Maximum feed in periodic profile deformation

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Abstract

This paper considers maximum billet feed into the deformation zone based on the concept of division of the process of periodic rolling into longitudinal rolling and vertical sinking with different conditions of contact interaction. It was determined that maximum feed shall be found by the limit conditions of sinking independent of the friction forces in the contact surface. Determination of maximum feed allows to design pilger head profile at an ultimate form change rate.

In tube production, periodic profile working cycles can be divided into sections of constant and varying height of the back border of instantaneous deformation zone depending on the form change conditions. Roll radius increase in each instantaneous section of the plain form change scheme at a constant position of the center of roll rotation relative the longitudinal axis is the characteristic feature of periodic deformation in main tube rolling processes (hot and cold pilgering). It quantitatively characterizes the sinking constituent in hot and cold Pilger mills but it is not characteristic for the mills where radius of the working tools (rollers) is constant in the instantaneous deformation zone.

To determine maximum feed in the periodic profile form change, consider a plain scheme taking into account the principle of dividing the process into longitudinal rolling and vertical sinking at different conditions of contact interaction [1].

Fig. 1 shows an intermediate position of an instantaneous deformation zone during deformation of a fed metal volume with a constant position of the front (DD′) and back (BB′) borders of the contact zone and a rolled-off profile AB of a variable cross-section due to the increase in the roll radius from r_0 to r_1. In this position, the contact zone is characterized by a neutral section angle γ at which roll velocity W_c and metal velocity V_c are equal at point C. As the linear metal velocity $V_{в}$ at section BB′ is greater than the linear roll velocity $W_{в}$ at section BC because of lead, position of the front border of the contact zone BB′ and profile height h_1 are determined by the center line O_1O_1 of the work rolls and curvature radius μ of the periodic profile at the rolled-off section AB of the fed metal amount is larger than the roll curvature radius in any position of the roll. The pilger head profile is concave if the roll ridge is designed by Archimedian spiral, i.e. the roll radius in any instantaneous deformation zone increases proportionally to the angle of rotation.

Because the roll radius increases, the marginal state does not occur according to the conditions of contact interaction (at γ = 0) and the profile deformation continues due to appearance of the sinking zone. It is why the maximum feed shall be found by the conditions of the marginal state of sinking independent of the friction forces at the contact surface.

