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Roll calibers for plugless rolling of pipes

The process of rolling pipes without mandrels (calibration or reduction) is the final operation in all technological manufacturing lines of hot-rolled seamless pipes. The parameters of metal forming in the case of continuous longitudinal rolling of pipes without mandrel largely determine the characteristics of quality and accuracy of the finished product. In the processes of reduction and calibrating, oval-shaped calibers are preferably used, the profile of the working area of which is formed by one or more forming radius R. Characteristics of a profile of one or another caliber (fig. 1, fig. 2) are defined by the number of radiuses R, their sizes, values of eccentricities e of those radiuses in relation to the center of the caliber (rolling axis) O and ovality of the caliber $\lambda = b/h$ (here, b, h – height and width of the caliber).

The most common are single-radius calibers (Fig. 1), which are used in industrial setups for almost 80 years. These calibers are relatively easy to manufacture. They allow to obtain pipes that until recently fully met the requirements of existing standards and specifications.

Based on the requirements of the new specifications of the world's largest consumers of steel pipes (Shell, Shevron, Exonn Mobil, ADCO, Saudi ARMCO, LUCOIL, GAZPROM, ROSNEFT etc.) requirements for product quality and accuracy are constantly increasing. Therefore, there is an urgent need for improvements in production technologies. One of the ways to solve this problem in terms of improving the accuracy of the pipe is to find rational profiles of calibers for rolling.

In the patent [1] a three-radius caliber roll for longitudinal rolling is proposed, which is presented in Fig. 2. A characteristic feature of this caliber is the requirement according to which the eccentricities e_1 and e_2 must only gain positive values. However, there are studies [2, etc.], according to which when $e_1 < 0$ deformation conditions help to reduce the transverse wall thickness variation of the pipes and to increase their accuracy.

In works [3, 4] a mathematical model was developed, which analyzed the influence of caliber parameters on the calculated transverse wall thickness variations of pipes rolled in a 24-stand reduction mill along the route 119x5 mm $\rightarrow$ 42.5x5 mm.

Fig. 3 represents the calculated values of the resulting wall thickness variations $B_{\Sigma i}$, which is accumulated when rolling the pipe from the first stand of the mill to the stand with the current number i when using one-radius caliber (curve 1) and three-radius calibers, the parameters of which are calculated using the condition $e_1 > 0$ (curve 2) and without it (curve 3) with the same distribution of partial deformations ε_i between the stands of the mill (curve 4). As follows from the data shown in Fig. 3 when rolling using single-radius calibers the resulting final relative wall thickness variation equals $B_{\Sigma 24} = 10.45\%$. If using three-radius calibers $B_{\Sigma 24}$ = 8.98% (if $e_1 > 0$), and $B_{\Sigma 24} = 4.67\%$ (if e_1 is not constrained).

This example shows that when designing three-radius calibers under the condition to have eccentricity $e_1 < 0$, the level of relative wall thickness variation of the finished pipes can be significantly reduced (1.9…2.2 times), that is, to increase tubes' accuracy.

Reduced value of the wall thickness variations $B_{\Sigma i}$ when using the proposed three-radius calibers can be explained by the characteristics of their shape, which is due to the fact that the eccentricity e_1 of the radius R_1 of the caliber is negative ($e_1 < 0$). Because of that in a stand

