Advanced Materials Research Vol. 586 (2012) pp 259-264
Online available since 2012/Nov/12 at www.scientific.net

doi:10.4028/www.scientific.net/AMR.586.259

Theoretical Basis and Technology Development of the Combined Process of Asymmetric Rolling and Plastic Bending

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Keywords: Vertical Asymmetric Rolling, Plastic Bending, Torque, Technology Development, Finite Elements Method, Parts Of Bulky Bodies Of Rotations.

Abstract. The article focuses at technology development of the vertical asymmetric rolling and combined process of vertical asymmetric rolling and plastic bending. It has been shown that vertical asymmetric rolling peculiarity relates to the presence of a mixed zone, in which friction forces on contact roll surfaces are directed are differently. Experimental research showed serious drawbacks in the rolling technology caused by the growth of dynamic loads arising at the moment of plate contact with the bending roller. For solving the problem it was proposed to make the roller position motile to allow its movement along the required trajectory. The application of the motile roller helps to reduce dangerous torque differentiation at working rolls by the value of 1,5-2,5 compared with the rigidly fixed roller. The most effective bending roller trajectory is a second-order curve that is convex parabola.

Introduction

The metal forming department at Magnitogorsk State Technical University has been developing the asymmetric rolling research direction for 30 years.

The classification which consists of 3 hierarchical levels has been elaborated. The upper level is referred to as a set of conditions when the asymmetry occurs no matter whether it is formed deliberately or caused by any kinds of disturbances. Another level is regarded as both horizontal and vertical spatial orientation of asymmetry. Finally, factors which define asymmetry like geometric, kinematic, frictional, elastic, etc. belong to the lower level. Asymmetry of some kind may often occur simultaneously.

It has been shown that vertical asymmetric rolling peculiarity relates to the presence of a mixed zone, in which friction forces on contact roll surfaces are directed are differently. This results in torque appearing and causes the turn of the deformation zone (Fig. 1).

$\varphi_j, \gamma_j, \alpha_j$ - a variable angular coordinate, neutral angle, gripping angle in the upper $(j=1)$and lower $(j=2)$rolls correspondently; β_i - an angle of inlet (i=0) and outlet (i=1) of the sheet out of the deformation zone; $p_{orj}(\varphi_j), p_{onj}(\varphi_j)$ - distribution of normal contact stresses in lagging and outstripping areas; $\tau_{orj}(\varphi_j), \tau_{onj}(\varphi_j)$ - distribution of shearing contact stresses in the same areas; q_{ij} - specific rear$(i=0)$ and front$(i=1)$ stresses on the upper $(j=1)$and lower $(j=2)$surfaces of the sheet in their linear distribution through thickness.

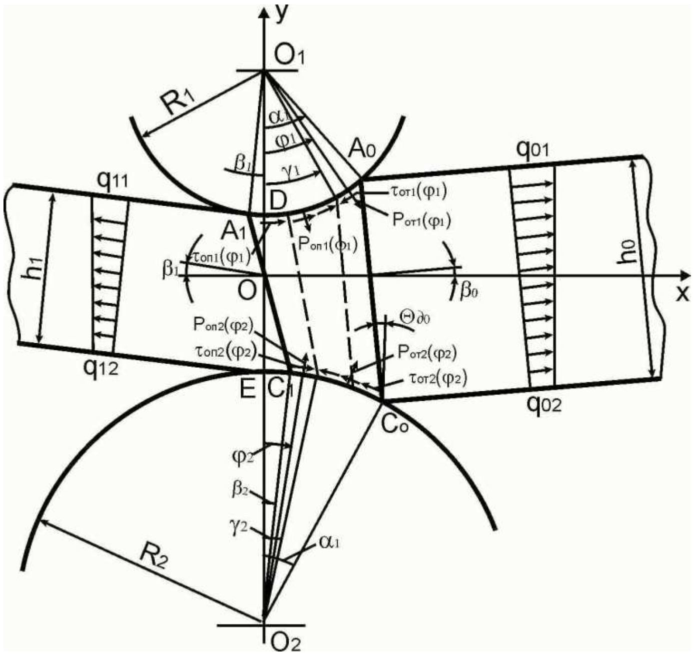


Fig.1 Scheme of deformation zone and its loads in asymmetric rolling where

Owing to this approach it became possible to verify the distribution of normal contact strain on contact arches (Fig. 2).

