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The theoretical and experimental analysis of the effect of asymmetrical rolling on the value of unit pressure

A. Kawałek

Faculty of Process & Material Engineering and Applied Physics
Technical University of Częstochowa,

1. INTRODUCTION

Competition on the flat-product market compels manufacturers to continuously improve solutions in the technology of metal sheet and strip production.
High quality requirements regarding the dimensional tolerances of rolled products entail the necessity of implementing systems that stabilize and improve the geometrical dimensions of rolled bands.

The demanded quality requirements can be satisfied by introducing the stabilization of stock parameters, bringing the effect of pressure force variations on rolling gap size to a minimum, and assuring the stability of the geometry of rolled product as a result of controlling the deformation process. The stabilization of product geometry by controlling the process involves the use of appropriate systems, such as the hydraulic roll positioning system, the working roll deflection system and the asymmetrical rolling system. Introducing asymmetrical rolling reduces the overall pressure force and the non-uniformity of thickness over the width, and improves the flatness and lateral profile of band.

A theoretical and experimental analysis of the asymmetrical rolling process in the last two stands of a finishing group have been carried out within the present study. The research programme included the effect of relative rolling reduction, ε; working roll peripheral speed asymmetry ratio, a_v; and deformation region shape ratio, l_d/l_{av}, on the force-and-energy parameters of the rolling process.

Investigations were carried out for conditions corresponding to the real conditions of hot sheet rolling in a continuous system. A band shape ratio of $H_0/R = 0.0066 \div 0.0385$ was assumed for the last-but-one stand (F9), and $H_0/R = 0.0058 \div 0.0299$ for the last stand (F10). The range of rolling reduction values applied was, respectively, $\varepsilon = 0.10 \div 0.40$ (F9), and $\varepsilon = 0.07 \div 0.20$ (F10). The asymmetry ratio was varied in the range $a_v = 0.95 \div 1.05$. For a detailed analysis, a group of steel grades of similar mechanical properties was chosen, comprising about 140 steel grades. The theoretical analysis of the asymmetrical rolling process was performed using the Elroll and FORGE2 computer programs based on the finite-element method. The verification of the theoretical studies was done in the hot rolling mill of one of the industrial works for sheets hot rolled to a final thickness of 1.80÷8.00 mm.

2. THE EFFECT OF R_G/R_D ON THE VALUE OF THE OVERALL ROLL SEPARATING FORCE

Examples of results of the theoretical investigations of the effect of roll peripheral speed asymmetry ratio, R_g/R_d; deformation, ε; and band shape ratio H_0/R, on the value of unit pressure are shown in Figs. 1 ÷2 (for the last-but-one stand) and in Figs. 3 ÷4 (for the last stand).

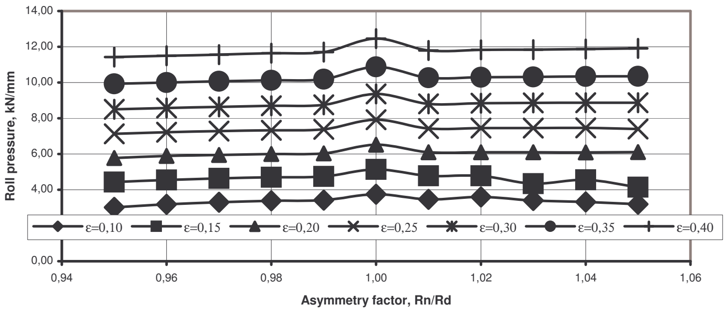

Fig. 1. The effect of asymmetry ratio, R_g/R_d, on the value of unit pressure (stand F9, for H_1=2.00mm)

