THE ANALYSIS OF PRELIMINARY ROLLING PROCESS OF X80 ÷X100 PLATES IN LABORATORY CONDITIONS

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Abstract

In the work the results of plate rolling process of the experimental steel designed for plate which meets the requirements for grade X80÷X100 according to API5L were presented. The simulations were carried out using laboratory stand mill duo 300. Aim of experiment was a verification of rolling conditions determined based on physical and numerical simulations. The structure and mechanical properties of plates after thermo - mechanical treatment were determined.

Keywords: HSLA steels, physical simulation, controlled rolling, accelerated cooling

1. INTRODUCTION

In 2011 at the Institute of Modeling and Automation of the Plastic Working Processes of Czestochowa University of Technology the work was carried out with the aim to design the basis for the technology of controlled rolling of plates meeting the requirements of grades X80÷X100 using the rolling plant line of one of the plate rolling plant in Poland. The chemical compositions were selected which are currently being tested regarding their suitability for rolling in order to obtain the strength parameters required by grades X80-X100 [1]. For better mechanical properties chemical composition of pipeline steel were modified [2]. The volume fraction of ferrite formation was limited. These steels were conventionally numbered: 350 and 351 and their chemical compositions are presented in **Table 1**.

Table 1 Chemical composition for investigated steel

No.	C	Mn	Si	Mo	Ni	Cu	Nb	Ti	N
350	0.076	1.91	0.23	0.27	0.20	0.08	0.05	0.026	0.004
352	0.056	1.88	0.19	0.30	0.27	0.017	0.04	0.022	0.005

The 100 mm x 100 mm x 1000 mm ingots of metal were melted in VSG vacuum furnace, were pre-rolled for 60 mm thickness in Institute of Ferrous Metallurgy in Gliwice in Poland. Based on result of physical modeling of rolling and accelerated cooling of investigated steel [2, 3] conditions of deformation and cooling processes were determined. The verification of this parameter was obtained during thermochemical rolling process in semi-industrial rolling mill with accelerating cooling device.

2. EXPERIMENTAL

In Faculty of Production Engineering and Materials Technology of Czestochowa University of Technology the laboratory rolling mill was built. Main element of mill is rolling stand duo 300 and air-water cooling device. A plan of laboratory mill arrangement is shown in **Fig. 1**

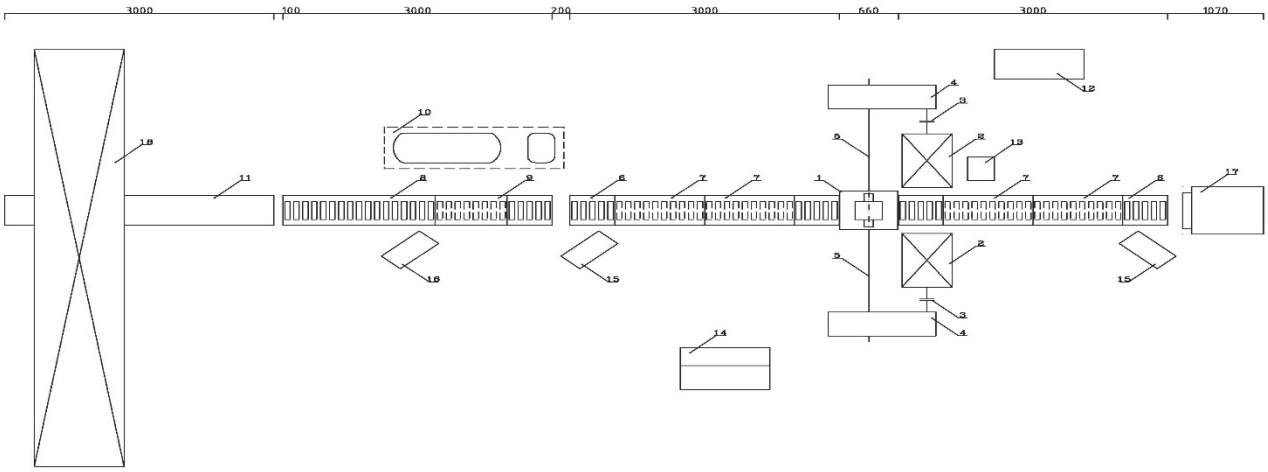

Fig.1 Scheme of laboratory rolling mill arrangement

The main equipment of this rolling system is ø300 mm x300 mm two-high reversing mill (1). Each roll has independent drive consists of electric motor (2), clutch (3), main gear (4) and shaft (5) horizontally symmetrical placed. On both sides of cage mill, two sections of roller bed are located (6). Over the each roller table, two section head shields (7) are placed. On extension of one conveyor, the cooling bed (8) with active zone of water air spray (9) is located. It is supply from compressed air and water pump station (10). An addition of cooling equipment is the quench bath (11). Drives of main motors and other control elements of the cage are integrated in main cabinet (12). Oil supply for hydraulic systems of rolling mill and conveyors is realized by hydraulic stations (13). Steering the working of the whole system is done from the control panel (14). Electrical equipment of roller tables heat shields and cooling bed are placed in steel cases (15,16) located next to them. The batch for rolling is heated in the electrical furnace (17). Operation of rolls exchange or other heavy services with help of the 2 Mg gantry is done (18). Total length of whole laboratory rolling system is over 14 meters. In the future, in the gap between roller table and cooling bed conveyor, the saw for hot strip cutting will be mounted.

