Development of forecasting method of change of transverse variation in wall thickness in case of cold rolling of pipes made of titanium alloys

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Abstract
The majority of products of expensive titanium alloys are produced with strict requirements to the accuracy of their geometrical parameters. The requirements for transverse variation in wall thickness of pipes are the most exigeant.
Influence of level of initial variation in wall thickness on the nature of its change from titanium alloys is analyzed with use of design analysis based on finite-element modeling. Results show that for great values of initial variation in wall thickness, the level of its reduction is higher.
The obtained experimental results of change of absolute variation in wall thickness along the length of zone of wall drafting when rolling on the mill HPT-55 showed that the dependences obtained in course of design analysis and in case of experiment on rolling on the industrial mill HPT show the sameness. The use of the developed forecasting method of transverse variation in wall thickness in

case of multipass rolling of pipes made of titanium alloys allows us to analyze quickly schedules at a stage of their development and to develop effective technologies.
Key words: COLD ROLLING, PIPE, TITANIUM, DEFORMATION CONE, DESIGN ANALYSIS, COLD DEFORMATION, FORECASTING OF VARIATION IN WALL THICKNESS, WALL THICKNESS VARIATION, MODELING, TECHNOLOGY

Researches analysis

Feature of rolling of pipes made of titanium alloys is use of minimum possible zone of reduction and performance of deformation on diameter and wall of a mandrel.

The researches on the mechanism of change of transverse variation in wall thickness of pipes executed for processes of cold rolling in a zone of reduction [2, 3] and for hot rolling on a mandrel [4, 5] are known.

Authors of this paper have executed a number of works on studying of the mechanism of reduction of transverse variation in wall thickness in case of cold rolling of titanium alloys in a mandrel and on development of a forecasting method of transverse wall thickness variation on their basis [6]. A basis of this work is accounting of different intensity of hardening of metal of thin and thick walls.

Work purpose

For understanding of process of change of eccentric wall thickness variation in case of cold rolling of pipes in a mandrel made of titanium alloys, analytical dependences of change of transverse wall thickness variation on deformations are necessary for certain brands of alloys. It will allow us to carry out calculations for forecasting of variation in wall thickness in case of multipass cold rolling with higher accuracy.

Researches results

Earlier, the theory of the mechanism of change of eccentric wall thickness variation [6] in case of cold rolling on a mandrel has been put forward. The design analysis of process of deformation of samples of different thickness between three plates was carried out (as the center of deformation of HPT mill) and the experiment on its approbation was conducted. It has allowed us to develop a technique for calculation of transverse variation in wall thickness in a zone of wall drafting. At the same time, the research on influence of initial value of variation in wall thickness on its change was not conducted that is necessary for the selection of bare pipes.

Therefore, the additional research on influence of value of initial variation in wall thickness of samples on process of change of variation in wall thickness has been conducted. Thus, in the program of finite-element modeling, according to earlier presented technique developed by authors of this paper, the design analysis for samples with variation in wall thickness of 20%, 15%, 10% and 5% was carried out. (Fig. 1).

The sizes of samples for design analysis are the following:

for 20% – 9.35 mm and 7.65 mm;
for 15% – 9.14 mm and 7.86 mm;
for 10% – 8.93 mm and 8.08 mm;
for 5% – 8.71 mm and 8.29 mm.

