A. KAWAŁEK

ISSN 0543-5846
METABK 55(4) 639-642 (2016)
UDC – UDK 539.374:621.771:669.15:621.41:531.65=111

THE EFFECT OF RELATIVE DEFORMATION ON THE ENERGY-FORCE PARAMETERS IN THE ASYMMETRICAL PLATE ROLLING PROCESS

Received – Primljeno: 2015-12-31
Accepted – Prihvaćeno: 2016-05-10
Original Scientific Paper – Izvorni znanstveni rad

The paper presents the results of asymmetrical plate rolling in the finishing rolling stand of a 3600 mill. The investigation was carried out for S690Ql steel sheets. Tests were conducted for two types of the asymmetric rolling process. In the first case, the asymmetry of the process was introduced by varying the speed of the upper working roll, while in the second case, two types of asymmetry were introduced simultaneously by reducing the rotational speed of the upper roll and reducing the diameter of the lower roll. Based on the obtained results it has been found that the simultaneous introduction of two types of asymmetry significantly reduces the energy-force parameters of the process, and regardless of relative deformation applied, it yields also a straight rolled plate.

Key words: deformation, asymmetrical rolling, S690Ql steel of plate, energy - force parameters, kinetic asymmetry

INTRODUCTION

Recent years have seen an increase in demand for plates [1,2]. Therefore, intensive studies are being conducted to improve the plate rolling process. The effect of various parameters, such as strip temperature, reduction magnitude, variations in the yield stress magnitude for individual steel grades, working roll rotational speeds and diameters, on both the geometrical parameters of plates, as well as their mechanical and plastic properties, is being examined [3]. The objective of the conducted studies is to determine the relationships between individual technological parameters of the rolling process, to establish the optimal rolling conditions and to improve the quality of manufactured products. The stabilization of product geometry can be achieved by using appropriate rolling process control system, as well as by introducing an asymmetric rolling process. By employing a controlled asymmetric rolling process, one can contribute to a reduction of the overall roll separating force and rolling power and provide a uniform distribution of moments on both mill spindles, which will result in an improvement in the crosswise and longitudinal geometry of the rolled plates [4,5]. This technology can be classified as an innovative way to improve the quality of steel products [6]. The asymmetric rolling process has also its drawbacks. Due to the difference in metal deformation conditions existing between the upper and lower working roll sides, bending of the strip on exit from the deformation zone takes place. The magnitude of the strip curvature depends on the employed deformation and the value of the applied asymmetry factor, as well as on other rolling process parameters [7]. Therefore, implementing the asymmetric rolling technology in industrial conditions will require a series of theoretical studies to be previously carried out in order to determine the permissible ranges of asymmetry factor variation for specified values of deformation and other process parameters, for which it is possible to obtain a straight strip with a curvature small enough that it will not hamper the rolling process in subsequent rolling passes, while simultaneously reducing the energy-force parameters of the process.

All of these effects can be achieved by using two types of asymmetry simultaneously.

TEST MATERIAL AND TESTING METHODOLOGY

Within this study, tests on plate of S690Ql grade steels (whose chemical composition is shown in Table 1) with an initial height of h_0 = 15 mm were carried out under the conditions of the finishing mill of the 3600 rolling mill.

Table 1 **Chemical composition of S690Ql steels used for tests / wt. %**

C	Mn	Cr	Ni	Mo	Nb
0,2	1,7	1,5	2,0	0,7	0,06
Ti	Cu	N	Si	P_{max}	S_{max}
0,05	0,5	0,015	0,8	0,025	0,015

For simulation of the asymmetrical rolling process, the FORGE® 2011, a finite element method-relying software application, was used. Working rolls, each of a of 970 mm, and a constant lower working roll rotational speed of n = 80 rpm were assumed for the numerical

A. Kawałek, Czestochowa University of Technology, Czestochowa, Poland

studies. One and two asymmetry types, respectively, were introduced to the rolling process. The first type of asymmetry was achieved by differentiating the rotational speeds of the working rolls so that the upper roll rotational speed was lower than lower roll rotational speed. The range of variations of the roll rotational speed factor, $a_v = v_d/v_g$ (where: v_d, v_g - respectively, lower and upper roll rotational speed) was 1,05 ÷ 1,20. The second type of asymmetry was introduced by reducing the lower working roll diameter, $a_d = D_d/D_g$ (where: D_d, D_g - respectively, the lower and upper roll working diameter); it was contained in the range of 1,05 ÷ 1,20. The tests were carried out for $a_v=a_d=a$. During rolling, the relative deformation was varied in the range ε = 0,10 ÷ 0,30. Simulations were conducted for feedstock at a temperature suitable for normalizing rolling, i.e. 840 °C. The rolling programme included the examination of the effect of relative rolling reduction ε, speed asymmetry and geometrical asymmetry factors on the force–energy parameters of the rolling process.

