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The physical modelling of a normalising rolling of plates of S460NL1 steel grade

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ABSTRACT

Purpose: The aim of the present work was to demonstrate that, in laboratory conditions and using a physical simulator of metallurgical processes, it us possible to reflect the actual production process and, at the same time, to simulate new, not necessarily perfect rolling technologies, while not incurring any outlays on industrial lots of a new product line.

Design/methodology/approach: The article present the results of physical simulations of the process of rolling plates of steel S460NL1 on the finishing stand of a reversing mill. The simulations were performed for three final plate thicknesses, namely 8, 10 and 12 mm.

Findings: The purpose of the simulations was to select the conditions of band deformation with the aim of obtaining, directly after rolling, a material structure corresponding to the structure obtained from normalizing annealing. Thus, the simulations reflected the normalizing rolling process.

Practical implications: The researches carried out has allowed to elaborate new technology of production of rolling plate without a additional thermal treatment like as normalisation. It allow to decrease a time and total cost of production for this sort of product.

Originality/value: The investigation carried out has confirmed that it is possible to obtain and manufacture 8, 10 and 12 mm-thick plates of S460NL1 grade steel by normalizing rolling in the conditions of the plant under consideration.

Keywords: Plastic forming; Controlled rolling; Plate rolling; Physical simulation

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

The modernization of the metallurgical industry is being conducted towards applying new, scientifically justifiable intensive technologies that are characterized by a continuity of processes, a reduced energy consumption and the economy of material consumption per unit of finished product [1-7,11,15]. A justified result of this trend in the development of the production of metals is the combination of plastic deformation and heat treatment into a single technological process, which leads to a reduction in the consumption of material outlays and energy. This, at the same time, widens the scope of application of plastic deformation that can be used not only to impart required shapes and dimensions to the products, but also to shape the essential mechanical properties of the rolling product [8-10]. Controlled rolling [1,2,8,12-14] is a variant of the plastic working of metals and alloys, which is characterized by controllable stock heating conditions, temperature and deformation parameters strictly defined for a given chemical composition and preset product cooling conditions at different plastic working stages. As a result, the preset structure is obtained, along with a special type of substructures and hardening phases that assure a simultaneous enhancement of strength and impact resistance or provide special properties for the material.

The proper design of the controlled rolling technology requires, however, the knowledge of numerous factors that influence the condition of the material after the process. Therefore, the verification of the developed technology becomes necessary. To avoid unnecessary costs associated with trial rolling in industrial conditions, physical simulations of processes are carried out, which reflect the industrial conditions in a laboratory scale [11-14]. The aim of the present work was to demonstrate that, in laboratory conditions and using a physical simulator of metallurgical processes, it us possible to reflect the actual production process and, at the same time, to simulate new, not necessarily perfect rolling technologies, while not incurring any outlays on industrial lots of a new product line.

2. Work methodology and materials for research

Steel of S460NL1 grade, whose chemical composition is summarized in Table 1, was used in the investigation.

Table 1.
Chemical composition of steel S460NL1

C	Mn	Si	P	S	Cr
0,14	1.55	0.42	0.019	0.004	0.08
Ni	Mo	Cu	Al	N_2	V
0,077	0.02	0.18	0.031	0.016	0.115
Nb	B	Ti	Sn	Ca	B
0,015	0.0001	0.003	0.014	0.0013	0.0001

The article discusses three different physical simulations of the deformation of steel S460NL1 for three final thickness: 8, 10 and 12mm, which were carried out in accordance with conditions, as shown below. Table 2 shows the scheme of rolling band of a final thickness of 8mm. The scheme of passes, temperature and break times, shown in Table 2, were taken from the engineering reports of the Plate Mill of a steelworks.

