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ANALYSIS OF THE TEMPERATURE CHANGE OVER THE CONTINUOUS INGOT LENGTH ON THE PARAMETERS OF ROUND BAR ROLLING PROCESS

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The paper presents results of theoretical and experimental studies on the effect of feedstock end overcooling before the first rolling stand on the plastic flow of metal and on the energy and force parameters during bar rolling process. From the obtained investigation results it has been found that the uniform heating of the feedstock in the stepped furnace does not insure the uniform plastic flow of metal over the rolled band length. Therefore, it is necessary to modify the method of feedstock heating in the stepper furnace in order to obtain a uniform temperature over the length of the feedstock before the first rolling stand.

Key words: groove rolling, heat exchange, metal plastic flow, energy and force parameters, thermovision investigation

INTRODUCTION

The accuracy of Shape Mill products is defined by their deviations of the actual cross-sectional dimensions of band from the nominal values. The principal dimensions of Shape Mill products is their height and width of finished product and the mass of one running metre. For round bars, their ovality is also determined as the difference between the horizontal and vertical diameters, while for square bars, the difference between the diagonals is determined. The manufacture of rolled products within negative deviations of dimensional tolerance arouses increasingly great interest among purchasers. Newly built Shape Mills [1] and existing Shape Mills that have been modernized in recent years [2] manufacture products with a dimensional accuracy tighter than the $^{1}/_{4}$ of that of the DIN Standard. Introducing new solutions to the rolling technology and Rolling Mill machinery and equipment assures the manufacture of rolled products within a narrow range of dimensional tolerance, which results in considerable metal savings, as well as a reduction in the mass of structures, equipment and machine parts [3].

Contemporarily constructed heating furnaces allow the end of feedstock to be heated up to a temperature higher than that of its beginning. It must be determined, however, how much the feedstock end temperature will have to be higher relative to the feedstock beginning temperature so that a uniform temperature distribution over the feedstock length be obtained before the first rolling stand.

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The main objective of the investigations carried out was to examine the effect of feedstock end overcooling before the first rolling stand on the metal plastic flow and on the energy and force parameters during bar rolling process.

EXPERIMENTAL CONDITIONS AND SIMULATIONS

The studies were carried out for one of Poland's continuous bar Rolling Mill.

The study analyzed the effect of the change in the temperature of the heated feedstock beginning and end on the plastic flow of metal during rolling of 20 mm-diameter bars. Round bars were rolled in 17 stands (17 rolling passes). The theoretical and experimental studies were carried out for the starting and end regions of the feedstock and the band and for the end region of the feedstock and the band heated to a temperature higher that the nominal temperature which was 1 150 °C for the entire volume of the continuous casting. The mill feedstock was a 14 000 mm-long 160×160 mm continuous casting. The use of that long feedstock caused the duration of cooling the feedstock end prior to the process of rolling in the first rolling stand to be much longer than that of cooling the feedstock beginning. This resulted in an uneven temperature distribution over the length of the feedstock and then the rolled band (overcooling of the end the feedstock, compared to its beginning). The theoretical and experimental study was divided into two stages. In the first stage of the study, a uniform temperature of 1 150°C within the entire continuous casting volume was assumed. Whereas, in the second stage of the study, to minimize the unevenness of temperature distribution over the casting length before the first rolling stand, the casting end temperature during heating the casting in the heating furnace was increased by 50 °C relative to the nominal casting temperature (1 150 °C).

The rolling speed ranged from 0,10 m/s in the first stand to 7,0 m/s in stand no. 17; the roll temperature was 60 °C, and ambient temperature 20 °C. The coefficient of heat exchange between the rolls and the band was α = 3 000 W/m²K, and the coefficient of heat exchange between the band and the air was α_{air} = 100 W/m²K. The friction coefficient and the friction factor were assumed to be variable, being dependent on the band temperature, and amounting to, respectively, μ = 0,3÷0,42 and m = 0,6÷0,8. The test material was steel 20MnB4 [4].

The following object's parameters were assumed for thermovision tests: emissivity, 0,82; distance from the object, 3 m; ambient temperature, 20 °C; reflected temperature, 20 °C; relative humidity, 50 % [5].

RESULTS AND DISSCUSION

Figure 1 shows example results of numerical computation of temperature distribution for the starting and end regions of the feedstock and for the end feedstock part heated up by 50 °C before the first rolling stand.

Unevenness of temperature occurring initially at the beginning and end of the feedstock decreased as the rolling process progressed in particular passes. The main cause of this phenomenon was the contact of the band with the rolls during the rolling process and the generation of heat due to plastic deformation. The temperature values computed numerically were compared with the actual values measured with a thermovision camera for all passes. For the feedstock upstream the first rolling stand (Figure 2) they amounted to, respectively: 15 °C (with a relative error of 1,4 %) for the feedstock beginning, 12 °C (with a relative error of 1,2 %) for the feedstock end, and 11 °C (with a relative error of 1,1 %) for the heated-up feedstock end.