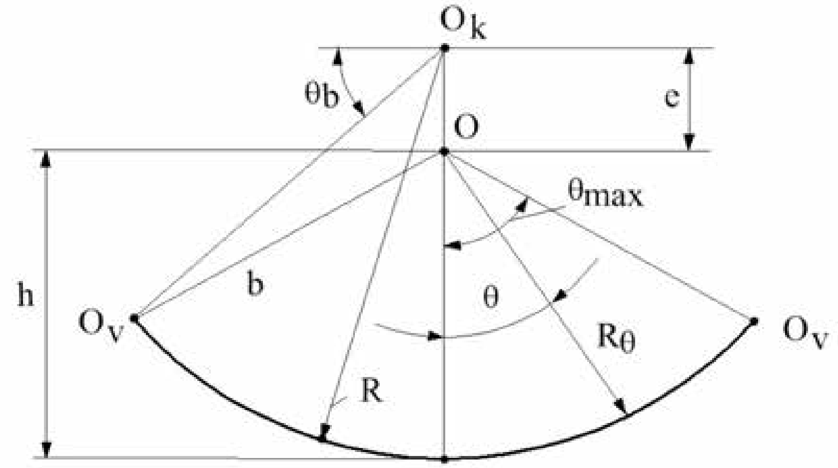

Fig. 1. One-radius oval caliber

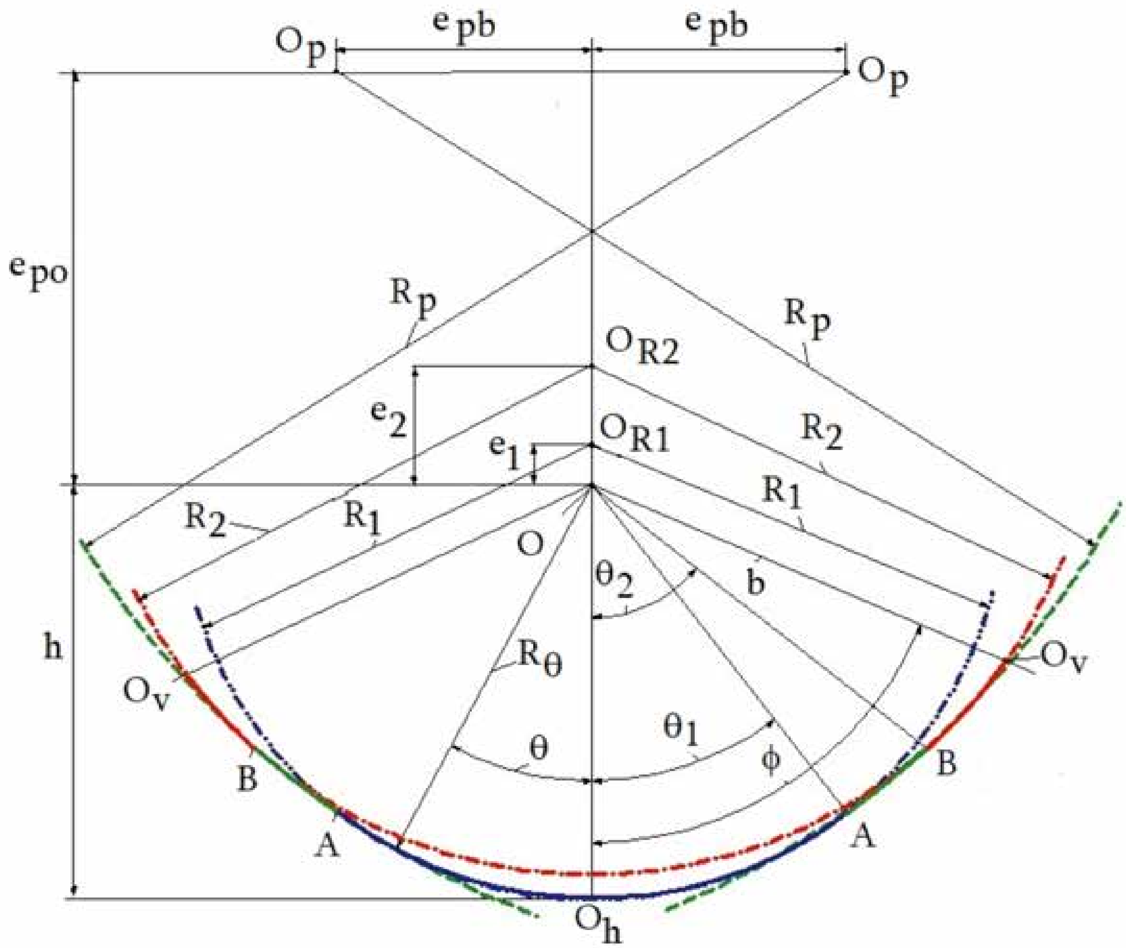

Fig. 2. Three-radius oval caliber

with a serial number $i = 16$, in contrast to the one-radius ($R = 29.347$ mm, $e = 1.851$ mm, $\lambda = 1.032$) and the known three-radius ($R_1 = 27.659$ mm, $e_1 = 0.010$ mm, $R_2 = 30.262$ mm, $e_2 = 3.300$ mm, $\lambda = 1.030$) calibers:

