THE COOLING EFFICIENCY OF TWO TYPES OF SPRAY NOZZLES DURING HOT ROLLING OF TUBES IN STRETCH REDUCING MILL

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Abstract

This paper deals with optimization of roll cooling during hot rolling of tubes in stretch reducing mill (SRW) in Železiarne Podbrezová. Temperature of the tube after rolling in SRW should be higher than Ar_3 as much as 30 - 50 °C. Current practice in SRW cooling system in Železiarne Podbrezová utilizes nozzles A with nominal flow rate of 10 l/min. These nozzles cannot maintain stable spray cone for lower flow rates that are necessary to pass the Ar_3 rolling temperature limits. Prospective nozzles B with nominal flow rate of 5 l/min were tested and evaluated. Although the highest possible rolling temperature is of primary importance here, overheating of the rolls should be avoided at all costs. All our experiments were carried out with single temperature of the furnace in which hollows are preheated prior to rolling. Surface temperature of the rolls was measured by means of K-thermocouple contact measurement system.

Keywords: Seamless steel tubes, stretch reducing mill, roll temperature, roll cooling

1. INTRODUCTION

Stretch reducing mill is a hot rolling mill for manufacturing of seamless tubes (see **Figure 1**). By means of this forming equipment, final tube dimensions and final mechanical properties of hot rolled tubes are achieved after cooling [1-5]. During rolling of seamless tubes in a stretch reducing mill (SRW) the tubular feedstock (the hollow) of a moderate length passes several stands with circular or oval rolling gap without using any internal tool. During stretch reducing the diameter and wall thickness of the hollow are changed, depending on the final dimensions. The input feedstock of a moderate length is usually stretched in row of rolls, depending on the final dimension. The stretch reducing mill can be used [1-6]:

- To extend the production range of tubes of small dimensions,
- To produce the tubes with small and medium diameter,
- To reduce the production costs.

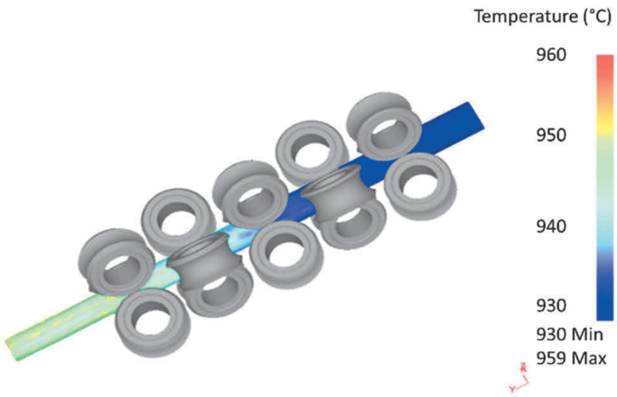

Figure 1 Numerical model of stretch reducing mill [2]

According to technological and operating norms of hot roll plant, the total reduction of diameter should not exceed 80 % [7-8]. The reduction is determined for *i*-th SRW stand as follows:

$$R_i = \frac{D_{i-1} - D_i}{D_{i-1}} \tag{1}$$

where:

R_i - diameter reduction in *i*-th SRW stand (%),

D_i - hollow diameter in *i*-th SRW stand (mm),

D_{i-1} - hollow diameter in (*i*-1)-th SRW stand (mm).

The rolls condition in SRW stands are of vital importance for obtaining the final diameter of the tube. In this process, it is necessary to focus on the surface temperature of the hollow and optimal surface temperature of the rolls. Therefore, decision has been made to optimize the roll cooling process by means of new nozzles with a smaller flow rate. With these nozzles we were aiming towards rolling in homogenous austenitic state of the material (i.e. 30 - 50 °C over the austenization temperature) and we also wanted to ramp up the finishing temperature as well. The aim of this article was comparison of the cooling efficiency of two types of nozzles during hot rolling of tubes in stretch reducing mill in Zeleziarne Podbrezova.

