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Maintenance of Required Mechanical Properties of Sheets with the Use of Rolling Heat

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Results of experimental investigation of possible development of required level of mechanical properties of low-alloy steel sheets during heat treatment with the use of rolling heat are presented.

Keywords: HEAT TREATMENT, NORMALIZATION, ROLLING, THICK SHEET, MECHANICAL PROPERTIES

Introduction

When making rolling and sheet products, the primary task is maintenance of high quality at the minimum expenses and maximum productivity. One of the most widespread methods to produce hot-rolled metal with necessary level of mechanical properties is heat treatment by various technological processes that is related to high power consumption, differs by low productivity and requires a special equipment.

Classical normalization at OJSC "Alchevsk Iron & Steel Works" is accomplished on the plate mill 3000. This kind of heat treatment provides necessary level of mechanical properties and metal structure, however has also such drawbacks as necessity to have a large number of heat-treatment furnaces, raised electric power and fuel consumption on roll stock heating as well as increased scale formation which leads to appearance of defects on the sheets in the form of honeycombs after leveling in mangles.

Classical normalization is possible to carry out also on mill 2250 at OJSC "Alchevsk Iron & Steel Works", however its application field is restricted and inevitably involves the necessity of flow process replanning under the given type of heat treatment and additional operations. Therefore normalization with the use of rolling heat 550-750 °C is an alternative of classical normalization. As hot rolling on mill 2250 at OJSC "Alchevsk Iron & Steel Works" is carried out at temperatures corresponding to heat treatment temperatures or slightly different from them, it is reasonable to heat treat roll stock directly after rolling [1].

It is necessary to note that normalizing rolling technology by temperature regime and structure is applicable for thickness more than 5 mm and represents the rolling process carried out in the lower area of stable austenite in order to obtain structure and properties similar to those after normalization. Besides, not all standards allow normalizing rolling instead of normalization. For example, normalizing rolling is impossible instead of normalization under the standards of American Society for Testing and Materials (ASTM) for steel grade ASTM A516/A516M which needs only normalization [4].

Analysis of literature data concerning heat treatment after rolling showed that the vast majority of publications are devoted to methods of rolled steel hardening intensification by quenching from rolling heat for the purpose to provide higher complex of mechanical properties [3].

As for normalization after rolling, it is known the method how to receive high characteristics of impact strength 0.74 MJ/m^2 and improved plasticity by controlled cooling of 17Г1С steel sheets with thickness 20 mm prior to normalization on mill 3600. Thus, monitoring of visco-plastic characteristics was carried out after both classical normalization and controlled cooling

with the subsequent normalization from rolling heat on mill 3600 at OJSC "Alchevsk Iron & Steel Works" [2]. The task of present research was to investigate the possibility of making sheets with required level of mechanical properties with the use of normalization from rolling heat on mill 2250 at OJSC "Alchevsk Iron & Steel Works".

Methodology

ASTM A516-70 steel sheets with thickness 6.35, 8, 10, 12 mm were rolled and heat treated with utilization of rolling heat. Similar steel sheet with thickness 10 mm was rolled and heat treated for comparative analysis of results of normalization after rolling and classical normalization on mill 3000.

Normalization regime from rolling heat on mill 2250:

- metal initial temperature prior to furnace 680-750 °C;
- temperature of through-type roller-hearth furnace by zones 940 °C;
- metal temperature after rolling 850-860 °C (Ac3 = 842 °C + 10-20 °C).

Classical normalization regime on mill 3000:

- temperature in heat-treatment furnace by zones 920 °C;
- metal temperature after rolling 890 °C;
- specific time of heating 2 min/mm.