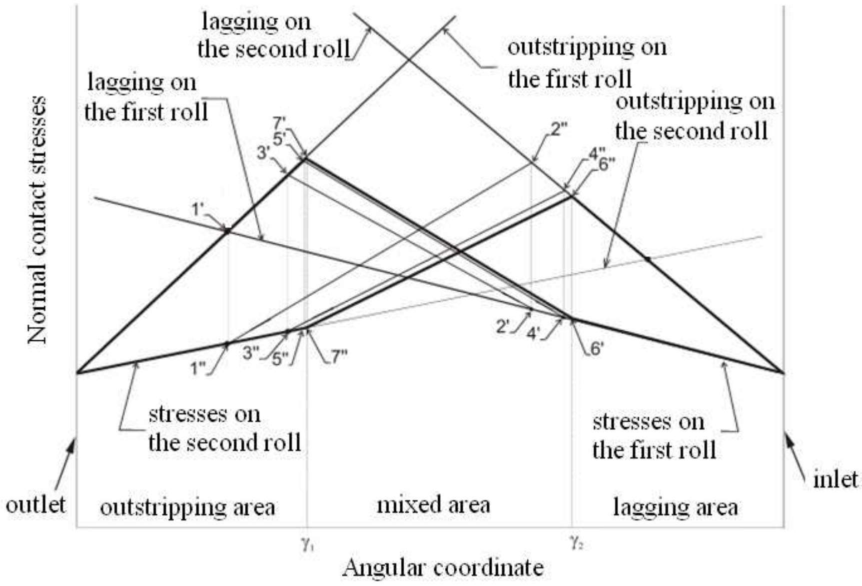


Fig.2 Search for normal contact stresses

New technology has been developed to produce parts of bulky bodies of rotations with pre-assigned camber on the basis of combined processes of vertical asymmetric plate rolling and plastic bending (Fig. 3).

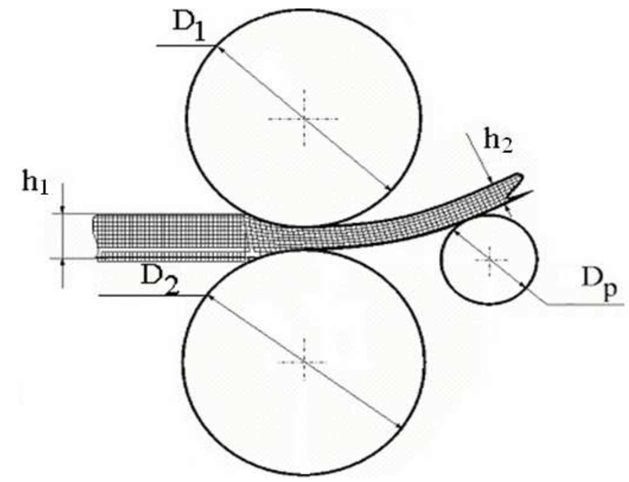


Fig. 3. Scheme of the combined process of asymmetric rolling and plastic bending

The combined process is supposed to have three stages: 1) vertically asymmetric rolling when the front end of the plate does not contact the unbending roller; 2) not adjusted combined process of vertically asymmetric rolling and plastic bend (it starts when the front end of the plate contacts the unbending roller); 3) adjusted combined process of vertically asymmetric rolling and plastic bend (it starts when the front end of the plate comes off the unbending roller).

Theoretical and experimental research showed serious drawbacks in the rolling technology caused by the growth of dynamic loads arising at the moment of plate contact with the bending roller (Fig. 4, 5). In a sufficiently short period of time (split second) a torque moment in the upper roll abruptly increases several times which might result in equipment damage. The reason of this increase is a rigidly fixed position of the bending roller. For solving the problem it was proposed to make the roller position motile to allow its movement along the required trajectory.

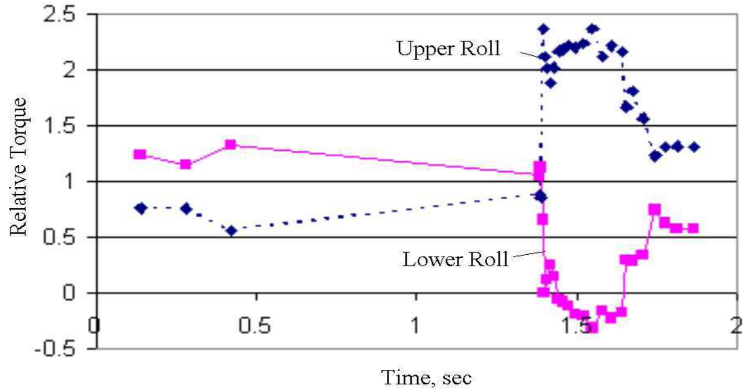
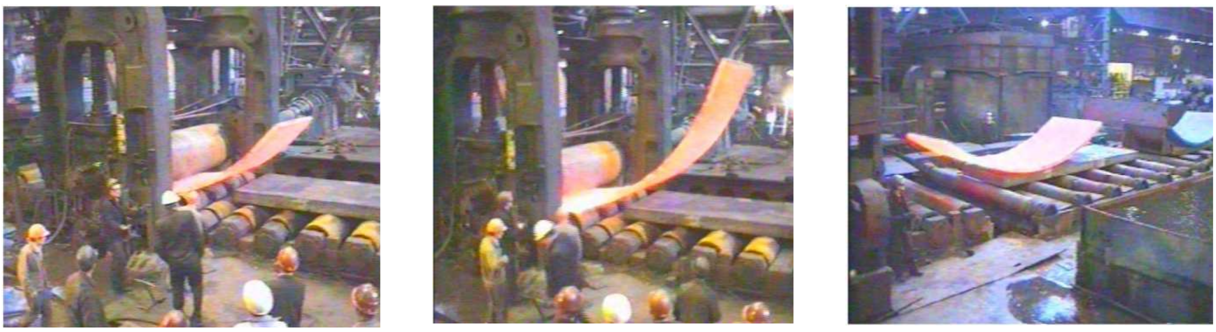