2. MEASURMENT METHODOLOGY AND INSTRUMENTS

When choosing the appropriate methodology of temperature measurement, two basic methods were at our hand: contact and contactless. The contact method proved to be more suitable for measuring the surface temperature of the roll [7-12]. Contactless measurement would be very difficult to use for several reasons (for instance the low emisivity of a rather glossy working surface of the roll, the presence of cooling water, steam etc.) Customized K-type thermocouple (TC) probe was used during our experiments. Based on our pilot measurements it can be concluded that the measurement methodology by means of TC probe was well chosen and successful. The measurement itself was carried out while the stretch reducing mill was put to a halt (cooling water and roll drives were turned off). The TC probe was put on the measurement spot of the working surface of the roll and the signal was recorded by a computer [11]. To ensure a reliable measurement (see **Figure 2**), the following conditions need to bemet [9-14]:

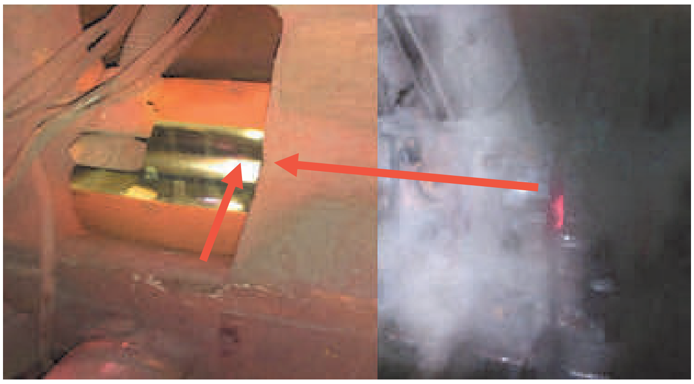

Figure 2 Detailed view on the working surface of the roll with red arrow pointing at the measurement spot when using contact temperature probe

- Perpendicular orientation of the probe body with respect to the roll surface [9-11],
- The rectangular sensing ribbon should be aligned so that the longer side matches the roll circumference [10-12],
- The measurement spot should lie on the symmetry plane of the working surface of roll [9-11],
- The measurement should take at least 5 seconds while fulfilling all the conditions mentioned above [9-11].

3. EXPERIMENTAL MATERIAL

The experiment was carried out during the process of hot rolling of seamless steel tubes at Železiarne Podbrezová. For this experiment the tubes with the diameter (OD) 26.9 mm and the wall thickness (WT) 2.6 mm were selected. These dimensions are quite extreme from thermal point of view as the very fast cooling of the material can be observed during stretch reducing. The steel grade chosen for the experiment was fairly ordinary and indicated in internal report [7]. The parameters of the process were as follows [7]:

- Feedstock (hollow) with the diameter 140 mm,
- Cooling power (%) for nozzle type A,
- Cooling power (%) for nozzle type B,
- Standard productivity of tube hot rolling plant in Železiarne Podbrezová

The diameter reduction used in our SRW rolling experiment (see **Figure 3**) is equal to the reduction observed during standard rolling process of tubes with OD = 26.9 mm.