Fig. 2 Photos of laboratory rolling mill

During the process, the main parameters, as the rolling force and torque were measured and recorded. The force was measured directly by two 250 kN sensors (CL21 type, manufactured by ZEPWN Czerwinscy), placed between housings of bearings of upper roll and the set screws. Signal from each load cell was gained and

conditioned by independent industrial instrumentation amplifier, CL100 type, to the voltage within 0-10V range. The rolling torque, separately for upper and down roll, was measured indirectly with using of feature of the main motors drives, ACS 800 type. On the analog output of RMIO boards installed on both frequency converters, the results of internal DSP calculation of motor torque as a function of angular speed and actual power was available as the current signal in standard 0-20 mA with 24 ms updating interval.

These all standardized signals were transferred to the analog inputs module of Vision V1210 programmable logic controller, to further processing, displaying and storing. In special subroutine, on the base of calibration function for each load sensors, the real value of rolling force has been calculated, Similarly, taking into consideration ratio of main gear (1:40) the rolling torque on the rolls was computed. Theses values on the PLC's screen were displayed and visualized as well as saved to the file with 100 ms interval.

Also the key issue from the point of view of new rolling processes development is monitoring of temperature of rolled strip. For technological reasons, continuous measurement can only provide non-contact methods [4]. Because it is important to also know the temperature profile across the width of the band's surface, applied on-line monitoring using infrared cameras, capable of measuring the temperature distribution in any of the selected line in the image. The four cameras, OPTRIS P160 with heat shield and water proof (IP67) were used. Two of them were located over the inputs to the rolling mill, next two, were placed over and under the cooling bed.

Analysis of industrial pipeline plate rolling process was done. The industrial process is carried out in two stages. The first step is preliminary rolling from 225 mm x 2250 mm slabs for 40 mm and 45 mm thickness strips. The second step is rolling for 15 mm thickness plates. There is no possibility to carried out rolling process in semi - industrial with the same conditions. The calculations for adjustment of the actual rolling conditions for rolling in semi-production line were done. To enable the rolling of the proposed schemes a reduction of initial width from 117.5 mm to 57 mm was done. The initial dimension was 60 mm x 57 mm x 450 mm and total force on the metal pressure rollers should not exceed the allowable pressure duo 300 mill, which is 500 kN. In **Table 2** calculated parameters of laboratory rolling line 40 mm plate dedicated to sheet thickness 15 mm are presented.

Table 2 Calculated parameters of preliminary rolling test 15mm sheet from half-product plate 40mm

h_0=60	Δh mm	ε	T. ºC	b mm	Δb mm	μ	p_{sr} MPa	F_c MN
h_1= 52	8	0.143	1180	62	5.0	0.323	143.8	0.30
h_2=45	7	0.145	1174	67	5.0	0.326	147.0	0.31
h_3=36	9	0.223	1167	74.5	7.5	0.330	151.2	0.39
h_4=28	8	0.251	1159	82.9	8.3	0.334	157.5	0.43

Table 3 The recorded parameters of rolling

Pass no	h_0 [mm]	h_1 [mm]	Δh [mm]	ε	b_0 [mm]	b_1 [mm]	Δb [mm]	T_P, [ºC]	p_{sr} [MPa]	F_{cz} [MN]
1	57.0	53.0	4.0	0.07	60.0	61.0	1.0	1168	125.3	0.1
2	53.0	43.0	10.0	0.21	61.0	63.9	2.9	1088	155.8	0.29
3	43.0	36.0	7.0	0.18	63.9	66.3	2.4	1045	187.6	0.37
4	36.0	30.0	6.0	0.18	66.3	68.8	2.5	972	221.9	0.41
5	30.0	26.0	4.0	0.14	68.8	70.8	2.0	920	253.4	0.43

The slab was heated in 1200 °C for 1 hour in argon's atmosphere. The rolling temperature by thermovision camera, torque and force were recorded. The exemplary temperature measuring during cooling is shown on

Fig. 3. After last pass strip was quenched in water (**Fig. 4**). The recorded parameters of rolling test from 60 mm x 57 mm are presented in **Table 3**. The 1st pass ε=0.07 for removing mill scale was used, and after that initial height of strip was 57 mm. The size of former austenite grain was determined and it was about 20 μm.