Fig. 4 Relative torque for the upper and lower roll with the rigidly fixed roller (D_1=1200 mm; D_2=1220 mm; h_1 = 104 mm; h_2 = 100 mm)



a b c

Fig. 5 Pilot testing of bulky bodies of rotation parts (BBRP) production technology in the conditions of plate mill 4500 at OJSC Magnitogorsk Iron and Steel Works; a, b – deformation process; c – finished part

Of practical interest is the research of bending roller trajectory influence on the torque moment redistribution (Fig.6) and pre-assigned camber part production accuracy. As shown in the scheme a roll moves out of its initial position O' with coordinates (x_0; y_0) into its final position O" with coordinates (x_f; y_f), for example, it moves either along a concave parabola (curve 1), straightly (2) or along a convex parabola (curve 3) (Fig. 7). Here it is required to determine the kind of trajectory of the bending roller, which provides: a) the maximum reduction in the differential torque moments and b) the required accuracy of the part on geometry.

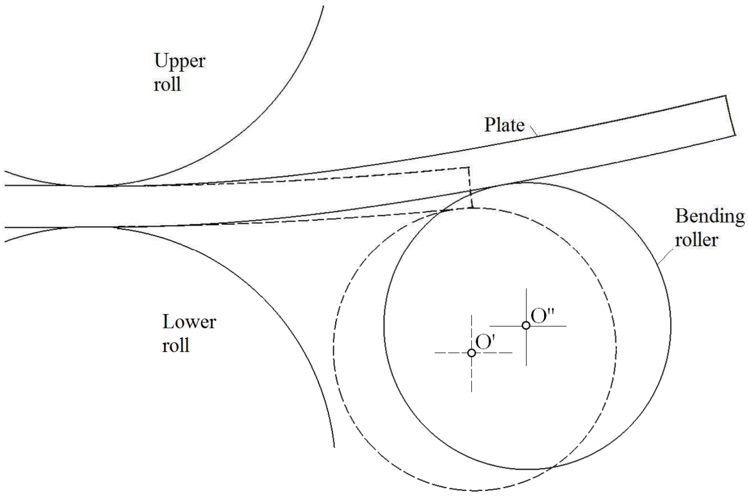


Fig.6 Trajectory scheme of the bending roller

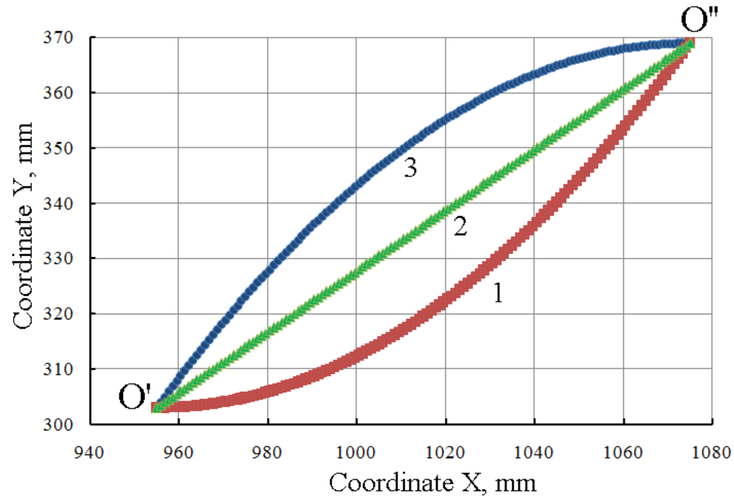


Fig.7 Bending roller trajectory variants: 1 – concave parabola (y_1=0,004x^2-8,754x+4483); 2 – straight (y_2=0,549x-221,7); 3 – convex parabola (y_3=-0,004x^2+9,854x-4927)

Numerical modeling and combine process of vertical asymmetric rolling and plastic bending analysis was carried out with the help of the finite elements method in the program complex DEFORM 3D [7] with the following assumptions: 1) three-dimensional scheme of stress-strained metal state; 2) the process is isothermal; 3) the deformed media is ductile; 4) Sybel's law of friction; 5) working rolls and the bending roller are rigidly fixed.