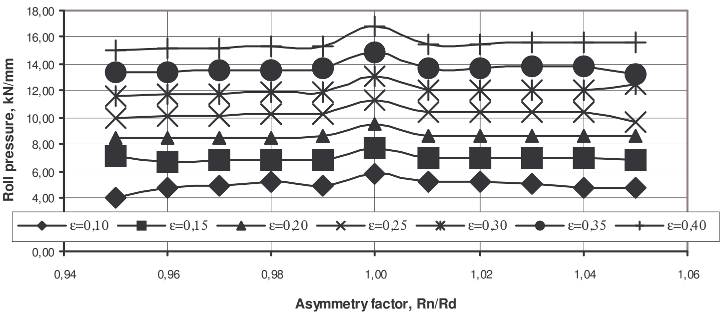

Fig. 2. The effect of asymmetry ratio, R_g/R_d, on the value of unit pressure (stand F9, for H_1=7.50.00mm)

It can be noted from the data given in Figures 1 and 2 that the reduction in the unit pressure value is greater for smaller deformations (ε = 0.10÷0.15) than for larger deformations (ε = 0.30÷0.40) by several percent.

Increasing the speed asymmetry in the last-but-one stand from a_v = 0.99 to a_v = 0.98 and from a_v = 1.01 to a_v = 1.02 causes a further, though very small (several-percent) drop in the value of roll separating force. The maximum drop in the value of unit pressure force was approx. 20% in this stand for asymmetrical rolling, for the maximum investigated value of speed asymmetry ratio, i.e. a_v=1.05.

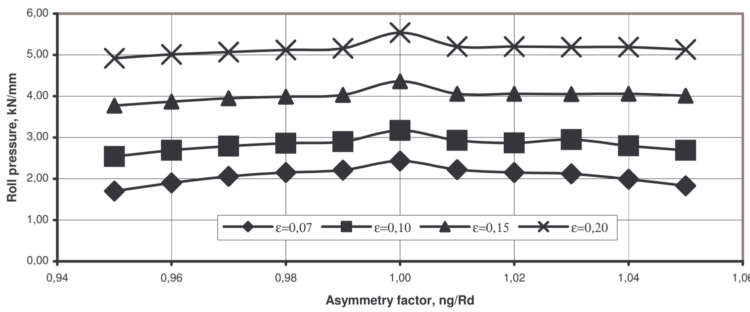

Fig. 3. The effect of asymmetry ratio R_g/R_d on the value of unit pressure (stand F10, for H_1=1.80 mm)

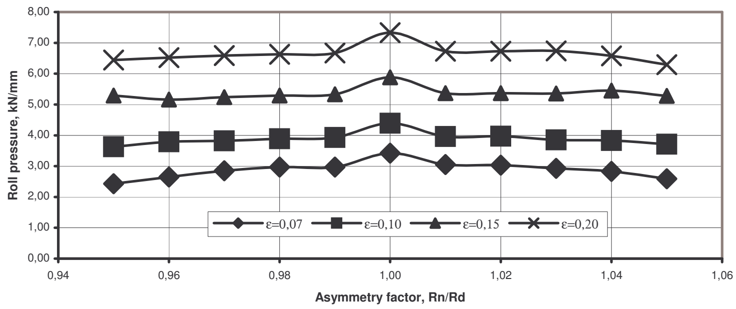

Fig. 4. The effect of asymmetry ratio R_g/R_d on the value of unit pressure (stand F10, for H_1=5.00 mm)

In the last stand, the influence of roll peripheral speed asymmetry ratio on the value of unit roll separating force is similar. The greatest decrease in this force (by 10÷16%) is observed for small values of speed asymmetry ratio, i.e. $a_v = 0.99$ and $a_v = 1.01$.

Increasing deformation, ε, from 0.07 to 0.20 (for $a_v = 0.99$ and 1.01) in this stand causes a decrease in the pressure force by 7÷10%. For this stand, no significant relationships were found between further variations in the pressure force and the thickness of the band being rolled and the value of deformation used.

In the last stand, the greatest effect of the value of speed asymmetry ratio on the value of unit pressure is observed. Increasing the a_v ratio up to a value of 1.05 may cause a drop in the pressure force by as much as 30% (with a deformation of $\varepsilon = 0.07$).