Results and Discussion

Results of experimental-industrial rolling and heat treatment of sheets are introduced in **Table 1**. Chemical composition of melts, %: C 0.22; Mn 1.15-1.17; Si 0.32-0.33; V 0.015; Al 0.023-0.028. It can be seen that as a result of heat treatment of sheets with thickness 6.35, 8, 10, 12 mm on mill 2250 at OJSC "Alchevsk Iron & Steel Works" by regime of normalization after rolling there are received stable mechanical properties according to results of metal breaking test: yield stress σ_{YS} = 401-442 MPa at the standard value not less than 260 MPa, ultimate resistance σ_b = 574-593 MPa at the standard value 485-620 MPa and specific elongation δ_5 = 23.5-26.0 % at norm not less than 17.0 %. Comparison of obtained values to results of mechanical tests after classical normalization of 10 mm thick ASTM A51670 steel sheet on mill 3000 at OJSC "Alchevsk Iron & Steel Works" allows concluding that these values are equivalent and correspond to requirements of the standard of specification ASTM A516/A516M.

Table 1. Results of experimental-industrial rolling and heat treatment of sheets

Test parameter	Mill 2250				Mill 3000
	Sheet thickness, mm				
	6.35	8	10	12	10
$T_{start\ rolling}$, °C	1000	1020	1000	1000	Rolling on mill 3000
$T_{end\ rolling}$, °C	820	830	840	840	
Reduction in the last pass, %	-	18	18	18	
$T_{furnace}$, °C	940	940	940	940	920
$T_{metal\ after\ rolling}$, °C	860	850	860	860	890
Grain point on the surface	10 – 9	10	9	9 – 8	10
Grain point in the center	10 – 9	10	90	8 – 9	10 – 9
σ_{YS}, MPa	442	412	401	404	398
σ_b, MPa	580	593	574	588	568
δ_5, %	23.5	24.5	24.5	26	25

Metallographic observation showed that microstructure of metal heat treated on mill 2250 was ferrite-perlite. Grain was 10-9-8 points by 10 point scale of GOST 5639. Comparing the microstructure of 10 mm thick sheet normalized on mill 3000 to the microstructure of sheet with thickness 8 and 10 mm normalized after rolling on mill 2250, it is necessary to note that their structures are equivalent.

Besides, additional investigations were carried out in order to check resistance of initial structure to secondary heat treatment of 09Г2С steel sheets with thickness 8 mm normalized with utilization of rolling heat on mill 2250. Samples of sheets after normalization from rolling heat were subjected to heat treatment by classical normalization regime in the laboratory environment (**Table 2**).

Normalization regime from rolling heat on mill 2250:

- metal initial temperature prior to furnace 710 °C;
- temperature of through-type roller-hearth furnace by zones 950 °C;
- metal temperature after rolling 880 °C.

Normalization regime in the laboratory environment:

- temperature in heat-treatment furnace by zones 930 °C;
- specific time of heating 2 min/mm.

By results of metallographic observation it was determined that microstructure of samples was ferrite-pearlite and fine-grained. Results of breaking tests in relation to yield stress, ultimate resistance, specific elongation and impact strength at 40 °C completely satisfy the requirements of GOST 5520-79. Thus, stability of structural condition of heat treatment from rolling heat after repeated normalization of samples is proved in the laboratory environment.

Also, we investigated microstructure of S355 steel sheet samples with thickness from 5 to 12 mm. Sheets were heat treated in the temperature range by regime of normalization after rolling. Metal structure was fine-grained, the grain was round equiaxial 10-9-8 points, banded orientation near the sample surface was 0 points and to 2.5 points in the central part of sheet.

Table 2. Heat treatment regimes and mechanical properties of steel grades under investigation

Steel grade	Sheet thickness, mm	Specified T prior to furnace, °C	Temperature at the exit from furnace, °C	σ_{YS}, MPa	σ_b, MPa	δ, %	Impact-bending test, KV –20 °C J/cm^2
S355	5	650	860–880	392 – 458 / 426.3	520 – 623 / 556.9	25 – 32 / 28.7	26 – 58 / 34.58
	6	667	860–870	368 – 443 / 414.3	514 – 580 / 556.0	24 – 34 / 28.4	25 – 59 / 35.48
	8 - 12	710 - 750	870–880	364 – 454 / 389.9	496 – 575 / 536.5	23 – 31 / 27.6	35 – 80 / 52.7 KCU –40 °C
09Г2С	8	710	880	351 – 434 / 364	487 – 570 / 511	28 – 34 / 31	67 – 112 / 85
	8		930				KV –46 °C
A516-70	6.35	680	860	370 – 439 / 408.4	512 – 580 / 532	27 – 28 / 27.5	-
	8	710	850	355 – 417 / 368.8	513 – 559 / 529.5	23.5 – 27 / 2497	23 – 57 / 33.7

