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Modes of roll piercing, providing decreasing of longitudinal nonuniformity of tube wall thickness in plug mills

M.I. Khanin /Dr.Eng./

National Metallurgical Academy of Ukraine

Abstract

The reasons of appearance of longitudinal nonuniformity of tube wall thickness in plug mills were analyzed. Ways and conditions of decreasing of longitudinal nonuniformity of tube wall thickness are shown. The main way of it – incensement of feed angle and rotary speed of piercing rolls.

Cooling rates of stock material and shell are different during the piercing of solid billet in a hollow shell. The hollow shell, inside which, moreover, a water-cooled draw bar is, loses heat more intensively. The result is a temperature difference ΔT_{diff} between the head (he) and rear (re) ends of the shell

$$\varDelta T_{diff} = T_{diff.re} - T_{diff.he} \quad (1)$$

being 35-105° [1-3]. The magnitude of this difference is greater for the thin-walled shells, at a higher temperature at the outlet from the deformation zone $T_{z.diff}$, with more cooling time $t_{diff} = l_{sh} / v_p$ (l_{sh} – shell length, v_p – axial velocity of piercing). Temperatures $T_{z.he}$ and $T_{z.re}$ are almost equal, as due to the cooling of stock material the drop of $T_{z.re}$ in the inlet trough is compensated by the lower heat loss in deformation zone due to the gradual heating-up of the instrument.

The phenomenon of regular temperature formation along the shell length is especially typical for tube plug mills - automatic or "tandem" mill, where the main deformation is produced on piercing mill.

The $\varDelta T_{diff}$ occurrence causes the difference of temperature $\varDelta T_p$ and rolling force $\varDelta P_p = P_{p.he} - P_{p.re}$ in plug mill (Fig. 1), the crevice change in it $\varDelta z_p = \varDelta P_p / C$ (C - the modulus of rigidity of plug mill stand) and the appearance of the longitudinal nonuniformity of tube wall thicken

$$\varDelta S_{long} = S_{he} - S_{re} = \varDelta P_p / 2C . \quad (2)$$

The magnitude of the longitudinal nonuniformity of wall thickness at different mixes is 0.2 - 0.7 mm [1-4]. Its occurrence results in average wall thickness increase and, accordingly, the metal consumption index during the plain tubes rolling and in addition in the difficulties of performing the quality thread at thickened and thinned tube ends during the threaded tubes rolling.

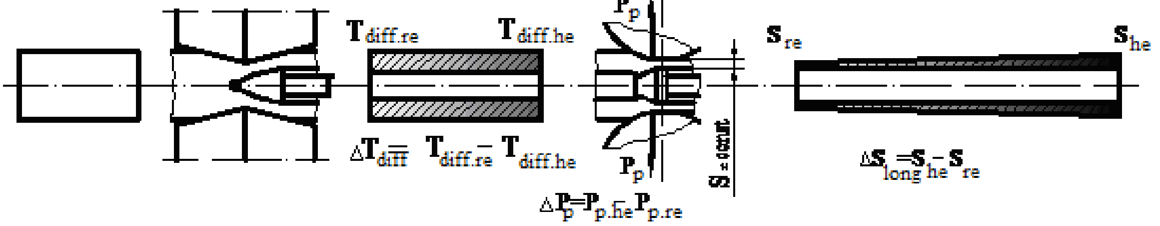


Figure 1 Scheme of tube rolling in plug mills (dark hatching corresponds to lower temperature of shell and tube)

Due to the above a great attention was always paid to reduction in the longitudinal nonuniformity of wall thickness. The following methods of its reduction are described in a number of studies:

- temperature equalizing along the length of the shell by its spray cooling with increasing intensity during the piercing process directly at the work stand of piercing mill: $\Delta T_{\text{diff}} \rightarrow \min$ [5];

- regulation of the rolling crevice in plug mill: $\Delta z_{\text{p}} \rightarrow \min$ [1, 2];

- piercing and subsequent rolling of the shell with variable wall thickness, which is less at its cooler head end, for the cancellation of change oft he metal temperature and the wall thickness reduction ΔS_{p} in plug mill $\Delta P_{\text{p}} = (\delta P_{\text{p}}/\delta(\Delta S))\,\Delta S_{\text{p}} + (\delta P_{\text{p}}/\delta T)\Delta T_{\text{p}} \rightarrow \min$ [3].