The investigation of the effect of rolling speed asymmetry on the overall pressure force indicate that, due to the decrease in this force and the elastic deflection of the rolling stand, in the continuous sheet rolling process it is sufficient to use a speed asymmetry ratio from the range $a_v = 0.99 \div 1.01$ in the last-but-one stand. For the last stand, on the other hand, this range can be wider (i.e. $a_v = 0.97 \div 1.03$).

Decreasing the value of roll separating force by approx. 7 ÷ 10% in the last-but-one stand and by 10 ÷ 14% in the last stand as a result of the application of asymmetrical rolling, already for the smallest speed asymmetry range (a_v =0.99 and a_v =1.01), will cause a reduction in the overall roll separating force by the same value.

3. EXPERIMENTAL VERIFICATION OF THEORETICAL INVESTIGATIONS

The verification of the theoretical investigations of the asymmetrical hot rolling of steel sheets to a final thickness of, respectively, 1.80mm, 2,20mm, 2,50mm, 3.00mm, 4.00mm, 6.0mm, and 8.00mm was carried out in the hot rolling mill of one of the industrial works. Examples of results of the experimental investigations of the effect of roll speed asymmetry ratio, R_g/R_d; deformation, ε; and band shape ratio, H_0/R, on the value of unit pressure for band rolled in the last-but-one stand (F10) to a final thickness of H_k=8.00 are shown in Fig. 5.

On the basis of the analysis of the values of actual average unit pressure obtained in the industrial tests of symmetrical and asymmetrical rolling bands to different final thickness it can be stated that rolling with a different diameter of working rolls ($R_g/R_d=0.99$) causes a decrease in the value of average unit pressure, on average, by approx. 11% for the last-but-one stand and by 12% for the last stand. The greatest decreases in the value of unit pressure occurred during the asymmetrical rolling of band ($h_k=6.00mm$) in stand F9 with rolling reductions of ε = 0.115 ÷0.130 and were from 22.24 to 25.83%. In stand F10, on the other hand, the greatest decreases in unit pressure occurred during the rolling of the thinnest band (h_k = *1.80mm*) for $\varepsilon = 0.115 \div 0.139$ and ranged from 17.76 to 22.53%. The results of the experimental investigations were confirmed by data obtained from computer simulations, where a decrease in the average unit pressure also occurred for the last-but-one stand by 9% and for the last stand by 12%.

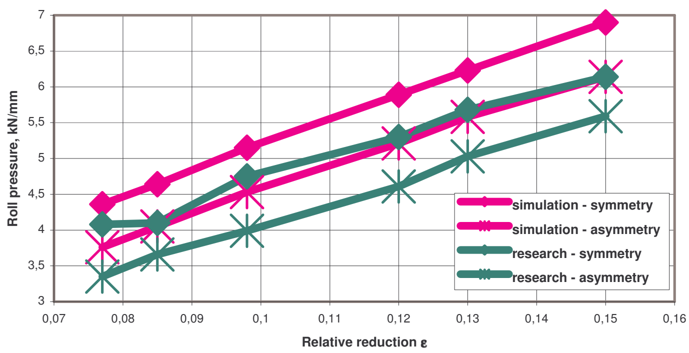

Fig.5. The effect of relative rolling reduction on the value of unit pressure (stand F10, a_v=0.99, H_k = 8.00mm)

4. CONCLUSIONS

From the theoretical and experimental investigations carried out, the following conclusions have been drawn:

1. When using a group drive, an asymmetry of rolls peripheral speed should be introduced by varying the diameters of working rolls.
2. The use of asymmetrical rolling in the last-but-one stand of a continuous system causes a reduction in the value of the overall roll separating force by approx. 9%.
3. The use of asymmetrical rolling in the last stand of a continuous system causes a reduction in the value of the overall roll separating force by approx. 12%.
4. In order to assure a continuous process of rolling and coiling band on a coiler, speed asymmetry ratios in the range a_v = 0.99÷1.01 in the last-but-one stand, and in the range a_v = 0.97÷1.03 in the last stand should be used.

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