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EFFECT OF PLATE ASYMMETRIC ROLLING PARAMETERS ON THE CHANGE OF THE TOTAL UNIT PRESSURE OF ROLL

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This work shows the results of theoretical analysis of asymmetric rolling process of plates in the finishing mill of plate rolling. Its aim was to determine the influence of asymmetry velocity of working rolls on decrease of unit pressure of metal on the rolls. The lower value of the unit pressure will reduce the elastic deflection of the finishing stand and improve the cross-section shape of plate. Three-dimensional simulation of asymmetric hot rolling of S355J2G3 steel plates was done with the aid of FORGE 2008® software. The tensor polynomial interpolation was used for comparing the values of the unit pressure obtaining from symmetric and asymmetric rolling.

Key words: numerical modelling plate, asymmetric rolling, pressure of roll

Učinak parametara asimetričnog valjanja platine na promjene ukupnog pritiska valjka. Rad daje rezultate teorijske analize asimetričnog valjanja platine u završnom stanu. Cilj je odrediti utjecaj asimetrične brzine radnih valjaka na umanjenje jediničnog pritiska metala na valjke. Niža vrijednost jediničnog pritiska smanjiti će elastičnu deformaciju završnog stana. i poboljšati oblik presjeka platine. Trodimenzionalna simulacija asimetričnog vrućeg valjanja S355J2G3 čeličnih platina izvedena je pomoću FORGE 2008® softvera. Polinomni tenzor interpolacije rabljen je za usporedbu vrijednosti jediničnog pritiska dobijenog sa simetričnim i nesimetričnim valjanjem.

Ključne riječi: numeričko modeliranje platina,asimetrično valjanje, pritisak valjka

INTRODUCTION

Plate purchasers constantly increase their demands on the mechanical and plastic properties and the dimensional deviations of plates. In order to enhance the quality of plates, various solutions are implemented, including normalizing rolling, rolling with accelerated cooling following the rolling process, as well as new roll gap control systems (such as hydraulic rolls positioning, or the working roll bending system). The implementation of those systems takes place at the cost of increased loads being applied to rolling stands and working tools. Another competitive solution is the implementation of asymmetric rolling which involves making an intentional change to the stress and strain state in the roll gap and, unlike the former systems, does not increase loads on the drives, but quite the opposite – it causes a reduction of the total roll separating forces [1-4].

INITIAL CONDITIONS USED FOR NUMERICAL MODELLING

The material used for tests was steel of the S355J2G3 grade, whose chemical composition is given in Table 1.

Table 1 **Chemical composition of the steel S355J2G3 / mas. %**

C	Mn	Si	P	S
0,15	1,36	0,33	0,017	0,03
Cr	Ni	Mo	Cu	Al
0,05	0,089	0,03	0,23	0,030

To determine the actual work-hardening curves for this steel for the conditions of preset deformations and temperatures used in the actual plate rolling process, tests were carried out using the Gleeble 3800 device. Then, the work-hardening curves determined for this steel grade were implemented into the material database of the FORGE 2008® program [5].

1000 mm-diameter working rolls and a constant lower working roll rotational speed of n = 50 rpm were assumed for the tests. The asymmetric rolling process was introduced by changing the rotational speed of the upper roll, v_g, to be less than that of the lower roll, v_d. The range of variation of the roll rotational speed factor, $a_v = v_d/v_g$, was 1,01 ÷ 1,15. A strip shape factor of h_0/D = 0,05 ÷ 0,014 was assumed. The range of rolling reductions applied was ε = 0,08 ÷ 0,50.

The rolled strip temperature was changed, depending on the initial height, h_0:

h_0=50 mm, the rolling temperature T=950 °C,

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h_0=35 mm, the rolling temperature T=900 °C,
h_0=27 mm, the rolling temperature T=950 °C,
h_0=22 mm, the rolling temperature T=890 °C,
h_0=18 mm, the rolling temperature T=880 °C,
h_0=16 mm, the rolling temperature T=860 °C,
h_0=14 mm, the rolling temperature T=850 °C,
in the temperature intervals applicable to normalizing rolling.