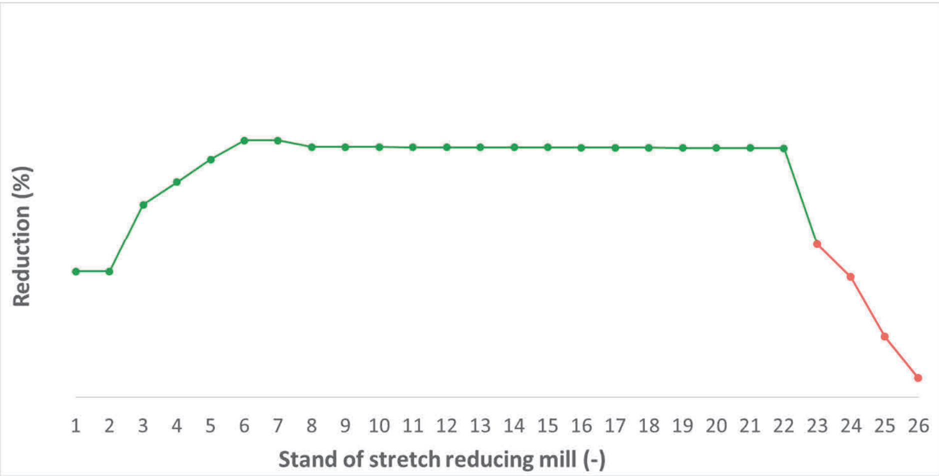

Figure 3 Diameter reduction for tubes with OD = 26.9 mm

In our experiment the cooling power for nozzle A and nozzle B was proposed. The cooling power for nozzle B was set up twice as high as for nozzle A. In **Figure 4** a graphical representation of cooling power for both types of nozzles is shown.

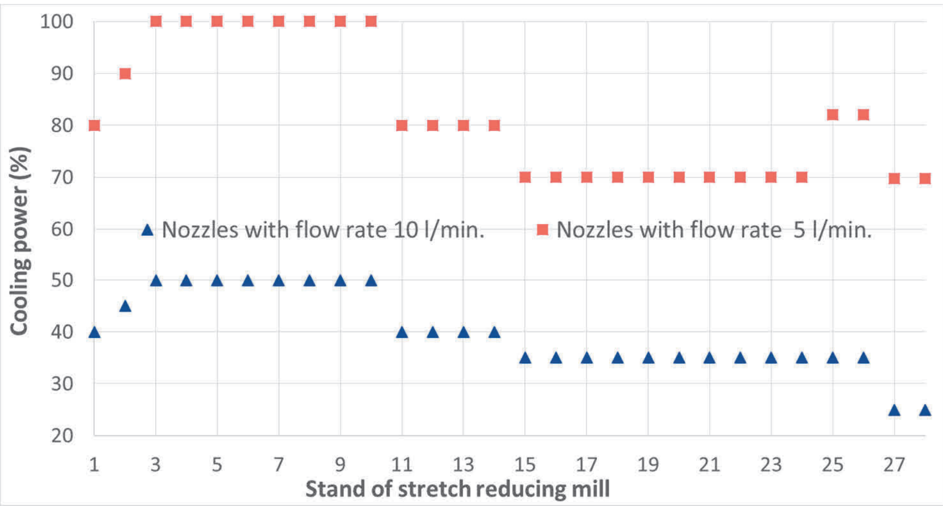

Figure 4 Comparison of cooling power of nozzle type A and nozzle type B

4. RESULTS

The experiments were carried out by means of contact temperature measurement. The first part of experiment was conducted with the nozzles having 10 l/min nominal flow rate (type A). The experiment involved SRW rolling of 300 hollows into tubes until stable surface temperature of the rolls and the final roll temperature were achieved. It was necessary the measure the roll temperature several times, therefore the final number of hot rolled tubes was set to 415 pieces. The result of surface temperature measurement can be seen in **Figure 5**.

