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Examination and further improving of the manufacture of longitudinal electric-welded pipes

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Longitudinal electric-welded pipes of small and intermediate size in diameter are widely used in various fields from mechanical engineering to pipelines technology all over the world.

Owing to the increasing demand for industrial-grade steel pipe and tube products the investigations into electric-welded pipes manufacture are of great scientific and commercial interest. Recognizing the clear connection between the quality of welded pipes and safety pipeline design also generates a high interest in improving of welded seam quality.

The present work is aimed at investigation of plastic deformation processes during forming a strip into a cylinder and subsequent welding operation. This work has been conducted at JSC "Severstal" in the line of the pipe welding mill using high-frequency welding. Theoretical and experimental studies of the specific features of deformation of strips in close grooved rolls and also in the welding units have been carried out on available equipment for pipes ranging from 10 mm to 76 mm in diameter. The statistical analysis of the experimental data allowed the determination of equipment schedules which reduce equipment downtime and provide a decrease in corrugation and other pipe defects. Edges of the tube billet are butted together more precisely, which resulted in enhanced welded seam properties

By the means of mathematical statistics we have found the regression equation, which allows us to work out the magnitudes of the longitudinal deformation of the tube billets after reduction in close grooved rolls in accordance with the pipe size for the purpose of maximizing the characteristics of welded seam quality (1).

$$\varepsilon = 0.938\, e^{-0.0017P}, \tag{1}$$

where: ε -the longitudinal deformation of the tube billet which correspond to pipe parameters of the maximal quality; P - the mean diameter of the finished pipe.

The longitudinal deformation in the bending deformation zone exhibits alternating behavior. During the pre-contact deformation beyond the active deformation zone, (before the grooved rolls) the sharp

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change in the banding angle proceeds and an edge of the billet first is elongated in lengthwise direction (ε_{xx}) and then in the contact-deformation zone (between grooved rolls) contracted longitudinally ($-\varepsilon_{xx}$). Both those processes cause the longitudinal plastic deformation, whose maximal value can exceed several times the value of elastic deformation $\varepsilon_{xx} > 0.2\%$.

It is well-known that transverse deformation under tension compression are proportional to longitudinal deformations (reduction of cross-section leads to an increase in the length). Since, the longitudinal contractile deformation occurring between grooved rolls ($-\varepsilon_{xx}$) is compensated (redistributed) at the expense of longitudinal tensile deformation (ε_{xx}), which, in turn, occurs due to compression of the tube billet in the transverse direction (ε_{yy}).

On reducing process with a relative longitudinal deformation equal to ε_0 (Fig. 1) a maximal longitudinal deformation in the stand $|\varepsilon_{0max}|$ does not exceed an elastic one at the expense of superposition of the contractile and tensile deformation occurring as a result of transverse reduction.

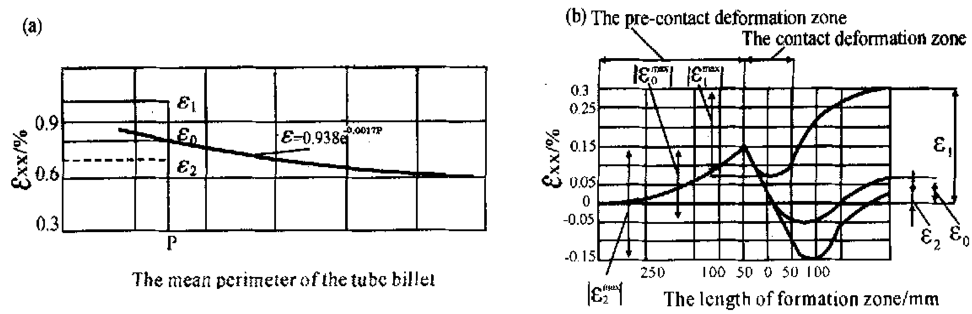

Fig. 1 Longitudinal deformation curves at different regimes of billet reduction
(a) — the efficient deformation of the tube billet during formation in close grooved rolls versus the finished tube size; (b) — the longitudinal deformation of the strip along the active deformation zone

In the case when the tube billet undergoes significant transverse contractile deformation, as a result the strip is subjected to the longitudinal tensile deformation ε_1, whose maximal magnitude noticeably exceeds the elastic strains $|\varepsilon_{1max}|$ 0.2 %.