These methods require an appropriate retrofitting of piercing or plug mills, have their inherent advantages and disadvantages. The most significant results were obtained in TPA 350 by the third method, the only one currently used.

The study is devoted to assessing the possible reduction in the longitudinal nonuniformity of tube wall thickness only by the choice of reasonable speed modes of piercing, determined by the feed angle α and rotary speed of rolls *n*. The calculation includes two steps: 1) calculation of the temperature difference along the length of the shell directly after piercing, during its transportation to the plug mill and rolling in this mill; 2) calculation of the plug mill force at the deformation of head and rear ends of the shell, the difference of elastic strains of the stand and longitudinal nonuniformity of tube wall thickness.

The first task is accomplished in two steps: the first (thermotechnical) one - calculation of the temperature field of cooling quill cylinder (shell) with a cylindrical rod inside with the piercing process and without it during the subsequent operations in function of the shell geometrical dimensions, the initial temperature and time; second step - determination of the time of piercing t_{pierc}, transportation and t_{transp} rolling in plug mill t_{p} and the temperature differencies ΔT_{diff} and ΔT_{p} (Fig. 2).

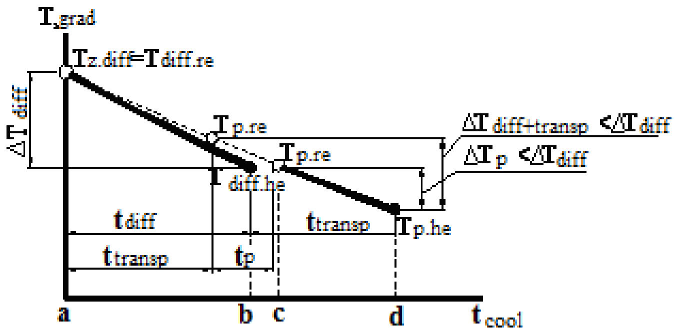


Figure 2 Metal temperature at different points of industrial process: *a*, *b* - outlet of the rear (re) and head (he) ends of shell from the piercing mill; *c*, *d* - inlet of the head and rear ends of shell into the plug mill; the rear end temperature at the inlet of the head end of shell into the plug mill.

The temperature distribution in the shell was determined by solving the differential equation of heat conduction for various border-line conditions in different periods (Fig. 3, 4). The regression equation, taking account of heat loss, emission and convection was deduced by the calculation data processing and is of the form

$$\Delta T_{\text{diff}} = k\,(\,0{,}016\,t_o^o - 0{,}45S - 7{,}03\,)\,t_{\text{cool}}\,, \quad (3)$$

where t_o^o – initial temperature at the outlet of piercing mill, °C; k = 1.05-1.07 – coefficient of convection cooling, t_{cool} – cooling time, s.

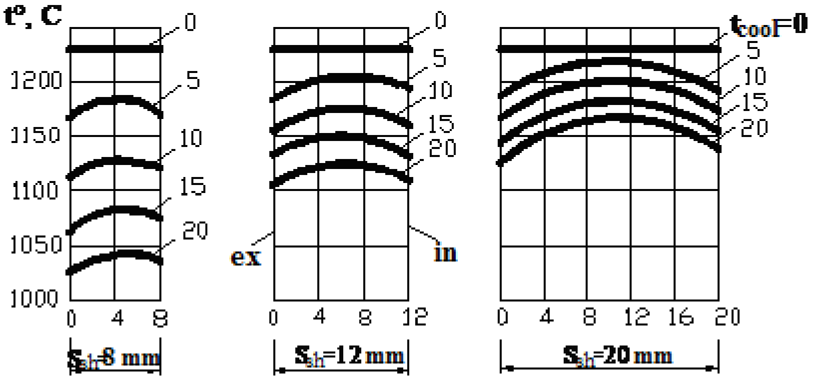
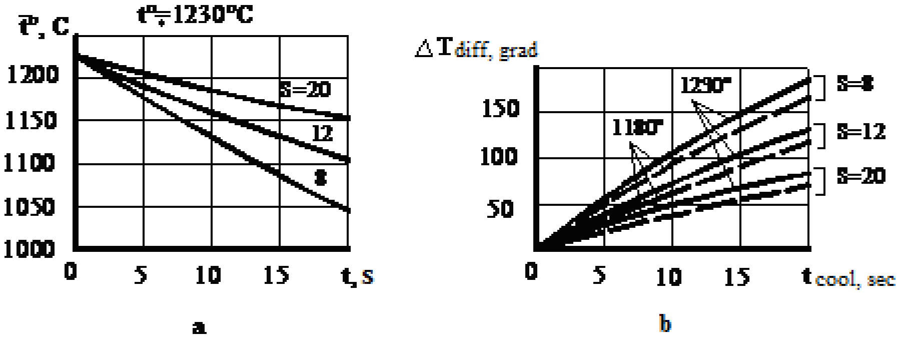