TESTING RESULTS

Figure 1 illustrates the results of the numerical studies of the effect of relative rolling reduction on the magnitude of the average roll separating force, P_u, for different values of kinetic asymmetry factors, a, and a constant value of initial feedstock height of h_0 = 15 mm.

The data in Figure 1 shows that the introduction of asymmetry by differentiating the rotational speeds of the working rolls results in a reduction of the average roll separating force for the entire examined range of relative deformations ε and values of asymmetry factors, a. The greatest reduction of the average unit roll separating force – by approx. 25 %, was observed upon employing relative deformations from the range of ε = 0,20 ÷ 0,30 and asymmetry factor values of a = 1,15 and 1,20.

Figure 2 illustrates the effect of relative deformation ε of the magnitude of the average roll separating force P_u, for feedstock with an initial height of h_0 = 15 mm.

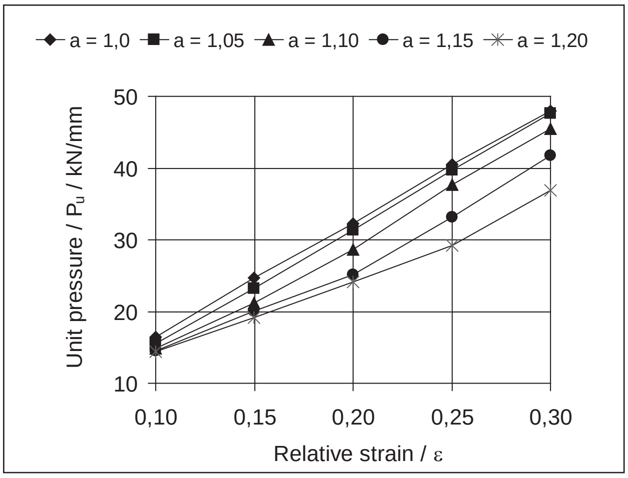

Figure 1 The effect of relative deformation ε on the value of the average pressure P_u, for different values of kinetic asymmetry factors, a

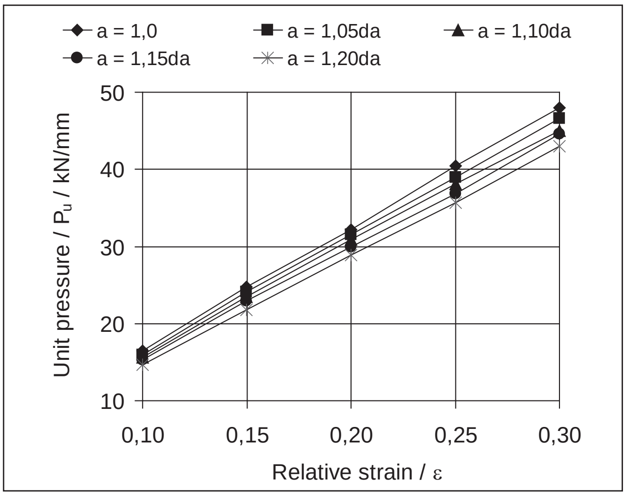

Figure 2 The effect of relative deformation ε on the value of the average roll separating force, P_u, for different values of kinetic and geometrical asymmetry factors, a; da – denotes the use of two types of asymmetry

Based on the data shown in Figure 2 it can be stated that by the simultaneous use of two types of asymmetry in the rolling process, a reduction in the unit roll separating force can be achieved for all of the examined relative deformation values. However, as compared to the process of rolling with one type of asymmetry, the decrease in roll separating force was smaller, amounting to 10 % for the largest values of preset relative deformation and asymmetry factors applied.

The effect of relative deformation in the asymmetric process of rolling feedstock with an initial height of h_0 = 15 mm (with one asymmetry type – geometrical asymmetry) on the magnitude and variations of rolling moments for the upper and lower working rolls and the total rolling moment is represented in Figure 3.