RESULTS AND DISSCUSION

Figures 1÷3 show sample results of the tests of the effect of the working roll peripheral speed asymmetry factor a_v, being variable in the range of 1,01 ÷ 1,15, and the relative rolling reduction ε = 0,08 ÷ 0,50, for the investigated feedstock thickness range (h_0/D = 0,05 ÷ 0,014), on the magnitude of unit pressures, p_m, kN/mm.

The data in Figures 1÷3 indicate that for the values of the strip shape factor h_0/D and the applied rolling reduction ε, investigated in this work, the effect of the applied working roll peripheral speed asymmetry factor on the variation in the magnitude of unit pressures (as computed per unit width of rolled strip) is different and depends on the remaining parameters: the feedstock thickness and the relative deformation used.

For feedstock of a thickness of h_0 = 35 mm (h_0/D = 0,35), no decrease in unit pressure values occurred for the entire range of a_v factors tested, when a rolling reduction of ε = 0,08 was used; the same was true for rolling reductions of ε = 0,15 ÷ 0,30 and for small preset values of a_v = 1,01 ÷ 1,03 (Figure 1). However, already for this deformation range, introducing greater rolling process asymmetry (a_v > 1,08) resulted in a fairly large (approx. 7 ÷ 10 %) decrease in unit pressures.

When using the asymmetric process during the rolling of feedstock of a thickness of h_0 = 22 mm (h_0/D = 0,022), practically for the entire range of relative rolling reductions and speed asymmetry factors applied (with few exceptions, where a_v < 1,03 and ε = 0,20 ÷ 0,25), a decrease in the unit pressures pœr was noted, as large as by approx. 20 % for ε = 0,15 and a_v = 115 (Figure 2). Even larger decreases in pressure force values – exceeding 27 % (for ε = 0,15 and a_v = 1,15) – were observed for the asymmetric rolling of 16 mm-thick feedstock (h_0/D = 0,016). For this feedstock, only when applying the least rolling reduction of ε = 0,08 and the least speed asymmetry factors (a_v = 1,01 ÷ 1,03), were not any changes (decrease) in pressure force observed (Figure 3). The greatest drops in pressure force value occurred upon introducing asymmetry, when the value of a_v > 1,05.

For the determination of the roll separating force variation as against the symmetric process for the feedstock thickness range investigated, tensor polynomial interpolation was used [6].

The idea behind this method is to search for the coefficients of a multi-variable interpo-lating polynomial of the grade depending on the number of variables and the number of interpolated points. The tensor polynomial interpolation method yields only one solution for a selected space of measurement points. It has been found from the investigation that the following parameters have the greatest influ-ence on the roll separating force in the asym-metric rolling process: relative rolling redu-ction, the working roll rotational speed asymmetry factor, and the strip shape ratio. Therefore, the tensor polynomial interpolation of strip curvature, occurring as the result of the applied rolling process asymmetry, was performed for three independent variables.

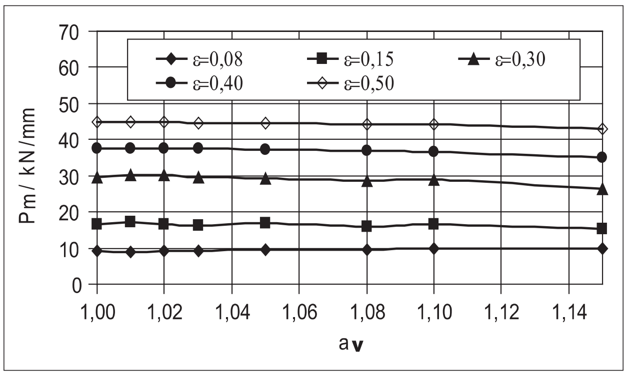

Figure 1 Effect of the asymmetry factor a_v on the magnitude of the average pressure force p_m for different relative rolling reduction values ε and a constant strip shape factor of h_0/D = 0,035