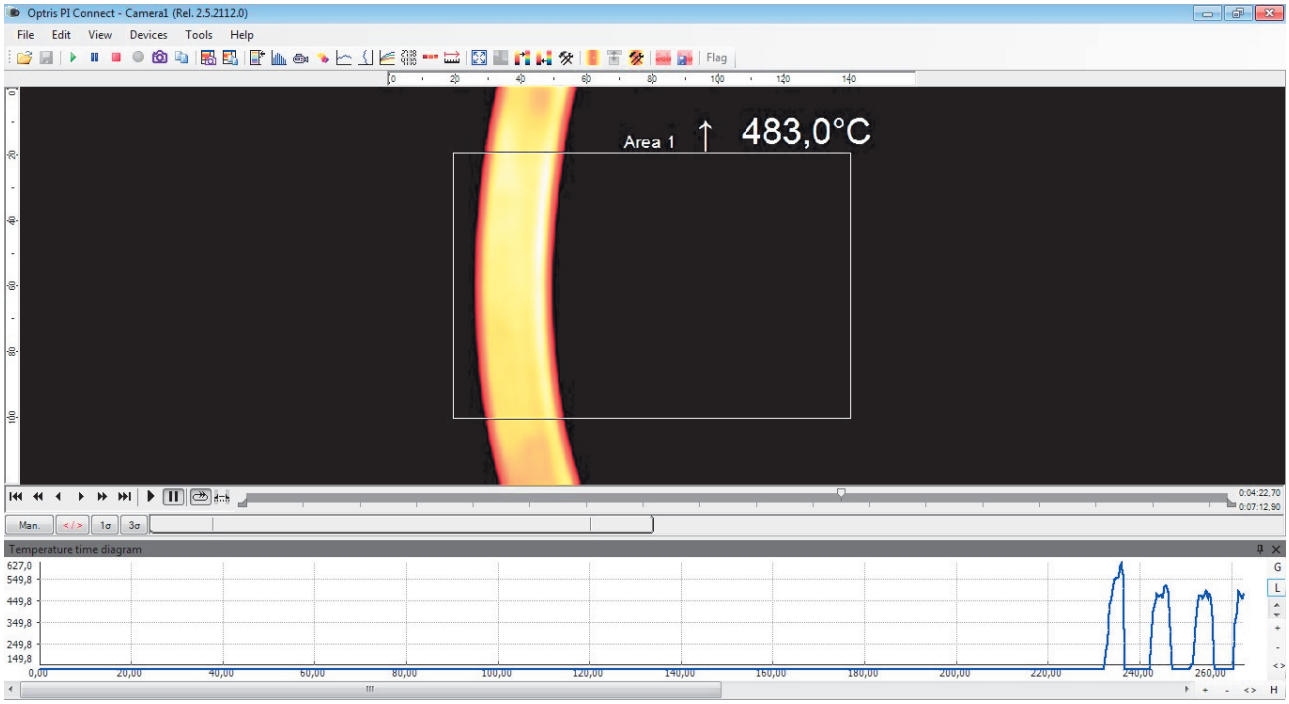

Fig. 3 The temperature measured during cooling after rolling

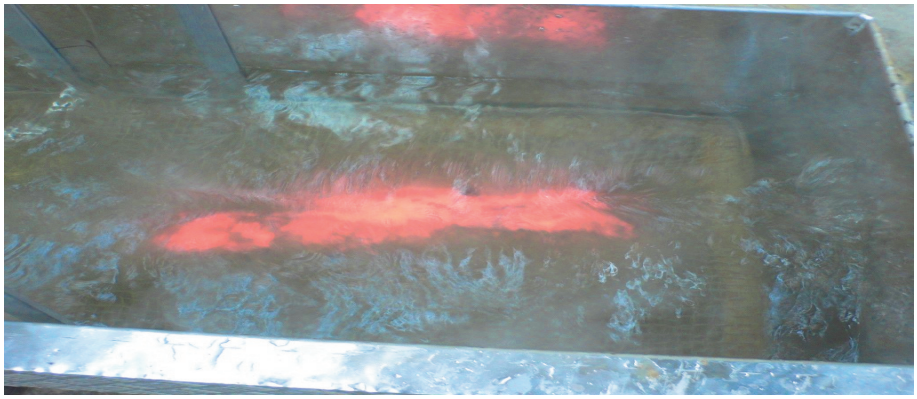

Fig. 4 The quenched strip

SUMMARY

The multipass rolling of low carbon steel in laboratory conditions was done. The parameters of rolling process determined based on analyze result of physical modeling were done. The process was carried out only in 4 passes but based on volume of former austenite grain size about 20 microns it can be concluded that properties of plate will be very high. For confirmation this thesis rolling process should be carried out with higher cross section reduction.

The problem with high decrease of temperature during rolling process was observed. The temperature after last pass was 920 °C. It is too low for preliminary rolling. Next stage of rolling process will be rolling with special covers for reduction heat transfer.

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