Table 2.
Parameters of the rolling process of 8mm final thickness plate, simulated in the experiment for a specimen of steel S460NL1

Pass no.	h_0, mm	h_1, mm	t_p, s	T, °C	ΔT, °C
1	27.75	18.88	0	1040	-
2	18.88	13.11	8.81	1037	3
3	13.11	10.02	10.01	1009	28
4	10.02	8.81	11.06	969	40
5	8.81	8.3	11.05	925	44
6	8.3	8.09	17.3	877	48

The specimen was heated up to the temperature of 1050°C, which corresponds to the temperature of band incoming form the break-down stand, soaked at this temperature for 60 s, and then cooled down (at a rate of 2°C/s) do a temperature of 1040°C, at which the first deformation took place. After the last deformation carried out at 877°C, the material was cooled at a cooling rate of 1.5°C/s. The cooling rates selected in the simulation correspond to the real conditions prevailing in the production line. Table 3 shows the scheme of rolling band of a final thickness of 10mm. The scheme of passes and break times were also taken from the engineering reports of the Plate Mill of a steelworks. The specimen was heated up to a temperature of 1050°C, soaked at this temperature for 60 s, and then cooled down (at a rate of 2°C/s) to a temperature of 910°C, at which the first deformation took place. After the last deformation carried out at 843°C, the material was cooled at a rate of 1.5°C/s.

Table 3.
Parameters of the rolling process of 10mm final thickness plate, simulated in the experiment for a specimen of steel S460NL1

Pass no.	h_0, mm	h_1, mm	t_p, s	T, °C	ΔT, °C
1	45.28	32.96	0	910	-
2	32.96	23.24	6.34	899	11
3	23.24	16.74	5.5	891	8
4	16.74	13.28	5.59	881	10
5	13.28	11.28	6.47	865	16
6	11.28	10.09	9.52	843	22

Table 4.
Parameters of the rolling process of 12mm final thickness plate, simulated in the experiment for a specimen of steel S460NL1

Pass no.	h_0, mm	h_1, mm	t_p, s	T, °C	ΔT, °C
1	39.93	30.79	0.00	955	-
2	30.79	23.19	10.50	938	17
3	23.19	16.71	12.00	926	12
4	16.71	13.99	14.60	910	16
5	13.99	12.72	15.10	889	21
6	12.72	12.12	13.60	864	25

Table 4 shows the scheme of rolling band of a final thickness of 12mm. The specimen was heated up to a temperature of 1050°C, soaked at this temperature for 60 s, and then cooled down (at a rate of 2°C/s) to a temperature of 955°C, at which the first deformation took place. After the last deformation carried out at 864°C, the material was cooled at a rate of 1.5°C/s.

3. Description of achieved results of own researches

Figure 1 depicts the S460NL1 steel structure obtained from the physical plate rolling simulation of a final thickness of 8 mm. The structure shown in this figure is a ferritic-pearlitic structure with considerable banding of the structure, the grain size of ferrite is 9 to 10 and that of pearlite is 10.

Figure 2 depicts the obtained structure of steel S460NL1 from the simulation of rolling plate of a final thickness of 10 mm according to the technology presented in the table 3. This is a fine-grained ferritic-pearlitic structure, the grain size of ferrite is 10 and that of pearlite is 10. At a magnification of 500x, the bands of ferrite and pearlite are visible. For this final thickness (10mm) the maximal equal distribution of the pressure in all passes was obtained.

a) b)

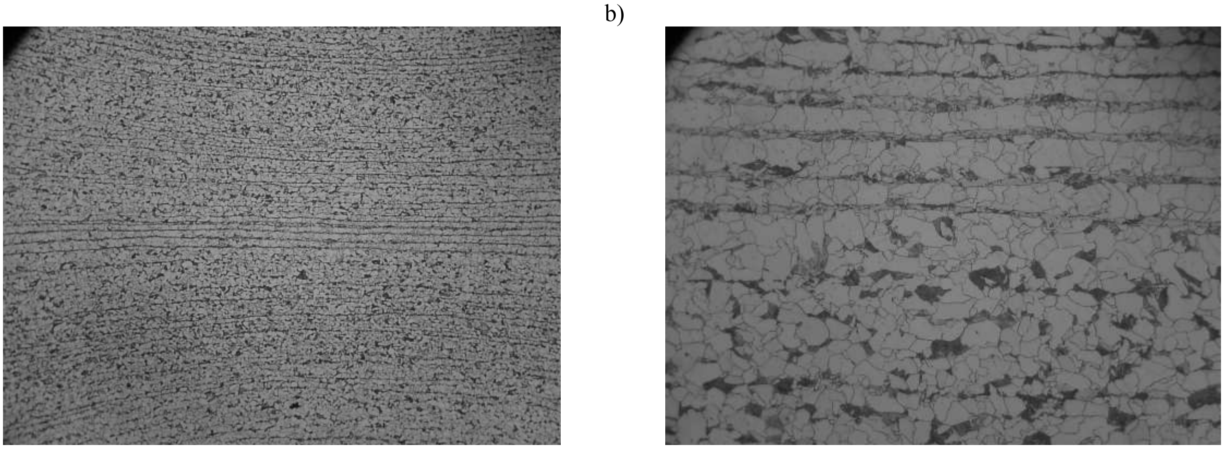

Fig. 1. Structure of steel S460NL1 obtained from the physical simulation of rolling plate of a final thickness of 8 mm according to the scheme shown in Table 2; a) magnification 100x; b) magnification 500x

a) b)