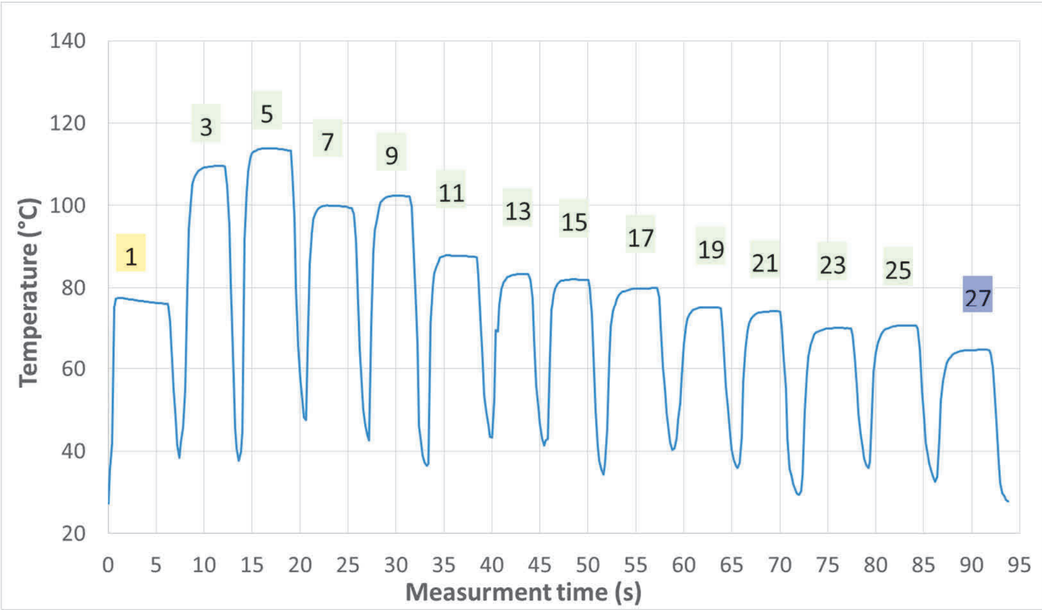

Figure 5 Measurement of surface temperature of rolls (A-type nozzles with nominal flow rate of 10 l/min.)

The second part of the experiment started with the replacement of nozzles. This time, nozzles with flow rate of 5 l/min (type B) were used. After all the nozzles were replaced, it was planned to roll 600 hollows into tubes to quantify the cooling effect of B-type nozzles. Therefore the final number of hot rolled tubes was set to 815 pieces. The result of surface temperature measurement can be seen in **Figure 6**.

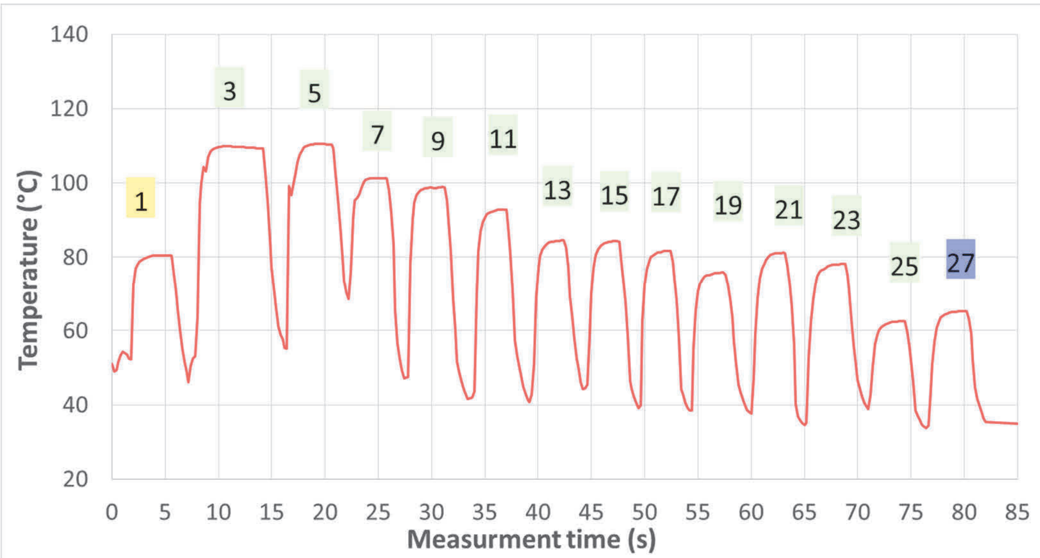

Figure 6 Measurement of surface temperature of rolls (B-type nozzles with nominal flow rate of 5 l/min.)

