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Anisotropy of plastic properties of the toughening steel plates rolled using the thermo-mechanical method

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Abstract: Results of investigations of the shear bands influence on the structure, mechanical properties and anisotropy of plastic properties of the toughening steel plates with Nb, Ti, and B microadditions after thermo-mechanical treatment and tempering, are presented.

It was found that the lack of the complete recrystallization of plastically deformed austenite between rolling passes was caused the increase in inhomogeneity of plastic deformation. It leads to forming of shear bands, causing a distinctive reduction of the crack resistance of the steel and a disadvantageus anisotropy of plastic properties of plates. The presence in the rolled product structure of shear bands decides about lowering of properties and practicability. It especially relates to plates.

1. INTRODUCTION

Steel plates with the high strength and required resistance to cracking are used in building strong loaded welded constructions, especially self-propelled cranes, road machines, heavy transport vehicles, overhead traveling cranes of high load capacity, machines and devices for the raising industry. Initially, the plates with $R_{0,2}$ from 550 to 960 MPa and $KV_{-40\,^{o}C} > 27$ J were produced of heat treated steels, containing ≤ 0,2% C, ≤ 1,6% Mn, ≤ 0,8% Si, ≤ 1% Cr, ≤ 2% Ni, ≤ 0,6% Mo and ≤ 0,1% V. The high value of the carbon equivalent of these steels C_E from 0,72 to 0,82% was a reason of preheating of welded elements, even up to a temperature higher than 200 ^{o}C [1÷3].

Introduction to a steel ≤ 0,005% B – increasing a hardenability, ≤ 0,04% Ti, ≤ 0,04% Nb and ≤ 0,08% V creating interstitial phases of MX - type (M - Nb, Ti; X - N, C), enabling production the products of fine-grained structure, permits to lower a contents of C ≤ 0,17%, Cr ≤ 0,8%, Mo ≤ 0,5% and C_E ≤ 0,56 in a steel and production of heat treated plates with $R_{0,2}$ from 700 to 1100 MPa and $KV_{-40\,^{o}C} \geq 40$ J, and lowering the preheating temperature of welded elements to ≤ 150 ^{o}C [2]. The used steels with Nb, Ti and B microadditions into the production of the plates require a limitation of the concentration P ≤ 0,015% and S ≤ 0,005% and a modyfication of non-metallic inclusions. It has an important influence in lowering the impact transicient temperature of steel and limiting the anisotropy of plastic properties of plates. The ratio of breaking energy of Charpy V specimens transverse/longitudinal ≈ 1 [4].

The aim of the work is to investigate a structure of bands and their interaction on mechanical properties and anisotropy of plastic properties of plates produced of the thermo-mechanically processed and tempered structural steel with Nb, Ti and B microadditions.

2. MATERIAL AND INVESTIGATION METHODOLOGY

The investigations carried out on low-carbon heat treated steel containing 0,17% C, 1,37% Mn, 0,26% Si, 0,012% P, 0,001% S, 0,24% Cr, 0,48% Mo, 0,05% Ni, 0,019% V, 0,004% Ti, 0,025% Nb, 0,06% Al, 0,002% B and 0,004% N. The steel is used in production of welded plates with $R_{0,2}$ > 960 MPa and an impact transicient temperature T_{45J} = - 40 ^{o}C.

A stock in a shape of 200 x 40 mm flat was rolled to a plate of 15 mm in thickness in five passes in a temperature range 1100 to 900 ^{o}C. The rolling temperature range was established on a basis of plastometric investigations of the kinetics of austenite strain hardening decay (static recrystallization) of plastically deformed steel with a rate of 3 s^{-1} up to a strain of ε = 0,2 in this temperature range [4]. Results of these investigations were useful in determining the $t_{0,5}$ time – required to production of 50% recrystallized austenite fraction and $t_{0,8}$, $t_{0,9}$, t_R time - corresponding successively 80%, 90% and full recrystallization of plastically deformed austenite under noted conditions. The flat was rolled in five passes. In the first three passes the reduction of area was 20%, and in the last two – 15%.

The thermo-mechanical processing of plates was carried out in two variants. In the first variant, the rolled stock was cooled in air to the predetermined rolling temperature for the successive pass (the cooling time for these conditions is much sorter than the time required for the complete recrystallization of the austenite, especially for the lower range of the rolling temperature. In the second variant, a retention shield was applied, making it possible to adjust intervals between the successive passes to the t_R – time and also the isothermal holding of the rolled plate in the finishing rolling temperature for the $t_{0,5}$ – time prior to quenching. The detailed rolling conditions of the plates in two variants of the thermo-mechanical processing are given in [4].

3. RESULTS OF EXPERIMENTS

The realized investigations showed significant difference of the structure and mechanical properties of the plates obtained in two variants of the thermo-mechanical treatment, both after quenching from a finishing rolling temperature and after tempering in a temperature range of 550 do 650 ^{o}C. Using the cooling in air in intervals between successive passes of rolling and holding for $t_{0,5}$ time of plates after finishing the plastic deformation before quenching (first variant of the thermo-mechanical processing) cause forming segregation bands (shear bands) propagating in the rolling direction (Fig.1).

In this case the time of intervals between rolling passes was much shorter from the t_R – time of full recrystallization of austenite and even the $t_{0,5}$ – time required to forming of 50% fraction of recrystallized γ phase. The conditions led to imposing a plastic deformation in successive passes causing its localization and forming segregation shear bands. Apparently, the cause of the bands does not reveal their direction on intersected grain boundaries of primary austenite or a crystallographic orientation of lath martensite (Fig.1b). However, the investigations of the structure of thin foils in a transmision electron microscopy revealed that within the precincts of segregation bands occured a strong fragmentation of primary austenite grains connected with a course of dynamic recrystallization and in their surroundings an intensive course of dynamic recovery with forming on their boundaries a continuous envelope of carbides (Fig.2, 3).