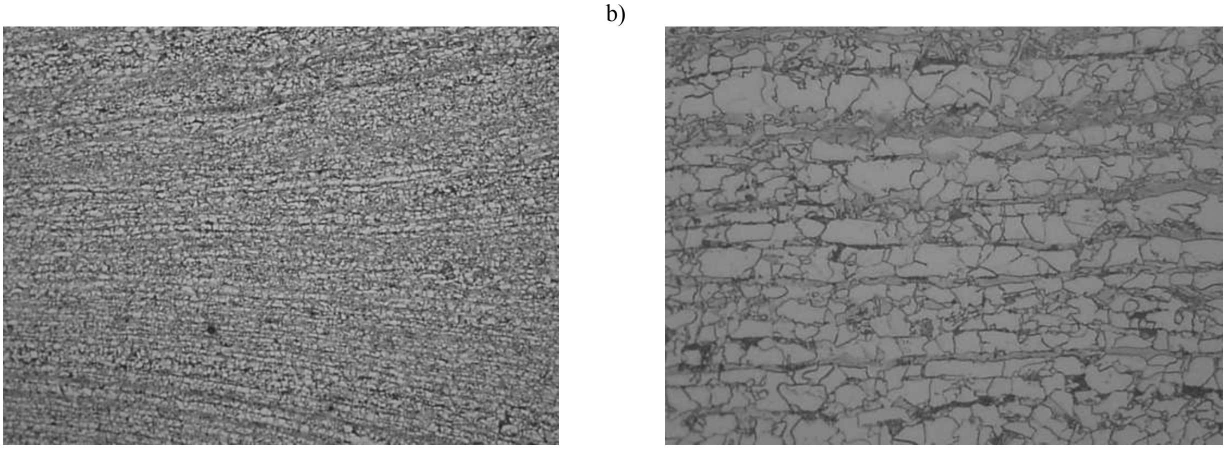

Fig. 2. Structure of steel S460NL1 obtained from the physical simulation of rolling plate of a final thickness of 10mm according to the scheme from Table 3; a) magnification 100x; b) magnification 500x

a) b)

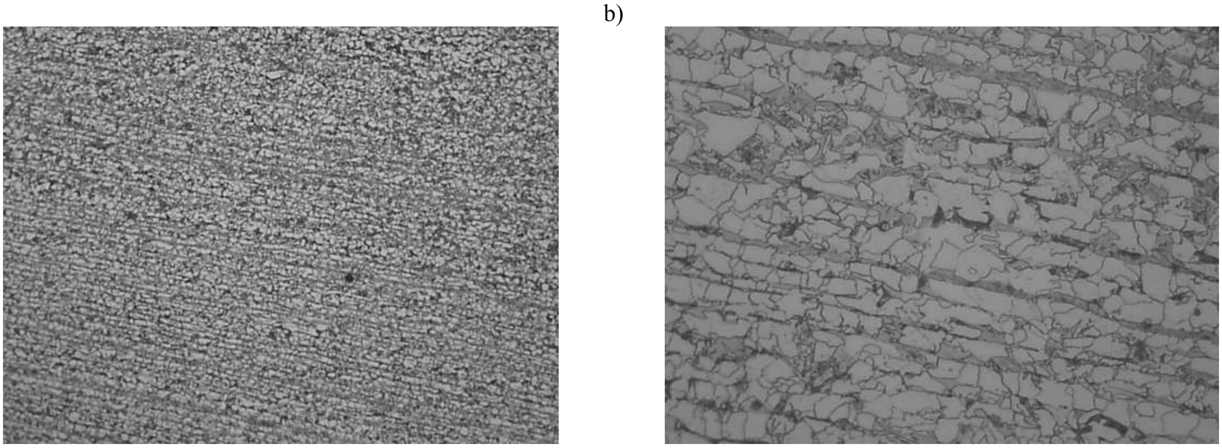

Fig. 3. Structure of steel S460NL1 obtained from the physical simulation of rolling plate of a final thickness of 12mm according to the scheme from Table 4; a) magnification 100x; b) magnification 500x