5. DISCUSSION

The main object of this paper as it was mentioned in the introduction was the optimization of finishing temperature of SRW tube rolling by means of changing of cooling nozzles. The decrease in the cooling effect of nozzles with flow rate of 10 l/min was supposed to be observed as the final effect. A further contribution could be seen in final mechanical properties of the tube or more precisely in the tube produced by normalized rolling. In case of the positive outcome it would not be necessary to carry out the subsequent annealing. The results of the experiment show only a slight increase of the finishing temperature - on average by 15 °C. In **Figure 7** the finishing temperature is compared for both types of nozzles (A-type with 10 l/min and B-type with 5 l/min, respectively) [13-17].

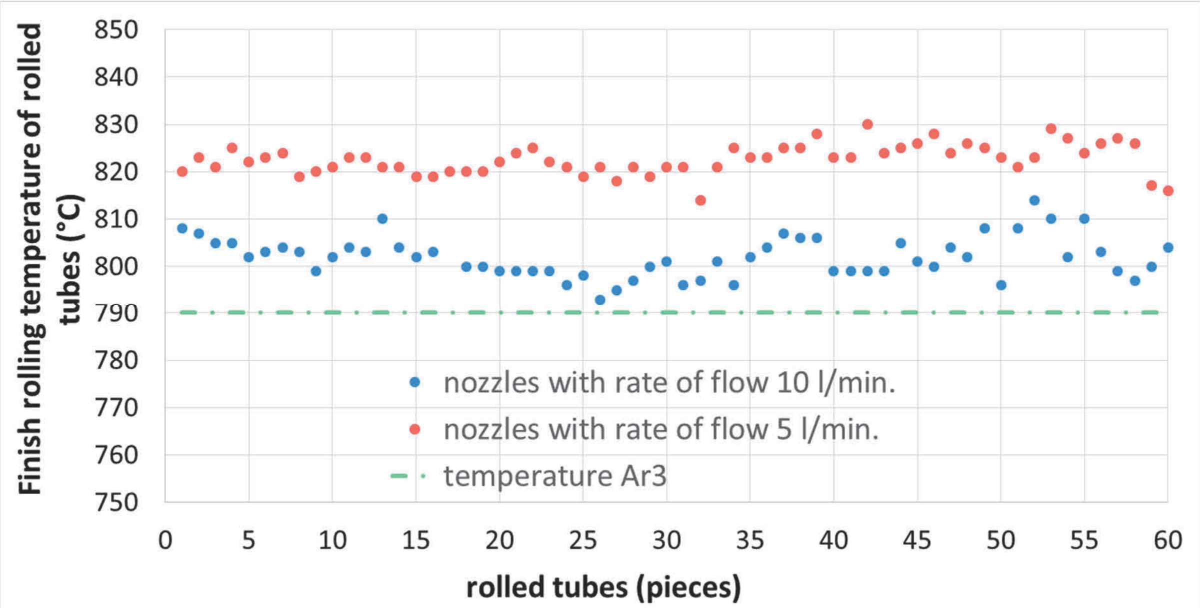

Figure 7 Comparison of finishing temperature using two types of cooling nozzles

Our experiment proved that the usage of nozzles with flow rate of 5 l/min is efficient only for good cooling of SRW rolls. It does contribute to the finishing temperature only slightly. This nozzle is capable of cooling the roll until the surface temperature ranging between +/- 5 °C is achieved for specific surface temperature of roll. In both cases, the rolls have the optimum working temperature in all SRW stands. The decrease of the flow rate from 10 l/min to 5 l/min causes the lowering of the cooling intensity of the rolls. As a result, the increase of the roll temperature was observed. This poses a risk of the roll or stand getting damaged or quality of the surface of rolled tube deteriorating. Nevertheless, the hollows are cooled more intensively in the last 5 SRW stands.