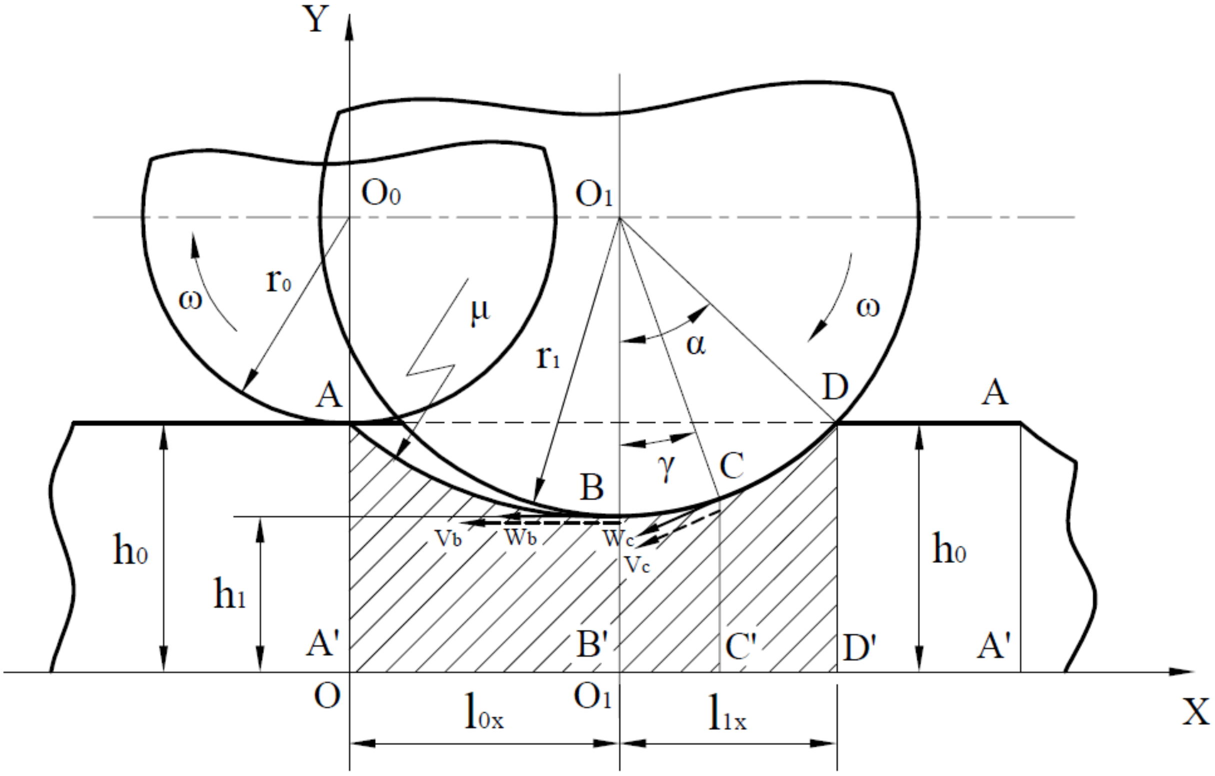

Fig. 1 Intermediate position of an instantaneous deformation zone in working the fed metal volume

Consider next a conventional plain scheme of the instantaneous deformation zone (Fig. 2) in rolling-off maximum feed m_{max} in accordance with equation of marginal state.

$$\alpha_{\max} = \rho + \sqrt{\rho^2 + 2\beta_{\max}^2},$$

where angle α_{max} characterizes the zone of rolling a band of height h_0 before the center line O_1O_1 and angle β_{max} characterizes the zone of sinking a profile of height h_1 after the center line O_1O_1 by a work roll with radius r_1. Friction angle ρ determines conditions of unidirectional friction in the contact zone and the turn of axial components of normal forces after the center line in the sinking zone makes the deformation capacity of the process almost twice as high [1]. In a marginal state, position of the back border of the instantaneous deformation zone with height h_1 is determined by a compulsory condition $\alpha_{max} \geq 2\rho$ because

$$\beta_{\max} = \sqrt{\frac{\alpha_{\max}}{2}\left(\alpha_{\max} - 2\rho\right)}, \qquad (2)$$

In this case, if values α_{max} and β_{max} are known, the borders of the instantaneous deformation zone are related by correlation

$$h_0 - h_1 = \frac{r_1}{2}(\alpha_{\max}^2 - \beta_{\max}^2) \qquad (3)$$

Simple transformations give the value of roll radius r_1 and the value of sinking in the rolling zone $\Delta h_п$ and in the sinking zone Δh_o.

$$r_1 = \frac{r_0}{1 - 2\sin^2\frac{\alpha_{\max}}{2}} \approx \frac{2r_0}{2 - \alpha_{\max}^2}; \qquad (4)$$

$$\Delta h_n = h_o - h_{\min} \approx \frac{r_1}{2}\alpha_{\max}^2 \qquad (5)$$

$$\Delta h_o = h_1 - h_{\min} \approx \frac{r_1}{2}\beta_{\max}^2 \qquad (6)$$

The shifted area in the rolling zone before the center line

$$S_n = \frac{\Delta h_n l_\alpha}{2} = \frac{\Delta h_n^2}{2tg\frac{\alpha_{\max}}{2}} \approx \frac{\Delta h_n^2}{\alpha_{\max}} \quad (7)$$