- radius R_θ of the proposed caliber ($R_1 = 17.540$ mm, $e_1 = -10.709$ mm, $R_2 = 33.591$ mm, $e_2 = 7.990$ mm, $\lambda = 1.022$), in the top area is smaller than the average radius of the caliber R_{cp} (Fig. 4);
- radial compression $\Delta R_\theta(\theta)$ gains maximum values in the middle of the caliber (when $\theta \approx 30^o$), rather than monotonically decrease from top to release (Fig.5);
- the initial contact of the workpiece with the roll happens not at the top of the caliber, but in its middle zone (Fig. 6).

The fact that the radius of the proposed caliber is smaller than the radius of the known caliber at $\theta \approx (20...55)^o$ (Fig. 7) and radial compression ΔR_θ gains its maximum values not at the top of the caliber but at $\theta \approx 30^o$ (Fig. 5), causes "bilateral" flow of the forming metal from the middle of the caliber in the direction of its top and release. In terms of the formation of the transverse wall thickness variation, such deformation conditions are more optimal than the conditions under which there is a one-way flow of metal in the direction from the top to the release of the caliber. This was confirmed by industrial tests under conditions of Pipe Rolling Machine 30-102.

Literature

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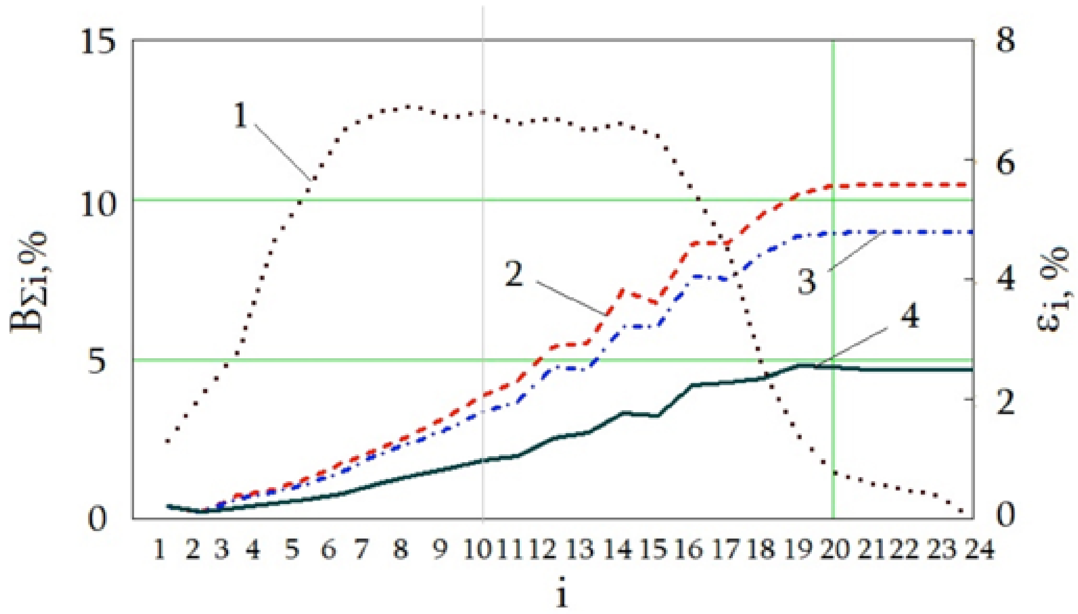

Fig. 3. Calculated dependencies $B_{\Sigma i}(i)$ and distribution of partial relative compressions ε_i (notation - in the text)