6. CONCLUSION

Based on the study of the effect of nozzles on the increase of finishing temperature during SRW rolling and their efficiency, the following conclusions can be drawn:

1) The temperature of the rolls measured during test using two types of nozzles provided significant information.
2) The change of nozzles A to nozzles B has a slight effect on finish rolling temperature (see **Figure 7**).
3) Less intensive cooling can be used in a controlled manner in case that the value Ar_3, which is lower than 815 °C, is determined.
4) By decreasing the cooling intensity, the temperature of the rolls increases, which causes the low quality of tube surface.

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REFERENCES

[1] POČTA, B. Steel tubes: Seamless tubes (in Czech). Praha. SNTL. 1963. 416 p.

[2] ĎURČÍK, R., PARILÁK, Ľ., TURŇA, J., BUČEK, P., MAŤAŠ, P. and PATIN, Ľ. Results of numerical simulation. (Internal report 20/2017/ŽPVVC, in Slovak). 2017. 46 p.

[3] MOJŽIŠ, A. Proposal of technology of pressing and rolling of tubes and calibration of stretch reducing mill (in Slovak). Diploma work. Košice. 1999. 50 p.

[4] REŠKOVIČ, S., KRIŽANIČ, R. and VODPIVEC, F. Numerical design of a hot-stretch reducing process for welded tubes. *Materials and Technology.* 2010. vol. 44, no. 5, pp. 239-242.

[5] MAPELLI, C. and MONTELATICI, L. Stretch reducing mill: a new approach by neural networks. *Metallurgical Research & Technology*.2001. vol. 98, no. 10, pp. 881-887

[6] MAÁR, K., KVAČKAJ, T. and BOGNÁR, J. Pressing and Drawing (in Slovak). Skriptá. ES VŠT. Košice. 1984.

[7] PARILÁK, Ľ., TURŇA, J., BUČEK, P., BEKEČ, P., BURIK, P. and KVAČKAJ, T. Measurment of surface temperature of rolls in stretch reducing mill - comparison of nozzles with flow rate 5 l/min. a 10 l/min. (internal report 15/2017/ŽPVVC, in Slovak). 2017. 49 p.

[8] Železiarne Podbrezova a.s. [online]. [viewed 21.3.2018], http://www.oceloverury.sk/potrubia/tvarovky.nsf/BBEFC66A64B30305C125751B004C2AE7/$File/Prirucka_Uzivatela_Ocelovych_Rur.pdf

[9] Work safety and technology prescription for operating the device IMS in stretch reducing mill (in Slovak) (SRW) PBTP-02.69-428/14

[10] Work safety and technology prescription for operating the device stretch reducing mill (in Slovak). PBTP-02.34-238/12

[11] TURŇA, J., PARILÁK, Ľ., BUČEK, P., MAŤAŠ, P. and KVAČKAJ T. Measurment of roll temperature in stretch reducing mill. *Hutnik: Wiadomości Hutnicze*. 2017. vol. 84, no. 8, pp. 380-382.

[12] OMEGA - 8 Thermocouple Data Acquisition system [online]. [viewed 22.3.2018]. Available from: https://www.omegaeng.cz/pptst/tc-08.html

[13] OMEGA - Thin Leaf-Type Thermocouples [online]. [viewed 22.3.2018]. Available from: https://www.omegaeng.cz/pptst_eng/88000_thinfoil.html

[14] OMEGA - Introduction to Temperature Measurment [online]. [viewed 22.3.2018]. Available from: https://www.omegaeng.cz/prodinfo/thermocouples.html, [on-line]

[15] HORSKÝ, J. and KOTRBÁČEK, P. Cooling for profile rolls (in Czech). In *Odborná konferencia ŽP VVC*. Tále: HLP grafik s.r.o. 2013, p. 206.

[16] IMS Messesysteme GmbH [online]. [viewed 21.3.2018]. Available from: http://www.imssystems.com/uploads/system_files/wall-thickness.pdf#page=17

[17] IMS Messesysteme GmbH [online]. [viewed 21.3.2018]. Available from: http://www.imssystems.com/uploads/system_files/quality-data-management.pdf