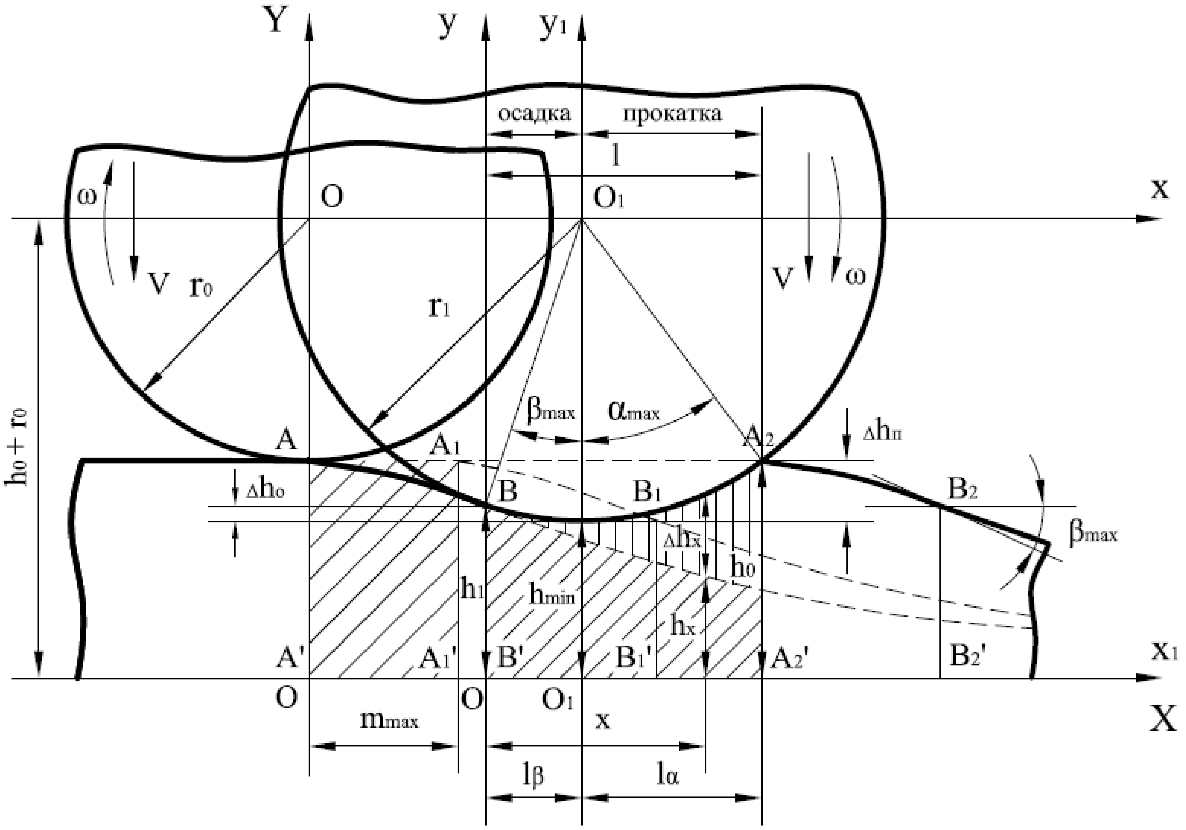

Fig. 2 Instantaneous deformation zone in working a maximum fed metal volume m_{max}

The shifted area in the zone of sinking with a round striker after the center line

$$S_o = \frac{\Delta h_o l_\beta}{2} = \frac{\Delta h_o^2}{2tg\frac{\beta_{\max}}{2}} \approx \frac{\Delta h_o^2}{\beta_{\max}} \quad (8)$$

Total shifted area

$$S = S_n + S_o = \frac{\Delta h_n^2}{\alpha_{\max}} + \frac{\Delta h_o^2}{\beta_{\max}} = \frac{r_1^2}{4}(\alpha_{\max}^3 + \beta_{\max}^3); \quad (9)$$

Maximum feed in periodic deformation is:

$$m_{\max} = \frac{r_1^2}{4h_o}(\alpha_{\max}^3 + \beta_{\max}^3) \quad (10)$$

Value of angle β_{max} characterizing the contact zone of sinking after the center line is determined according to the conditions of plasticity in working material with a round striker from a fixed center [2].

Conclusions

Determination of maximum feed allows to design an optimum pilger head profile with a high form change rate and consequently to work out new principles of work tool design.

References

1. Balakin V.F., Belan K.S., Perchanyk V.V. Extreme conditions of periodic rolling . Teoriya I Praktika Metallurgii .2009, No. 5-6, - p. 54-56.
2. The extreme deformation ratio in sinking (not published).