On the basis of computer modeling it was established that maximum BBRP camber deviation of pre-assigned (template) value is 28,0 mm in the roller movement along trajectory 1 and 9,6 mm – along trajectory 3 (Fig. 8). In roller movement along trajectory 1 relative torque moment differentiation was 2,196; in roller movement along trajectory 2 torque moment differentiation was 1,024; in roller movement along trajectory 3 torque moment differentiation was 1,212 (Fig. 9).

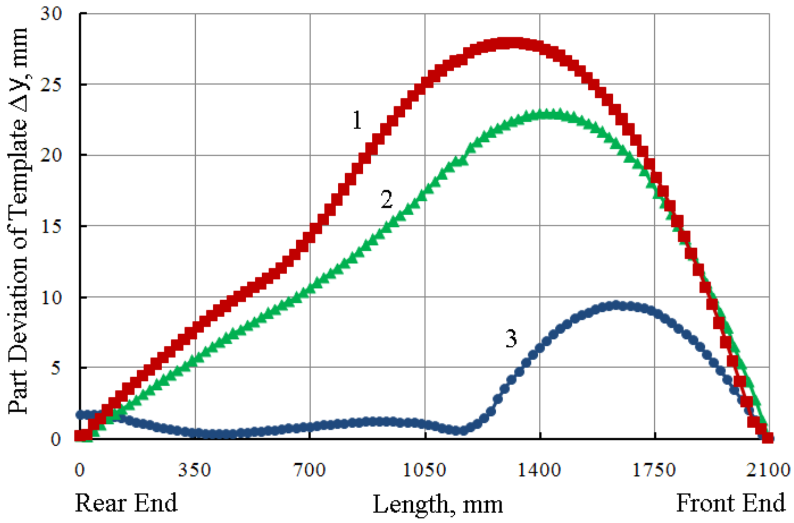


Fig.8 Distribution of camber deviation Δy over part length: 1 – roller movement along concave parabola; 2 – straight roller movement; 3 – roller movement along convex parabola

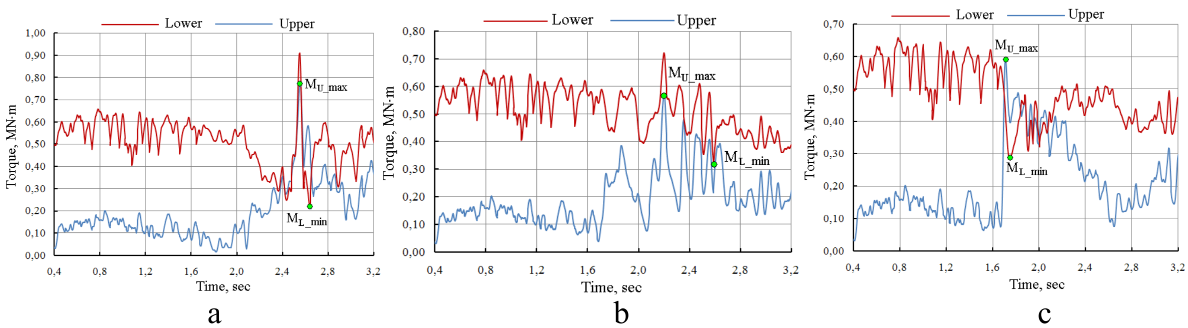


Fig.9 Torque differentiation in roller movement along trajectory 1 (a), 2 (b) and 3(c)

Thus, for the given modeling conditions the efficient bending roller trajectory is trajectory №3, the convex parabola y_3=-0,004x^2+9,854x-4927.

Conclusion

Three-dimensional finite elements model of strip rolling from ingots with asymmetric cross-section relative to the vertical plane has been developed. It is characterized by the description of lateral metal deformations during this process. Basic regularities and technological peculiarities of this type of rolling have been studied. It can be clearly seen that considerable lateral metal flow resulting in ingot thickness variation.

Technology of combined asymmetric rolling and plastic banding process has been improved. To lower the dangerous torque moment differentiation it was proposed to make the bending roller motile which will allow its movement along the given trajectory. Process efficiency evaluation method was proposed, the analysis of the energy-power parameters bending roller trajectory influence was carried out and the given part geometry production accuracy was determined.

The application of the motile roller helps to reduce dangerous torque moment differentiation at working rolls by the value of 1,5-2,5 compared with the rigidly fixed roller. The most effective bending roller trajectory is a second-order curve that is convex parabola.

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10.4028/www.scientific.net/AMR.586

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