A presence of segregation bands did not reveal in the structure of the plate produced in the second variant of the thermo-mechanical treatment, that is, under conditions enabling adapting the time of intervals between successive passes of rolling to the time of full recrystallization of rolling to the time of holding for $t_{0,5}$ - time the plates before quenching at a finishing plastic deformation temperature using a retention shield [5].

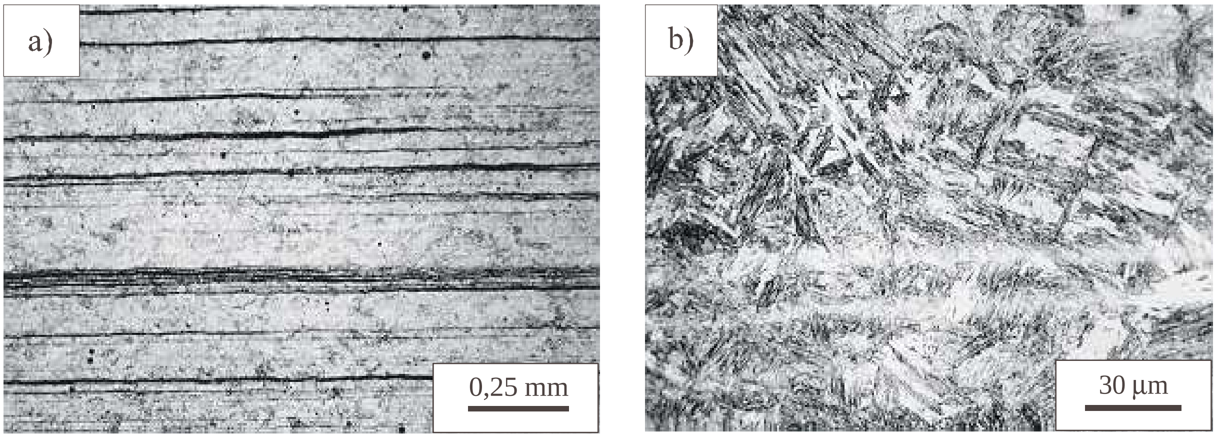

Figure 1. Austenite structure (a) and lath martensite (b) with distinct segregation bands

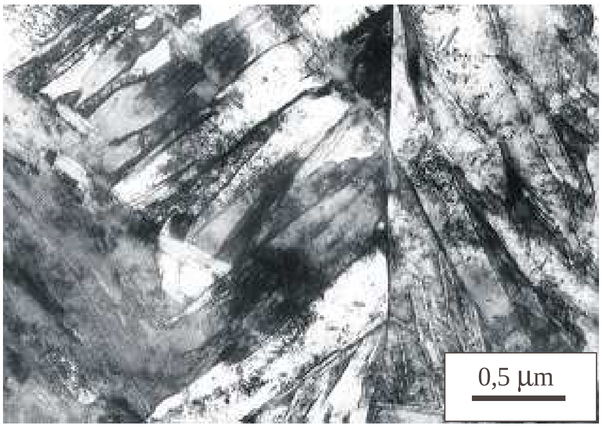

Figure 2. Lath martensite structure; finishing rolling temperature: 900°C

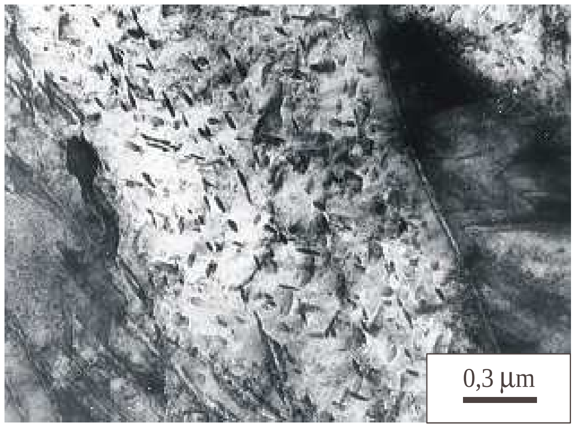

Figure 3. Dispersive precipitations of MC-type carbides in the plate of martensite; finishing rolling temperature: 900°C

4. CONCLUSIONS

The realized investigations showed, that a lack of full recrystallization of austenite between sucessive cycles of rolling leads to forming in the austenite segregation bands enriched in C, Cr, Mo, Nb, Ti and V.

Using the retention shield allowing to nearly complete recrystallization of plastically deformed austenite in intervals between successive passes of rolling and isothermal holding of rolled strip prior quenching in a properly chosen finishing rolling temperature for the $t_{0,5}$ - time, prevent forming segregation bands and guarantee the the products after tempering an advantageous assembly of mechanical properties, especially the high resistance to cracking and low anisotropy of plastic properties of the plates.

REFERENCES

1. J. Adamczyk: Inżynieria wyrobów stalowych, Wyd. Politechniki Śląskiej, Gliwice, 2000.
2. Swenskt Stäl Oxelösund WELDOX.
3. Thyssen Stahl AG, N-A-XTRA/X-A-R.
4. J. Adamczyk, M. Opiela: Inżynieria Materiałowa, 6, 131 (2002) 717.
5. M. Opiela: PhD Thesis, Silesian University of Technology, Gliwice, 2000.