From the obtained results it was found that the initial temperature difference for the beginning and end of the feedstock, being about 65 °C, decreased to about 30 °C after rolling stand no 17. Whereas, when examining the temperature change on the feedstock surface before the first rolling stand for the heated-up feedstock end, as compared to the temperature of the feedstock beginning it was determined that the existing feedstock surface temperature difference, being about 47 °C, decreased to about 15 °C after rolling stand no 17. Heating up the feedstock end by 50 °C resulted in a decrease in the band surface temperature difference after rolling stand no 17 by more than twofold, compared the rolling of the feedstock end heated up to the nominal temperature (1 150 °C).

Figures 3 and 4 represent the variation of temperature in the core and on the surface of band after individual passes.

By analyzing the change of temperature in the band core (Figure 3) is established that during rolling of the initial band region in rolling stands nos. 1÷3 a constant temperature existed, whereas for both the band end and the pre-heated band end, a drop in temperature occurred in these stands. This is due to the fact that during rolling the band end and the heated-up band end, very large temperature differences exist between the core temperature (Figure 3) and the lateral band surface temperature (Figure 4) values. Downstream rolling stand no 1, the differences in temperature for the heated-up end of the band between its core and lateral surface were greater by as much as 50 % compared to the beginning of the band.

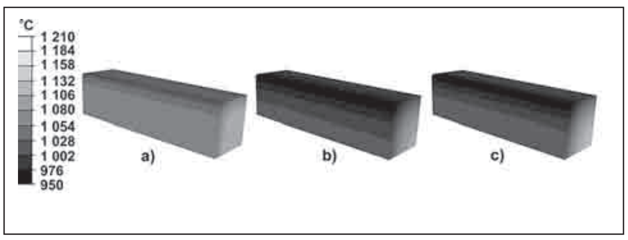

Figure 1 Distribution of temperature over the feedstock surface before stand no. 1, as computed numerically: a) feedstock beginning, b) feedstock end, c) heated-up feedstock end

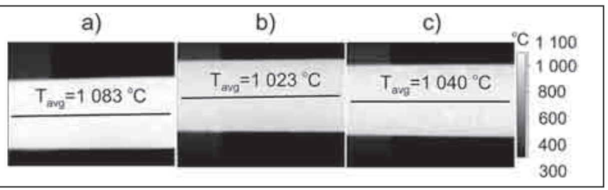

Figure 2 Thermogram before stand no. 1, a) feedstock beginning, b) feedstock end, c) heated-up feedstock end

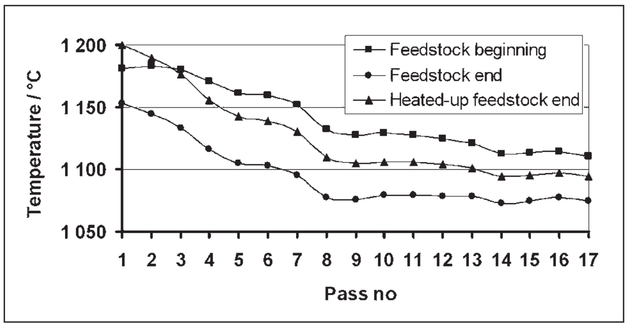

Figure 3 Change of feedstock core temperature after each pass

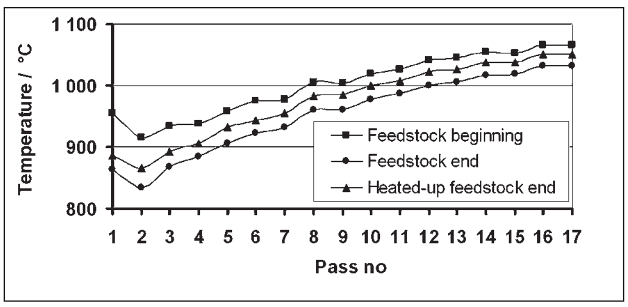

Figure 4 Change of feedstock surface temperature after each pass

For the temperature change on the band surface (Figure 4) during the round rod rolling process, a temperature drop was found to occur after rolling stands no 1 and 2. This is caused by the cooling of the lateral band surfaces as a result of the band contacting the rolls and the long duration of band air cooling between rolling stands 1 and 2. By contrast, from rolling stand 3 on, a gradual increase in band surface temperature follows, as the band cross-section decreases and the rolling speed increases. This causes a decrease in both the duration of contact between the band and the rolls and the time of band cooling between particular stands, and an increase in the heat gain on the band surface caused by the generation of heat during metal plastic deformation and the flow of heat from the core of the band to its surface regions.

