ISSN 0967-0912, Steel in Translation, 2013, Vol. 43, No. 2, pp. 47–49. © Allerton Press, Inc., 2013.
Original Russian Text © M.V. Erpalov, D.Sh. Nukhov, A.A. Bogatov, 2013, published in "Izvestiya VUZ. Chernaya Metallurgiya," 2013, No. 2, pp. 16–18.

Distortion of the Depression on the Rear of the Blank in Broaching

M. V. Erpalov, D. Sh. Nukhov, and A. A. Bogatov

Yeltsin Ural Federal University, Yekaterinburg

Received August 13, 2012

Abstract—When using continuous-cast billet in pipe rolling, it is expedient to roll the billet prior to broaching, so as to improve the structure and properties of the steel. To that end, a three-high screw-rolling mill for billet reduction has been installed at the TPA-80 pipe-rolling unit at OAO Sinarskii Trubnyi Zavod. Introduction of the new process was associated with increase in the rejection rate on account of indentations in the pipe. These indentations may be attributed to the depression formed at the rear of the billet in reduction and the subsequent formation of metallic semicircles on broaching; the semicircles break away and enter the deformation zone. The sources of the indentations on the rolled pipe are investigated. The broaching of the billet on a screw rolling mill is mathematically simulated. Recommendations are made with a view to reducing the surface defects on pipe produced by the TPA-80 unit with a reduction mill.

DOI: 10.3103/S0967091213020095

In the production of hot-rolled pipe, the use of continuous-cast billet poses certain problems. Within that context, a three-high rolling mill has been introduced in the TPA-80 pipe-rolling system at OAO Sinarskii Trubnyi Zavod (OAO SinTZ). With reduction of the continuous-cast billet from a diameter of 150 (156) to 120 mm, the productivity of the TPA-80 system increases by 15%, with 10% decrease in cost [1]. However, the introduction of the new mill within the TPA-80 system increases the rejection rate on account of indentations in the pipe (Fig. 1). These defects may be attributed to the depression formed at the rear of the billet in reduction (Fig. 2a) and the subsequent formation of metallic semicircles on broaching (Fig. 2b). Those semicircles break away and reach the pipe surface, where they create impermissible defects.

Physical and mathematical simulation at OAO SinTZ indicates that the depth of the depression mainly depends on the shape of the billet's rear surface. If the billet's rear surface is shaped before reduction, the depth of the depression is reduced by 62%. To shape the end of the billet, a new cutting method has been developed [1]. This method reduces the rejection of the pipe on account of indenting. However, the lack of data regarding the distortion of the billet's rear surface on broaching hinders the identification of optimal conditions for the new technology.

In the present work, we investigate the distortion of the depression at the billet's rear surface on broaching. In addition, we use DEFORM-3D (v. 10.0) software for finite-element simulation. Geometric models of the rollers, guides, and mandrels are created on the basis of SolidWorks software. The billet, ancillary components, and push-rod unit are formulated by means of DEFORM-3D software. The rollers are positioned as a function of the supply angle $\beta = 12°$ and the aperture $\delta = 8°$. The roller configuration ensures a billet diameter of 120 mm at the exit from the broaching mill. The billet temperature is 1180°C; the tool temperature is 150°C; and the ambient (air) temperature is 20°C. Boundary conditions of the third kind are formulated for the temperature: the heat flux $q = \alpha_i \Delta\theta$, where α_i is the heat-transfer coefficient, W/(m K); and $\Delta\theta$ is the temperature difference, °C. The heat-transfer coefficient is assumed to be 0.02 W/(m K) for the air and 5 W/(m K) for the rollers. At the billet–tool contact surface, besides the heat-conduction conditions, we assume the Siebel frictional law: $\tau = \psi\tau_s$, where τ is the frictional stress, MPa; ψ is the frictional coefficient; and τ_s is the resistance to shear deformation. We assume that $\psi = 1$ for the roller and billet, $\psi = 0.2$ for the mandrel and billet, and $\psi = 0.4$ for the guide and billet. To ensure reliable results, the

Fig. 1. Indentation on surface of finished pipe.

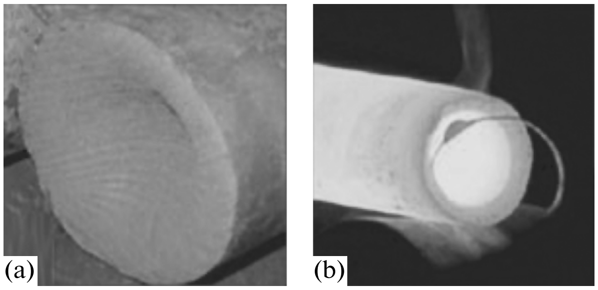

Fig. 2. Formation of a depression on the billet (a) and of a metal semicircle at the end of the sleeve (b).