In the case of reduction process with the relative longitudinal deformation ε_2, i. e. with applying to the strip the transverse contractile deformation, the strip undergoes a notable longitudinal contractile deformation, whose maximal magnitude also exceeds the elastic strains $|\varepsilon_{2max}|$ 0.2 %.

For both those cases the formation process accompanied by crinkling of the billet edges. Moreover, excessive transverse compression of the tube billet leads to a curvature (displacement) of the edges, which resulted in the deterioration of welded seam quality and a rapid wear of the equipment.

On the basis of a theoretical analysis of the parameters of the billet reduction in close grooved rolls we have devised a formula for calculation a coefficient of the overall elongation of the tube billet on condition that a thickness of the tube wall during forming is constant:

$$\mu = \exp\left\{ \frac{\left| \ln\left(\frac{P_0/\pi}{P_p/\pi}\right)\left\{1.48\left[\left(\frac{S}{A}\right)^{157}+\left(\frac{S}{B}\right)^{157}\right](1-Z_{KP})+(Z_{KP}+1)\right\}\right|}{\left|1.48\left[\left(\frac{S}{A}\right)^{157}+\left(\frac{S}{B}\right)^{157}\right](1-Z_{KP})+(Z_{KP}+1)\right|} \right\} \quad (2)$$

where P_0- the perimeter of the tube billet prior to reduction; P_n- the perimeter of the tube billet after reduction; S - the thickness of the tube wall; z_{cr}- the value of the coefficient of a plastic tension in the stand at which chances in the tube wall thickness do not occur (z_{cr}= 0.34-0.5); $A=\frac{P_0+\pi S}{\pi}$, $B=\frac{P_P+\pi S}{\pi}$.

It is common practice to express the coefficient of plastic tension as the ratio of longitudinal (axial) tensile stresses σ_l to the strain resistance k_f of the metal deformed

$$z=\frac{\sigma_l}{K_f} \tag{3}$$

If the width of the initial tube billets is known (the perimeter of tube billet prior to reduction $B_3 = P_0$), one can calculates its perimeter after reduction P_p using the equation (1), which allows the efficient everall elongation of the tube billet in the close grooved rolls to be determined

$$P_P=\frac{P_0}{\mu} \tag{4}$$

Taking into account that $\mu=\frac{1}{1-\varepsilon}$. Insertion of the P_0 and P_p values into equation (2) gives us the theoretical values of the overall elongation for two values z_{cr}= 0.34 and z_{cr}= 0.5, at which the wall does not increase in thickness. The calculation data for the overall elongations are plotted in the Fig. 2. A correlation was made between the theoretical data indicating the area of deformation of the tube billet without changes in the wall thickness (curves 1, 2) and the novel regime of deformation offered by the authors (curve 3). One can see that they coincide qualitatively. From the result obtained it may be deducted that the regimes offered for reduction of tube billets in the close grooved rolls proceed under the conditions which correspond to the constancy of the billet wall thickness.

On the basis of the present work a novel procedure of the roll-profile calculation is developed. It applies the new formula, taking into account the required distribution of the longitudinal deformation of strip among the mill stands. This new technique allowed us to calculate the geometric parameters for both roll profiles and roll elements. It is applicable for the horizontal and vertical forming and welding stands. Using this technique the novel computer programme was designed for calculation, archiving the data and plotting the roll profiles. The programme designed has been implemented at JSC "Severstal" and successfully used in the manufacture of longitudinal electric-welded pipes.

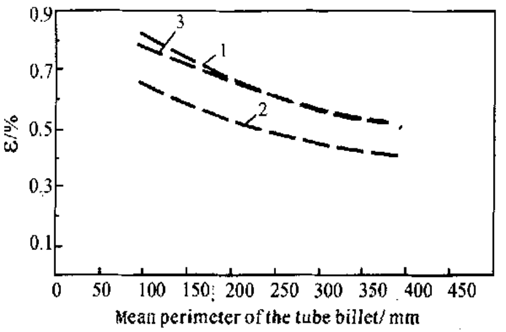

Fig. 2 Relative deformation of the tube billet during the reduction process in the close grooved rolls providing the constant thickness of billet wall versus the mean perimeter of the tube billet