The next stage of the studies included comparison of the cross-sectional shape and dimensions of finished bars obtained in the rolling process (Figure 5).

From the obtained results (Figure 5) it was found that during band rolling from the feedstock end at a temperature lower than that of the remaining feedstock part, an increase in friction forces occurred on the band and roll contact surface, which resulted in an increase in band width by about 0,10 mm, compared to the bar obtained from the initial feedstock region. As the numerical modelling of the 20 mm-diameter bar rolling process did not consider the continuous rolling process (the occurrence of band tension and piling up between individual rolling stands), the obtained results do not allow for the effect of the band tension and pile-up change in the inter-stand space, which appears when rolling feedstock with variable temperature along its length. The results reported in study [6] on the effect of the change in the temperature of feedstock along its length on the continuous rolling process have demonstrated that the obtained numerical study results for the continuous rolling process are more accurate, and the obtained differences in the band width change along the band length are up to four times greater than in the case when the continuous rolling process is modelled as single rolling passes. By analyzing the obtained results it has been found that during rolling band from the end feedstock region, a drop in temperature occurs, resulting in a change in the friction conditions, speed increment and band advance, which, with a continuous rolling process, may bring about a metal pile-up between rolling stands and a band widening. Introducing the feedstock end heat-up operation during feedstock heating in the heating furnace results in a reduction of the temperature difference between the heated-up end and the band beginning, thus enhancing the capability to obtain finished product of desired dimensions conforming to the acceptance standard.

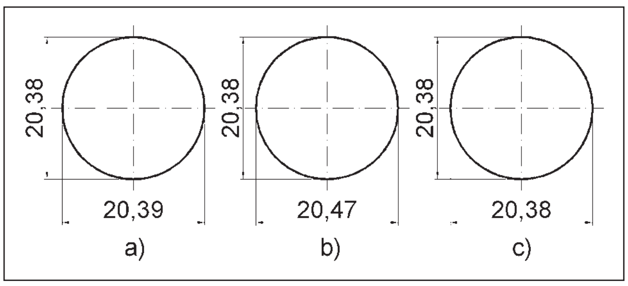

Figure 5 Shape and dimensions of the 20mm in diameter round bar obtained from the: a) feedstock beginning, b) feedstock end, c) heated-up feedstock end

Figures 6÷8 shows the diagram of variations in energy and force parameters in individual rolling stands of the rolling line.

As a result of the decrease of temperature along the rolled band length due to the cooling before the first stand of the rolling line, an increase in the energy and force parameters was observed during the process of rolling the end section of the band, compared to the beginning of the band.

In the case of the total roll separating force and rolling torque, greater differences in the obtained values of these parameters can be observed at the initial rolling stage. In

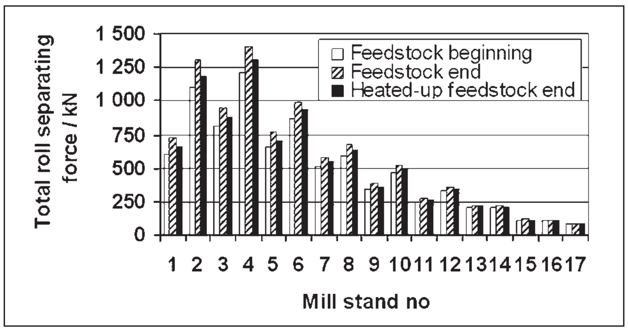

Figure 6 Diagram of variations in the total roll separating force in individual rolling stands of the rolling line

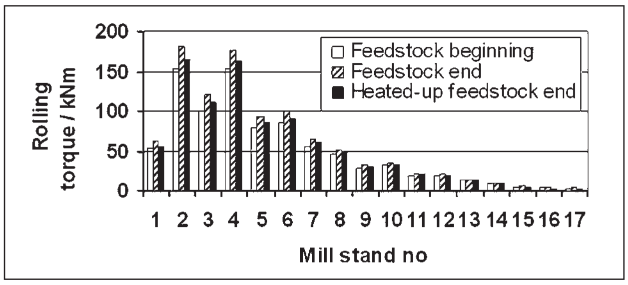

Figure 7 Diagram of variations in rolling torque in individual rolling stands of the rolling line

