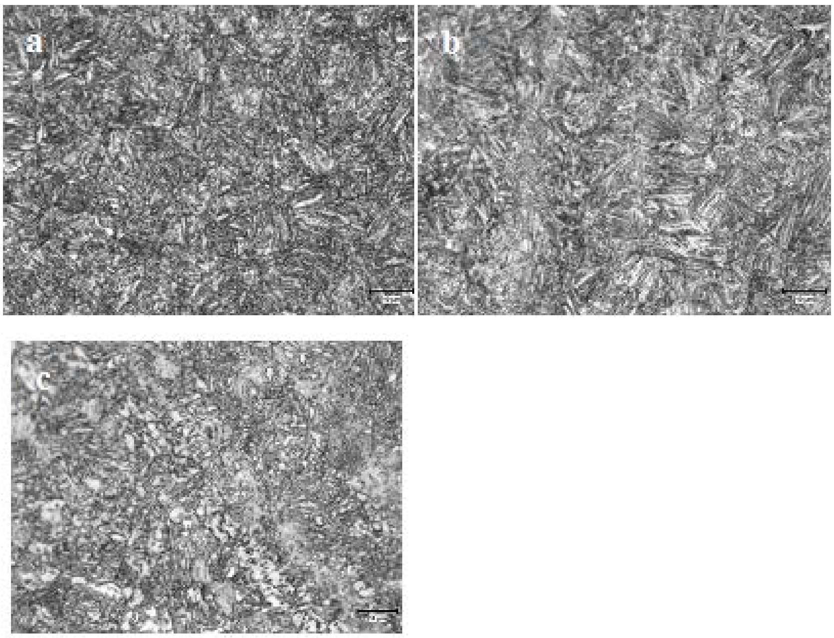

Fig. 3. Steel structure heated to 880 °C at isothermal transformation: *a)* 280 °C (martensite); *b)* 330 °C (low bainite); *c)* 450 °C (top bainite).

At continuous cooling a structure significantly different, depending on the cooling rate, is forming (Fig. 4); it consists of a set of various phases (Table): at cooling rate less than 0.05 K/s – ferrite-perlite with dispersed carbides; at cooling rate more than 3 K/s – martensite; in the range between 0.05-3.0 K/s – with various ratios between ferrite-perlite mixture, martensite, bainite.

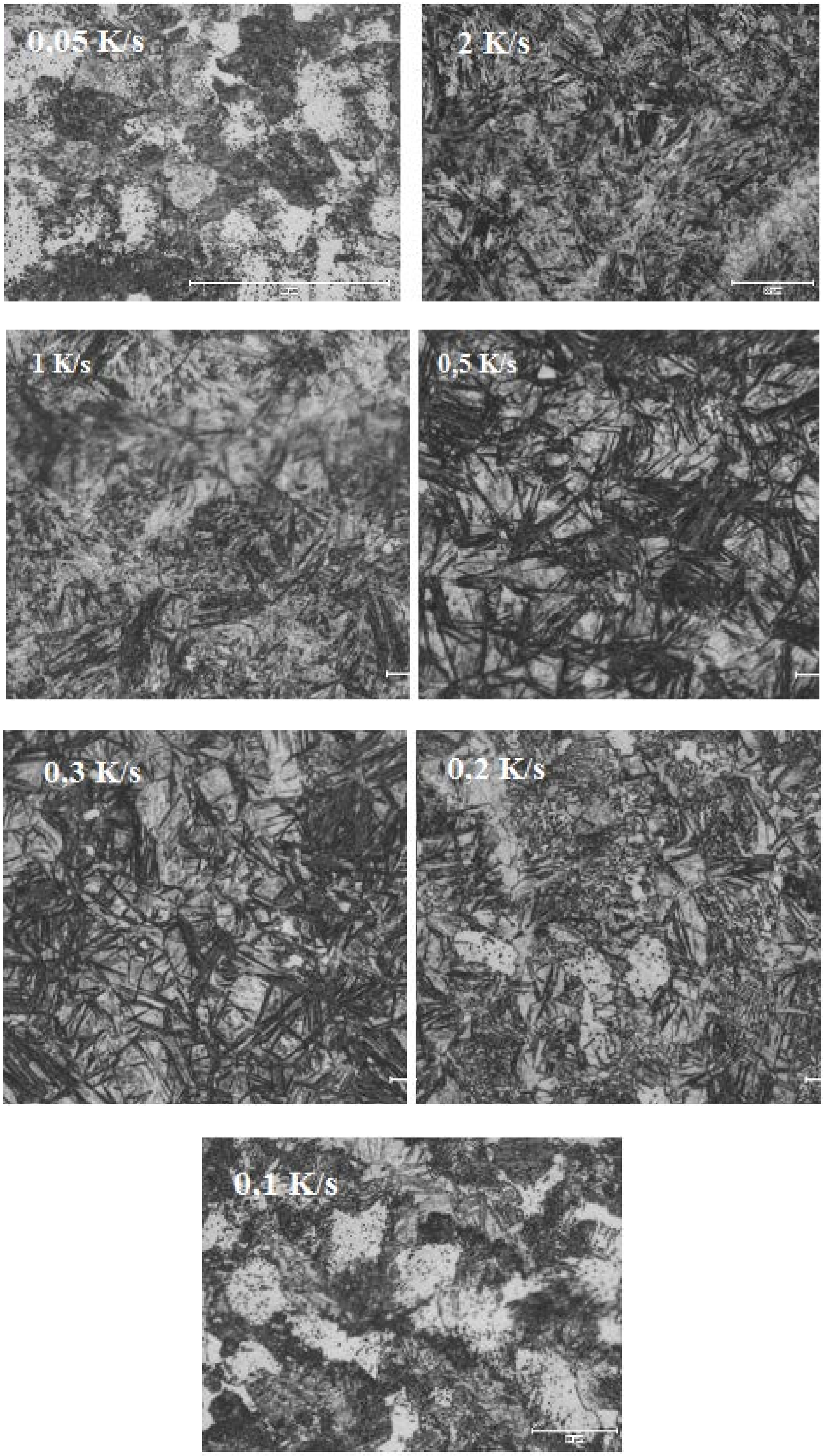

Fig. 4. Steel structure at continuous cooling with rate from 0.05 to 2.0 K/s.

Table. Structural components ratio in steel after cooling from 880 °C at various rates

Cooling rate, K/s	Ferrite+ perlite	bainite	martensite
0.05	100	0	0
0.1	85	15	0
0.2	25	75	0
0.3	0	85	15
0.5	0	30	70
1	0	0	100
2	0	0	100

Thus, a multiphase structure that can consists of martensite (non-diffusion), perlite (diffusion) and bainite (intermediate) transition products having different mechanical properties and different resistance to operational loads, is generated in a local part of a metal block during steel quenching. It determines a significant spread of 0.4C-1.0Cr-1.0Ni-1.5Si-0.5Mo steel efficiency especially at shock loading.

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