As a result of metal microstructure analysis, dependence of grain point on thickness of sheet rolled on mill 2250 (**Figure 1**) is obtained. It can be seen that as sheet thickness grows from 5 to 12 mm, grain size reduces which is characteristic also for sheets with thickness 8-12 mm normalized on mill 3000.

In view of the above it is possible to mention that at normalization after rolling heating on mill 2250 there is a phase recrystallization of austenite grain in the high temperature field, formation of more homogeneous metal structure due to uniform distribution of superfluous component (ferrite) as well as decrease of internal stresses in steel. Obtained microstructure and properties correspond to normalized rolled sheet with high renormalization stability of original structure.

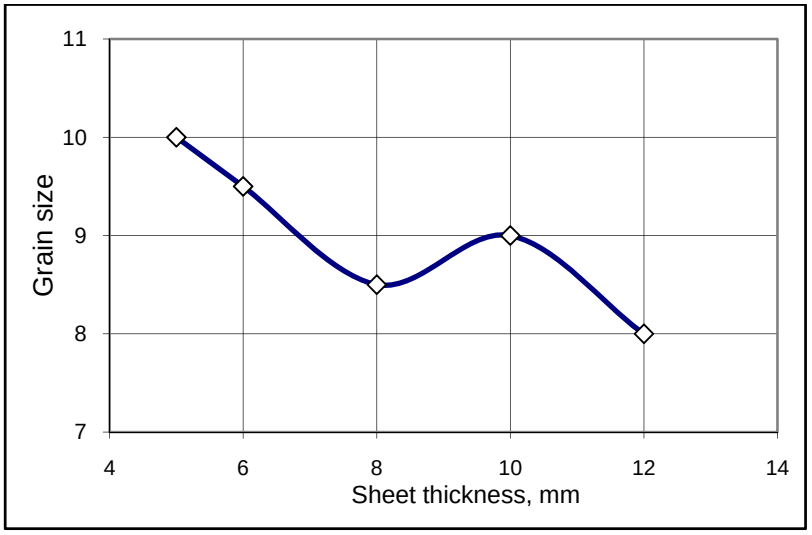

Figure 1. Dependence of grain size of low-alloy steels on sheet thickness at normalization after rolling

Conclusions

It is determined that application of normalization after rolling of low-alloy steel 5-12 mm thick sheets on mill 2250 at OJSC "Alchevsk Iron & Steel Works" allows developing the required level of mechanical properties of metal.

References

1. M. S. Podgayskiy, N. T. Egorov, A. N. Zannes. *Bulleten Nauchno-Tekhnicheskoy Informatsii Chernaya Metallurgiya*, 1975, No. 8, p. 50-51.*

2. *Review "The Newest Achievements Abroad"*, Moscow, Chermetinformatsiya, 1992, No. 5-6.*

3. I. G. Uzlov, V. K. Babich, N. G. Bochkov. *Heat and Thermomechanical Treatment of Rolled Metal,* Moscow, Metallurgiya, 1981, 104 p.*

4. V. I. Spivakov, V. Ya. Sovenkov, M. S. Babitskiy. *Stal*, 1983, No. 12, p. 39-43.*

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Получение требуемого уровня механических свойств листов с использованием тепла прокатного нагрева

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Приведены результаты экспериментальных исследований возможности получения необходимого уровня механических свойств листов из низколегированной стали при термообработке с использованием тепла прокатного нагрева.