Based on the tests carried out it was found that by introducing the asymmetrical rolling process different values of rolling moment on the upper roll, T_u, and on the lower roll, T_l, can be achieved. An increase in the total rolling moment occurs with the increase in the preset values of relative deformation and asymmetry factors. Depending on the value of the employed asymmetry and the remaining rolling process parameters, an uneven distribution of moments between the lower and higher rotational speed rolls takes place. From the data shown in Figure 3 it can be found that the moment on the higher rotational speed roll (lower roll) is always positive. This roll is always a driving roll. The rolling moment of the lower rotational speed roll (lower roll) is negative, except for cases, where the asymmetry factor value is a_v = 1,05, and the relative deformation value varies in the range of ε = 0,2 ÷ 0,3. For these values, the rolling moment on the upper roll takes on a zero value and then becomes positive. In the case of negative rolling moment values, this roll becomes a powered roll.

The increase in rolling moment values and their uneven distribution onto individual rolls should be ranked among the drawbacks of the asymmetric rolling process.

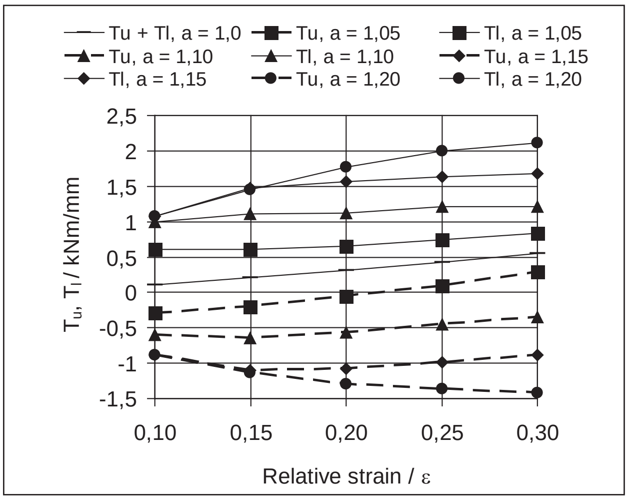

Figure 3 The effect of relative deformation ε on the rolling moment values T_u and T_l, for different values of kinetic asymmetry factors, a

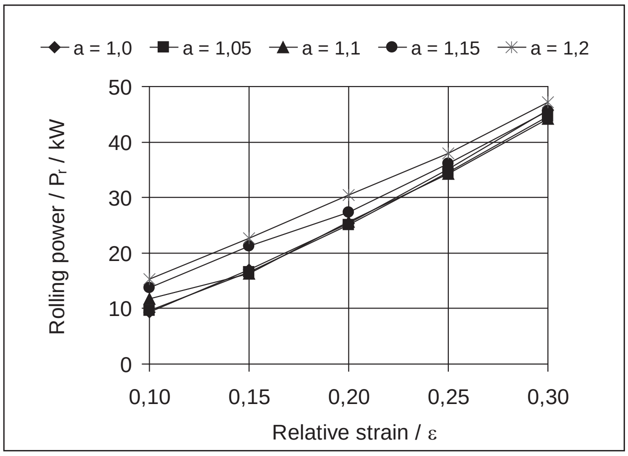

Figure 4 The effect of relative deformation ε on the value of rolling power P_r, for different values of kinetic asymmetry factors, a

After introducing the two symmetry types (kinetic and geometric) to the rolling process, the even distribution of the rolling moment values on the upper and lower working rolls was restored, and in addition to that, the total rolling moment was smaller by approx. 10 % compared to symmetric rolling for the greatest asymmetry factor values.

Figure 4 represents the effect of relative deformation ε on the value of rolling power P_r, for feedstock with an initial height of h_0 = 15 mm, rolled with different values of kinetic asymmetry factors, a.

The data in Figure 4 shows that the application of kinetic asymmetry in the rolling process results in an increase in rolling power for the entire examined range of variation of relative deformations, ε = 0,1 ÷ 0,3, and asymmetry factors, a = 1,05 ÷ 1,20. The greatest increments in rolling power occurred for relative deformations from the range of ε = 0,10 ÷ 0,15 and the largest values of asymmetry factors, a 1,15 ÷ 1,20.