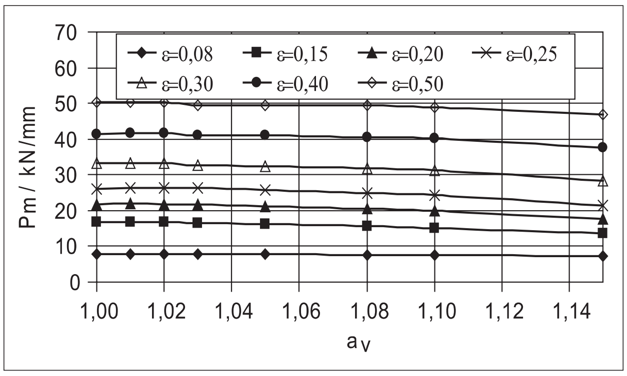

Figure 2 Effect of the asymmetry factor a_v on the magnitude of the average pressure force p_m for different relative rolling reduction values ε and a constant strip shape factor of h_0/D = 0,022

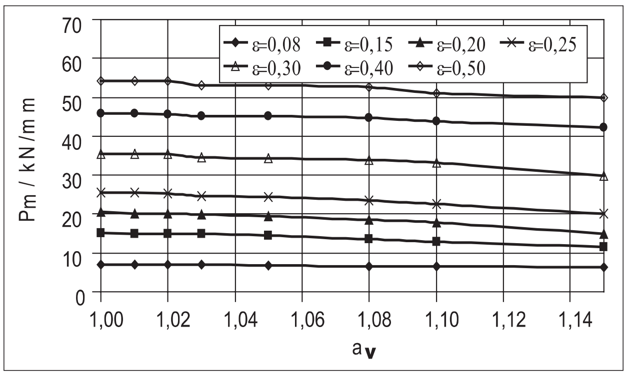

Figure 3 Effect of the asymmetry factor a_v on the magnitude of the average pressure force p_m for different relative rolling reduction values ε and a constant strip shape factor of h_0/D = 0,016

For the three-variable case considered in the work:
– $X_1 = h_0/D$ (strip shape factor),

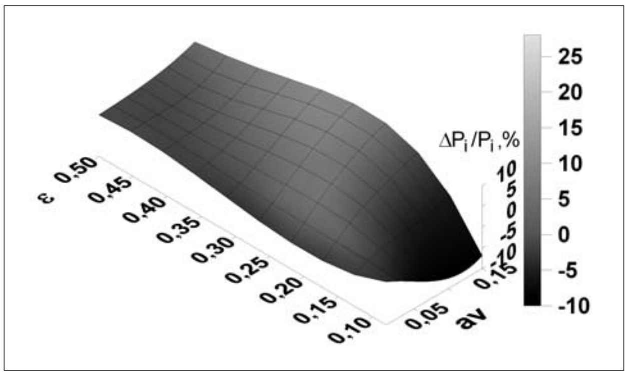

Figure 4 Relative change of roll separating force compared to the symmetric rolling process as a function of rolling reduction and the asymmetry factor for the initial thickness of h_0 = 35 mm, as determined from the interpolation of the test

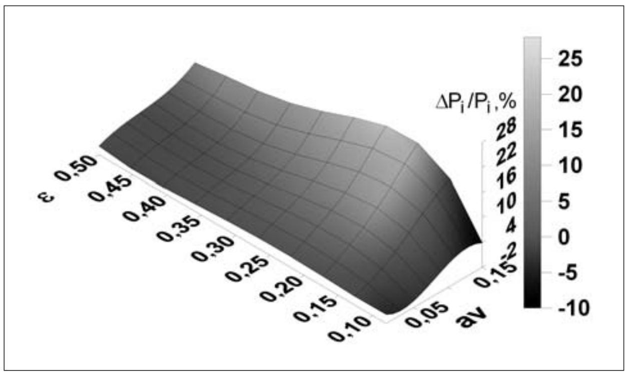

Figure 5 Relative change of roll separating force compared to the symmetric rolling process as a function of rolling reduction and the asymmetry factor for the initial thickness of h_0 = 22 mm, as determined from the interpolation of the test results