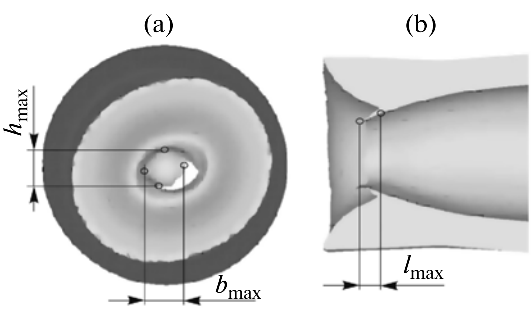

Fig. 3. Characteristic dimensions of blemish (a) and annular flaking (b).

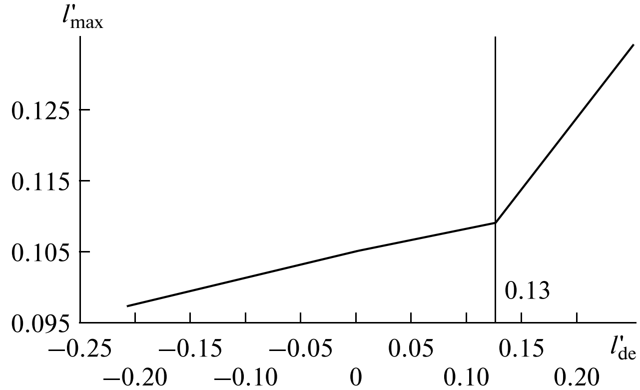

Fig. 4. Dependence of the relative length l'_{max} of the annular flaking on the relative depth l'_{de} of the depression at the rear of the billet before broaching.

number of finite elements adopted for the billet (diameter 120 mm, length 700 mm) is 200000. On the recommendations of the DEFORM-3D developers, the size of an element must be no more than 2.5 mm. In the present case, the actual geometric parameters of the deformation zone are adopted.

The goal here is to determine the influence of the shape of the billet's rear surface in broaching. The depth of the depression is assumed to be $l_{de1} = 30$ mm, $l_{de2} = 16$ mm, $l_{de3} = 0$ mm (billet with a flat end), or $l_{de4} = -25$ mm (billet with a convex end). The only variable is the depth of the depression relative to the billet diameter: $l'_{de} = l_{de}/d_b$. The constant parameters are the billet diameter $d_b = 120$ mm; the supply angle $\beta = 12°$; the aperture $\delta = 8°$; the roller speed $n = 100$ rpm; and the tool adjustment in the broaching mill. Solution of the problem does not indicate the formation of metal semicircles in broaching, in conflict with practical experience. However, finite-element solution reveals the formation of blemishes (Fig. 3a) and annular flaking (Fig. 3b) at the ends of the billet. To assess measures intended to reduce semicircle formation, we may confine our attention to annular flaking. We introduce the following notation: b_{max} and h_{max} are the width and height of the blemish; l_{max} is the length corresponding to annular flaking.

The table presents calculated values of the dimensionless quantities l_{max}/d_b, b_{max}/d_b, and h_{max}/d_b. On that basis, in Fig. 4, we plot l_{max}/d_b as a function of the relative depth l_{de}/d_b of the depression before broaching. According to Fig. 4, l_{max}/d_b is least for billet with $l_{de}/d_b = 0.208$. When $l_{de}/d_b = 0.130$, which exceeds the critical value (corresponding to l_{de} = 16 mm), the length of annular flaking sharply increases. That indi-

Results of mathematical simulation

Geometric parameter	Value when the initial depth of the depression is			
	−0.208	0	0.130	0.250
Length of annular flaking $l'_{max} = l_{max}/d_{de}$	0.097	0.105	0.109	0.134
Width of blemish $b'_{max} = b_{max}/d_{de}$	0.199	0.206	0.203	0.208
Height of blemish $h'_{max} = h_{max}/d_{de}$	0.192	0.188	0.190	0.219

cates less likelihood that metal semicircles will be formed on broaching.

CONCLUSIONS

The depth of the depression at the rear of the billet beyond the reduction mill significantly affects the annular flaking and the rejection rate of the pipe on account of indentations. The influence of l'_{de} on the length of annular flaking has a critical value. At $l'_{de} >$ 0.130, the annular flaking increases sharply and hence there is considerable likelihood that metal semicircles will be formed on broaching. Optimal reduction of the continuous-cast billet and profiling of its rear end ensures that $l'_{de} < 0.130$, when the rejection rate due to indentations will be reduced.

REFERENCES

1. Ovchinikov, D.V., Bogatov, A.A., and Erpalov, M.V., *Chern. Met.*, 2012, no. 3, pp. 18–21.

Translated by B. Gilbert