Figure 3 depicts the obtained structure of steel S460NL1 from the simulation of rolling plate of a final thickness of 12mm according to scheme from Table 4. This is a fine-grained ferritic-pearlitic structure with a visible banding of pearlite, with a grain size of ferrite from 10 to 9 and that of pearlite of 10.

4. Conclusions

The investigation carried out has confirmed that it is possible to obtain and manufacture 8, 10 and 12 mm-thick plates of S460NL1 grade steel by normalizing rolling in the conditions of the plant under consideration. The obtained structures of specimens deformed according to the schemes from Tables 2÷4 are fine-grained ferritic-pearlitic structures, similar to those obtainable by means of normalizing annealing.

The testes carried out have allowed to work out new technology of hot plate rolling for this steel grade. This technology allows to eliminate additional thermal treatment from production process.

References

[1] L.A. Dobrzański, E. Hajduczek, Physical metallurgy and thermal treatment of metal alloys, WNT, Warszawa 1987 (in Polish).

[2] S. Kajzer, R. Kozik, R. Wusatowski, Selected problems from metals plastic working processes, Gliwice, 1997 (in Polish).

[3] P. Akerstrom , M. Oldenburg, Austenite decomposition during press hardening of a boron steel – computer simulation and test, Journal of Materials Processing Technology 174/1-3 (2006) 399-406.

[4] Y. Zhang, D. Li, Y. Li, Modeling of austenite decomposition in plain carbon steels during hot rolling, Journal of Materials Processing Technology 171/2 20 (2006) 175-179.

[5] L. Skalova, R. Divisova, D. Jandova, Thermo-mechanical processing of low-alloy TRIP-steel, Journal of Materials Processing Technology 175/1-3 (2006) 387-392.

[6] L. Chabbi, W. Lehnert, Controlled hot forming of heat treatment steel grades in the intercritical (γ–α) region, Journal of Materials Processing Technology 106/1-3 (2000) 13-22.

[7] B. Smoljan, An analyzing of heat treatment process planning, Journal of Achievements in Materials and Manufacturing Engineering, 20 (2007) 563-566

[8] M. Jahazi, B. Egbali, The influence of hot rolling parameters on the microstructure and mechanical properties of an ultra-high strength steel, Journal of Materials Processing Technology 103/2 (2000) 276-279.

[9] M. Opiela, Influence of the V microaddition on the structure and mechanical properties of 60CrV7 spring steel, Journal of Achievements in Materials and Manufacturing Engineering, 20 (2007) 275-278

[10] P. Korczak, Influence of controlled rolling condition on microstructure and mechanical properties of low carbon micro-alloyed steels, Journal of Materials Processing Technology 157-158 (2004) 553-556.

[11] H. Groβheim, K. Schotten, W. Bleck, Physical simulation of hot rolling in the ferrite range of steels, Journal of Materials Processing Technology 60/1-4 (1996) 609-614.

[12] J. Markowski, M. Knapiński, T. Frączek, H. Dyja, A. Kawałek, Analysis of a deformability of a steel grade 2CS75 in hot plastic working conditions, Metallurgist-Metallurgical news 2 (2005) 97-100 (in Polish).

[13] H. Dyja, J. Markowski, M. Knapiński, A. Kawałek, B. Koczurkiewicz, The physical modeling of the process of normalizing rolling of S355J2G3A steel plates, Proceedings of 13th International Scientific Conference on "Machines and Technology of XXI century", Doneck, 2006, 241-244.

[14] H. Dyja, M. Knapiński, J. Markowski, T. Frączek, A. Kawałek, Modelling of the structure of steel P265GH in the conditions of plate hot rolling, AKAPIT Scientific Publishers, Cracow, 2006, 507 -512 (in Polish).

[15] J. Li, X.A. Yan, G.D. Wang, A.D. Jia, Numerically controlled rolling process of thick metal plate, Journal of Materials Processing Technology 129/1-3 (2002) 299-304.