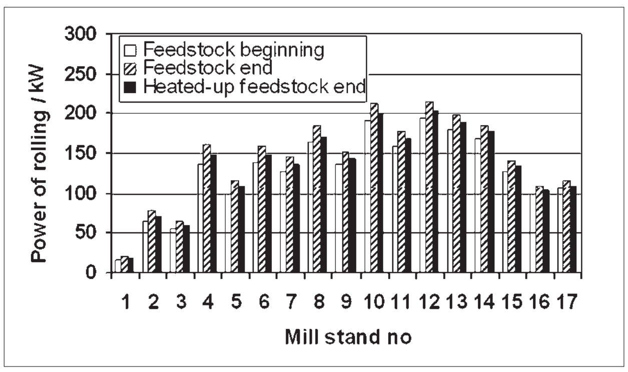

Figure 8 Variations in rolling power in individual rolling stands of the rolling line

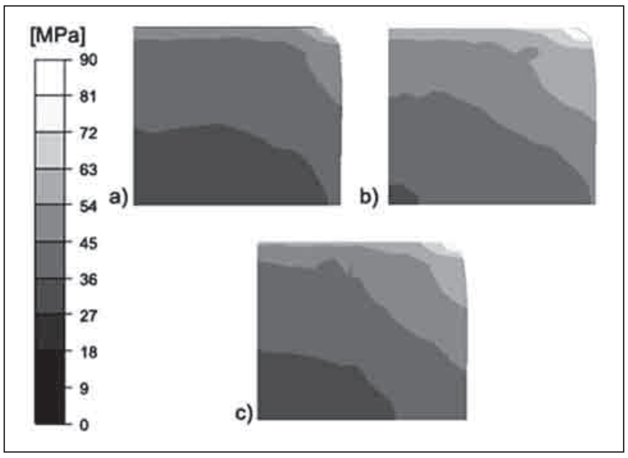

Figure 9 Yield stress distribution on the cross-section of the examined steel after the first rolling stand

the subsequent stands of the rolling line, these differences decrease, which is caused by the higher band speed, shorter times of breaks between passes, and generation of heat due to plastic deformation. The analysis of the values of the total roll separating force and rolling torque for the heated-up band end found that the modification of the feedstock heating process prior to rolling, developed by the authors of the present study, reduced the values of the total roll separating force and rolling torque. This results in more uniform loading of individual rolling stands during rolling the entire band length.

Rolling power magnitudes increase with decreasing rolled band temperature. When analyzing the data in Figure 8 it can be seen that, in the rolling process under examination, rolling power initially increased to reach the highest values in rolling stand no 12, and then its level decreased.

From the analysis of the rolling power magnitude for the heated-up band end it was found that in this case, too, the pre-rolling feedstock heating process modification, as developed by the authors of this study, allowed a reduction in the rolling power magnitude necessary for the rolling process.

Figure 9 presents yield stress distribution on the cross-section of the examined steel after the first stand of the rolling line.

Average yield stress value for the initial band part was about 40,8 MPa. The average yield stress value for the rolled band end was approx. 49,7 MPa, while the average yield stress value for heated up rolled band end was around 45,8 MPa. From the analysis of yield stress variations it was found that there was a direct relationship between rolled band temperature and yield stress. It was also found that, also for yields stress, the authors' modification of the feedstock heating process prior to rolling allowed a reduction in yield stress, which has an effect on metal flow during rolling and on the energy and force parameters of the rolling process.

SUMMARY

The uneven distribution of temperature over the continuous casting (rolled band) length, resulting from the duration of band cooling between the heating furnace and the first rolling stand, affects the plastic metal flow in individual rolling passes. When rolling bars from a lengthy feedstock, heating up of the feedstock end to a temperature higher than that of the remaining feedstock part should be employed with the aim of reducing the unevenness of temperature distribution over the feedstock length prior to the rolling process.

There is a direct relationship between rolled band temperature and the yield stress of the material being deformed and the energy and force parameters of the rolling process.

REFERENCES

[1] L. Giacomini, Go long - go strong, Metals and Mining, 2 (2007), 34-35.
[2] H. Mueller, Economic production on bar and wire rod mills, Iron and Steel Technology, 4 (2007), 50-57.
[3] E. Łabuda, H. Dyja, L. Lesik, Efektywność i kierunki poprawy dokładności wyrobów walcowni bruzdowych, Hutnik – Wiadomości Hutnicze, 8 (1992), 265-270.
[4] PN-EN 10263-4, Walcówka, pręty i drut do spęczania i wyciskania na zimno, cześć 4, ISBN 83-243-3779-2, PKN Warszawa (2004).
[5] User's manual, ThermaCAM™ QuickView, program version 2.0 FLIR Systems, January 25 (2006), publication no. 1558344.
[6] P. Sygut, Wpływ rozkładu temperatury wlewka ciągłego na plastyczne płynięcie metalu w wykrojach. Ph.D. Thesis, Częstochowa (2011), unpublished.

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