Figure 5 shows the results of the examination of the effect of relative deformation ε on the value of rolling power P_r, for the process of rolling feedstock with an initial height of h_0 = 15 mm with the simultaneous use of two different types of kinetic and geometrical asymmetry.

It can be found from the data in Figure 5 that introducing the two types of asymmetry to the rolling process has brought about a considerable reduction of the rolling power value. The largest reduction has been achieved for relative deformations ε > 0,2 and asymmetry factors a ≥ 1,15.

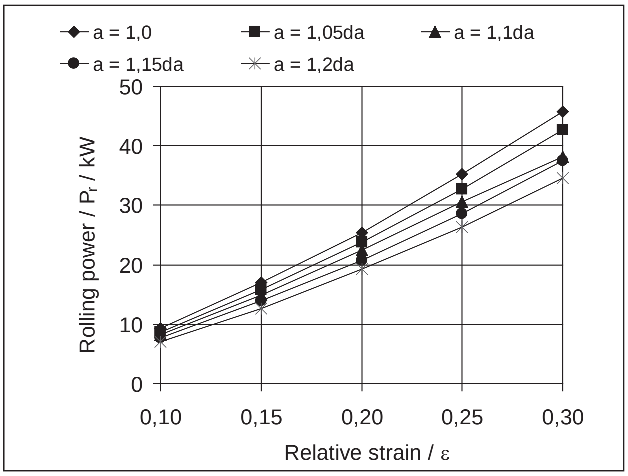

Figure 5 The effect of relative deformation ε on the value of rolling power, P_r, for different values of kinetic and geometrical asymmetry factors, a; da – denotes the use of two types of asymmetry

SUMMARY

The investigation carried out within the study enables the following conclusions to be drawn:

- upon introducing one type of asymmetry to the rolling process, a reduction in the value of unit roll separating force can be achieved, but at the same time, in the majority of cases, a bending of the strip beginning follows, which is an adverse phenomenon, as the strip gets a permanently deformed (wavy) shape, which cannot be removed; moreover, if the strip bends towards the lower roll, fast wear of the mill equipment and working roller table rollers may occur;
- during rolling with one asymmetry type, an increase in rolling moment values and their uneven distribution onto individual rolls take place, which may lead to exceeding of the permissible moment values;- in the asymmetric process with one type of asymmetry, also rolling power considerably increases;
- upon applying two types of asymmetry to the rolling process, a smaller reduction in the value of the average roll separating force occurs, compared to rolling with one asymmetry type, and at the same time, a straight strip is obtained for all of the technological variants examined in the study;

- in the process of rolling with two types of asymmetry, the distribution of rolling moments among the working rolls is uniform, and the total moment is lower than in the symmetrical process;
- the simultaneous application of kinetic and geometrical asymmetries in the rolling process contributes to a reduction of rolling power, compared to the symmetrical process, for the identical process parameters.

References

[1] H. Dyja, M. Pietrzyk: On the theory of the process of hot-rolling of bimetal plate and sheet. Journal of Mechanical Working Technology 8 (1983), 309-325.

[2] D. Rydz, M. Krakowiak, T. Bajor, G. Stradomski: The analysis of the impact relative rolling reduction at the area connector bimetallic plate after the rolling process. Solid State Phenomena 199 (2013), 514-517.

[3] K. Laber, H. Dyja, M. Kwapisz: Numerical modelling of the cooling ability of device for the plain round bars accelerated cooling process. Archieves of Metallurgy and Materials 56 (2011) 2, 385-392.

[4] A. Kawałek, H. Dyja, S. Mróz, M. Knapiński: Effect of plate asymmetric rolling parameters on the change of the total unit presssure of roll. Metalurgija 50 (2011) 3, 163-166.

[5] V. A. Nikolaev: Izvestija vysshikhuchebnykh zavedenij. Chernaja metallurgija (2007) 3, 20-23.

[6] Z. Skuza, R. Prusak, C. Kolmasiak: Restructuring of the metallurgical industry in the aspect of economics – system changes and integration with the european union, Metallurgy, 46 (2007) 3, 221-224.

[7] V. A. Nikolaev, A. A. Vasil'ev: Izgib polosy i drugie parametry nesimmetrichnoj prokatki, Stal' (2013) 7, 42-49.

Note: The person responsible for the English translation is Czesław Grochowina, Studio Tekst, Czestochowa, Poland