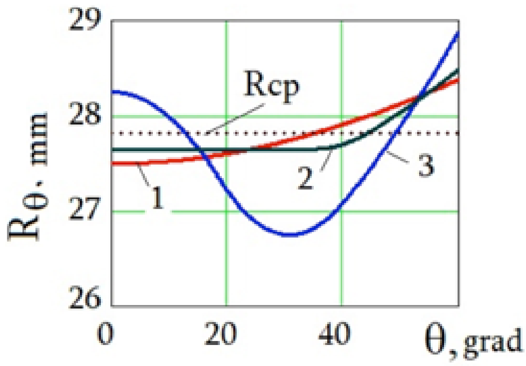

Fig. 4. Change of radius R_θ at ½ of caliber's perimeter: 1 – one-radius; 2 – three-radius [1]; 3 – proposed three-radius

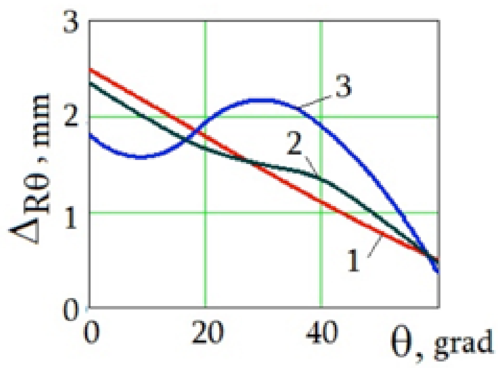

Fig. 5. Change of compression ΔR_θ at ½ of caliber's perimeter: 1 – one-radius; 2 – three-radius [1]; 3 – proposed three-radius

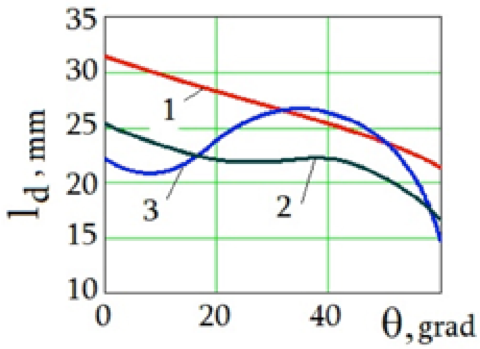

Fig. 6. Change in length of the deformation zone l_d at ½ of caliber's perimeter: 1 – one-radius; 2 – three-radius [1]; 3 – proposed three-radius

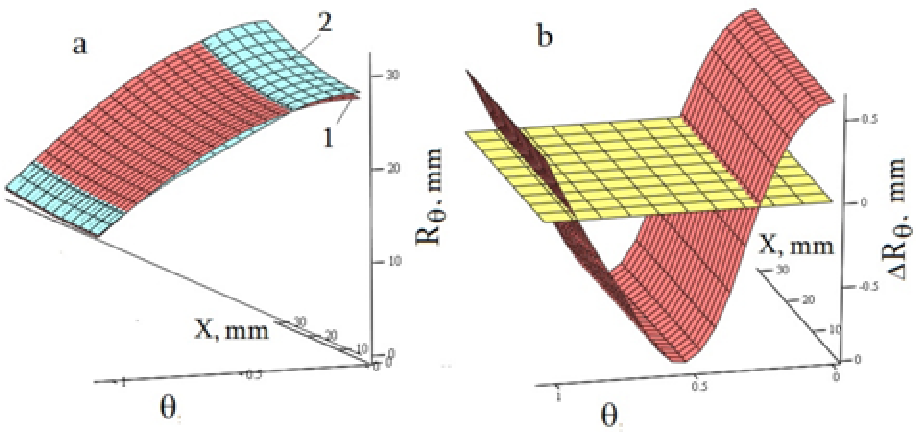

Fig. 7. Change of caliber's radius R_θ (a) and differences between radiuses ΔR_θ (b) along the length and perimeter of the deformation zone at ½ of caliber's perimeter: 1 – proposed three-radius; 2 – three-radius [1]

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