– $X_2 = a_v$ (working roll peripheral speed asymmetry factor),

– $X_3 = \varepsilon$ (relative rolling reduction),

in the following ranges:

X_{10} = 0,014; X_{11} = 0,016; X_{12} = 0,018; X_{13} = 0,022; X_{14} = 0,027; X_{15} = 0,035; X_{16} = 0,050,

for the shape ratio;

X_{20} = 1,01; X_{21} = 1,02; X_{22} = 1,03; X_{23} = 1,05; X_{24} = 1,08; X_{25} = 1,10; X_{26} = 1,15,

for the working roll peripheral speed asymmetry factor;

and X_{30} = 0,08; X_{31} = 0,15; X_{32} = 0,20; X_{33} = 0,25; X_{34} = 0,30; X_{35} = 0,40; X_{36} = 0,50,

for the relative rolling reduction.

The interpolation polynomial for the relative change of roll separating force as against the symmetric process has the following form:

$$\rho = W(X_1, X_2, X_3) = a_{000} + a_{100}X_1 + +a_{010}X_2 + + a_{001}X_3 + \ldots\ldots\ldots\ldots + a_{666}X_1^6X_2^6X_3^6$$

where: the coefficients a_{000}, a_{100}, a_{010}, a_{001},..a_{666} depend both on the measured values w_{000}, w_{100}, w_{010}, w_{001},...w_{666} of roll separating force, and on the values X_{10},..X_{36} of the assumed ranges.

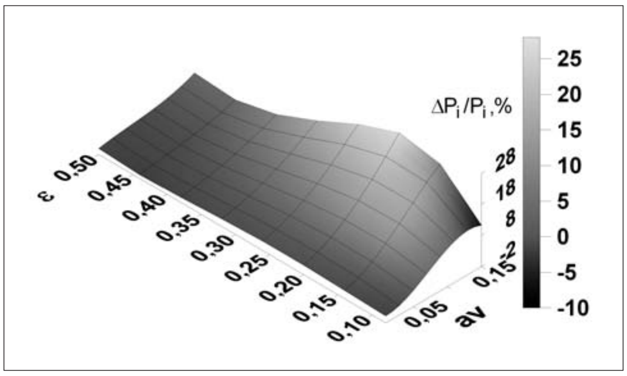

Figure 6 Relative change of roll separating force compared to the symmetric rolling process as a function of rolling reduction and the asymmetry factor for the initial thickness of h_0 = 16 mm, as determined from the interpolation of the test

Sample computation results are shown in Figures 4÷6.

The data shown in Figures 4 ÷ 6 indicate that the greatest decrease in the roll separating force occurred for the strip with the initial thickness of h_0 = 14 ÷ 22 mm for rolling reductions from 8 to 30 % and asymmetry factors of 1,10 and 1,15, and amounted to 27 % max.

For strips with a thickness from 27 to 35 mm, this decrease was slightly smaller for rolling reductions from 15 to 40 % and asymmetry factors of 1,10 and 1,15, and was approx 12 %.

SUMMARY AND CONCLUSIONS

From the theoretical studies carried out, the following conclusions have been drawn:

- by introducing the asymmetric plate rolling process through differentiating working roll peripheral speeds, depending on the asymmetry factor used, the magnitude of the total roll separating force can be reduced by up to 27 %;
- the reduction of the total roll separating forces decreases the elastic deflection of the rolling stand parts, which in turn may contribute to a reduction of the required magnitudes of working roll bending forces;
- owing to the reduced elastic deflection of the working rolls and the action of the complementary tension and back tension stresses in the roll gap, finished plate with smaller dimensional deviations on its width and length can be obtained at lower magnitudes of the total roll separating forces during the normalizing rolling of plates.

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Note: The responsible translator for English language is Czesław Grochowina, Czestochowa, Poland.