Figure 3 Temperature distribution along the shell wall thickness S_{sh} at different cooling time t_{cool}, s; ex, in - external and internal surfaces of the shell



a

b

Figure 4 The average temperature along the shell cross section (s) and temperature difference (b) dependence on the initial temperature, wall thickness and cooling time

The initial temperature

$$t_o^o = t_{warm} + \Delta T_h, \quad (4)$$

where ΔT_h - heating temperature in the piercing mill

$$\Delta T_p = k_0 . k_1 . a_т / c,$$

k_0 – coefficient of thermal yield with deformation [6], k_1 – the heat portion stored in metal, $a_т$ – specific energy consumption for piercing per 1 t of shells (calculated by a special algorithm), c – specific heat of steel

Calculation according to the equation (3) compared with experimental data obtained by measuring by various types pyrometers shows the deviation towards underestimation ΔT_{diff} not more than 10% (which is explained by the scale formation in the cooling process, affecting the readings of pyrometers).

The rolling heat in plug mill was calculated according to the time $t_{diff} + t_{transp}$ for the head end of shell, the time $t_{transp} + t_p$ for the rear end of shell.

The cooling process in piercing mill have a major impact on the ΔT_p value. In this process ΔT_{diff} depends on the $t_{cool} = t_{diff}$ in accordance with the expression (3), which in turn, primarily depends on the feed angle α and the rotation speed of rollers n

$$T_{cool} = l_{sh} / v_{diff} = l_{sh} / ((\pi D_{pierc} n / 60) \cdot \sin\alpha \cdot \eta_o), \ (5)$$

D_{pierc} – diameter of the piercing mill rollers, $\eta_o(\alpha, n)$ – axial velocity coefficient as a function of α and n.

The dependence $t_{cool}(\alpha, n)$ and $\Delta T_{diff}(\alpha, n)$ is shown in Fig. 5. ΔT is slightly lowered with the subsequent transportation and rolling: $\Delta T_p < \Delta T_{diff}$.

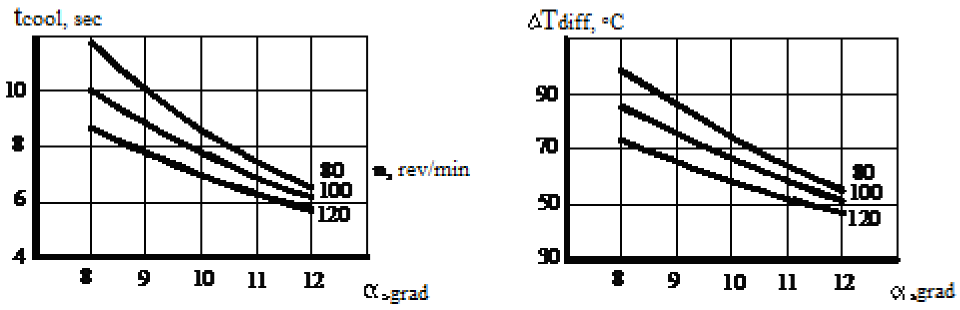


Figure 5 Dependence of the cooling time and temperature difference after the piercing on kinematic parameters of the process (diameter of roller - 850 mm, stock material - 150 mm, shell - 157x11x6500 mm)

Dependencies of the rolling force difference $\Delta P_p(\Delta T_p) \approx \Delta P_p(\alpha, n)$ and longitudinal nonuniformity of tube wall thickness $\Delta S_{long}(\alpha, n) = \Delta P_p / 2C$ are shown in Fig. 6. These data show that an increase in α and n leads to a decrease in the longitudinal nonuniformity wall thickness of finished tubes ΔS_{long} by changing the process parameters allowable in terms of the features of mechanical equipment and main engines of piercing mills. Changes in the calibration of the piercing mill process tool should be made to save the level of longitudinal nonuniformity of wall thickness with the increase in α.

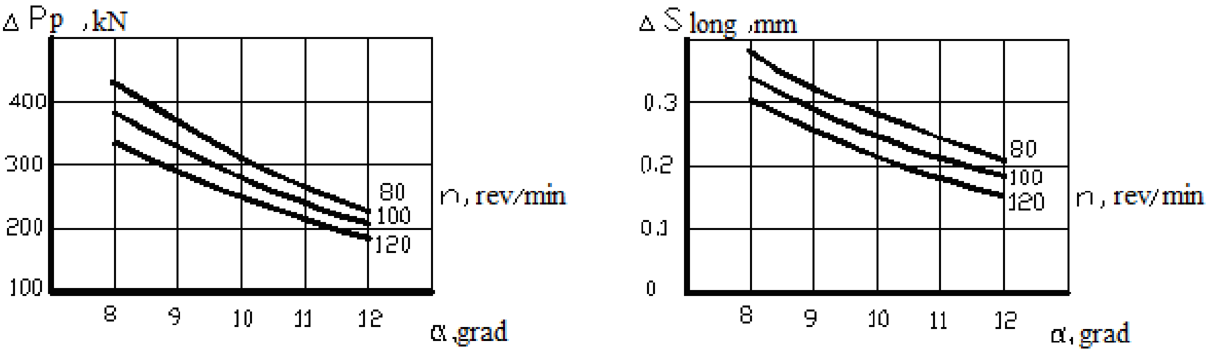


Figure 6 Dependence of the rolling force difference and longitudinal nonuniformity of tube wall thickness on kinematic parameters of the process (diameter of roller - 850 mm, stock material - 150 mm, shell - 157x11x6500 mm)

A change in the lengthening coefficient in piercing mill λ_p and a corresponding change in the shell length l_{sh} have a double impact when the deformation redistribution between the piercing and plug mills is possible: a) with the λ_p reduction and shell shortening the t_{cool} , ΔT_{diff} and ΔS_{long} are decreased; b) an increase in compression in plug mills leads to the strength P_p increase, rolling force difference ΔP_p and longitudinal nonuniformity of wall thickness ΔS_{long}.

Conclusions

Reduction in the longitudinal nonuniformity wall thickness of finished tubes and the related metal consumption index is achieved by the intensification of roll piercing modes by the feed angle and rotation speed of rollers increase within a certain range.

References

1. Chekmaryov A.P., Vatkin Ya.L. *Osnovy prokatki trub v kruglykh kalibrakh* [Principles of tube rolling with round

passes]. Moscow, Metallurgizdat Publ., 1962. 222 p.

2. Khanin, M. I. (2002). Thin-walled tubes rolling technology of high accuracy in automatic mill using unsteady deformation modes in piercing. *Metallurgical and Mining Industry*, 8,9, 361-363.
3. Osipov, E. A., Osipov, G. A., Permiakov, V. I. (1974). Regulation of longitudinal nonuniformity of seamless tubes wall thickness. *Production mechanization and automation*, 1, 22-23.
4. Ostrenko, V. Ya., Brodskiy, I. I., Berdyanskiy, M. G., Ponomarev, V. N. (1974). Decrease in the longitudinal nonuniformity of tube wall thickness, rolled in automatic mill. *Bull. TsNIITEI ChM.*, 21, 42-43.
5. Stoletniy M.F. *Tochnost' trub* [Accuracy of tubes]. Moscow, Metallurgy Publ., 1975. 240 p.
6. Yalovoy N.I., Tylkin M.A., Polukhin P.I., Vasiliev D.I. *Teplovyye protsessy pri obrabotke metallov i splavov davleniyem* [Heat processes in the metals and alloys treatment by pressure]. Moscow, High School Publ., 1973. 631 p.

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