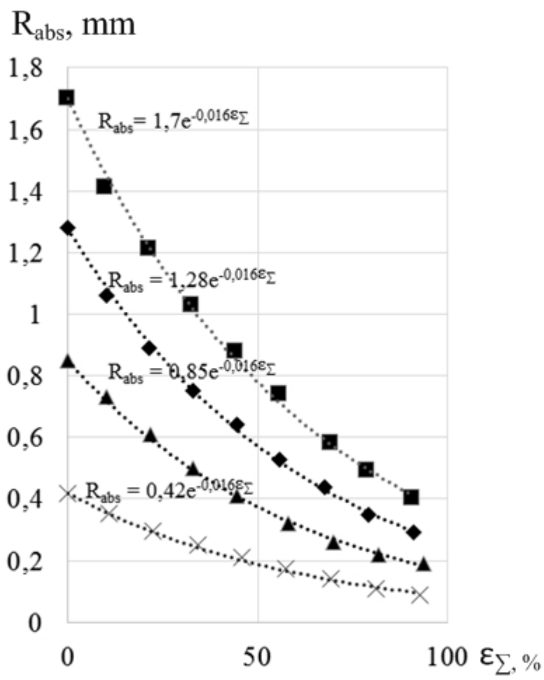

Figure 1. Change of absolute variation in wall thickness of samples with initial variation in wall thickness of 20%, 15%, 10% and 5% in the design analysis conducted by means of the program of finite-element modeling:

■ – value for initial variation in wall thickness of 20%; ♦ - value for initial variation in wall thickness of 15%; ▲ – value for initial variation in wall thickness of 10%; × – value for initial variation in wall thickness of 5%; dashed line – approximation

As a result of approximation of data of the design analysis, the functions describing them are constructed. These formulas describe value of transverse variation in wall thickness and are of the form:

$$\Delta R_{abs,fc} = \Delta R_{abs.beg} e^{-\alpha \varepsilon_{\Sigma}} \quad (1)$$

Where $\Delta R_{abs.beg}$ – initial absolute variation in wall thickness of billet; *e* – fundamental mathematical constant; α – coefficient of intensity of change of an absolute transverse variation in wall thickness; β – coefficient of intensity of change of relative transverse variation in wall thickness; $\varepsilon_{S\Sigma}$ – total relative deformation along the pipe wall.

Schedules show that for great values of initial variation in wall thickness, the level of reduction is higher, but at the same time, the functions describing intensity of change of wall thickness variation are identical.

For obtaining additional data on change of wall thickness variation and comparative assessment with industrial process, an experiment according to change of an absolute wall thickness variation along a deformation cone when rolling on mill HPT-55 along schedule 38x4.5 → 25.4x2.25 mm was conducted (Fig. 2).

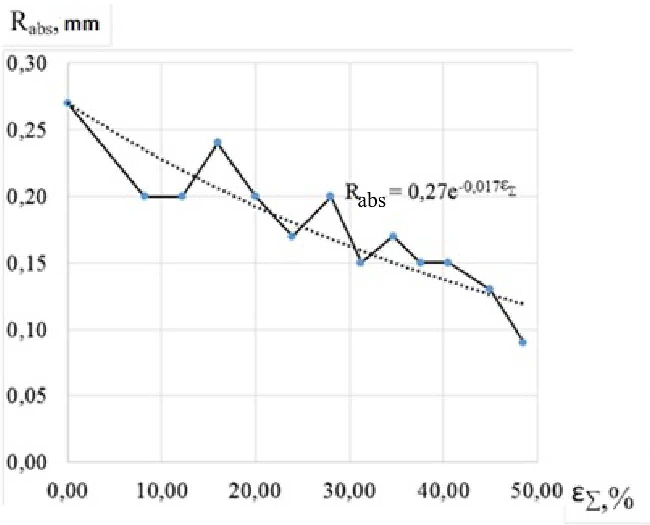

Figure 2. The diagram of change of wall thickness variation in a zone of wall drafting when rolling on mill HPT-55 along schedule 38x4.5 → 25.4x2.25 mm

The dependences obtained in the design analysis and from experimental data on rolling on industrial mill HPT show the similarity.

The final variation in wall thickness described by a formula ($\Delta R_{tot.fc}$) at multipass rolling is based on the use of dependence (1), accounting of the variation in wall thickness induced by mills and calculation of value of coefficient of intensity of reduction of transverse variation in wall thickness with application of the finite-element program.

In this case, formula will be of the form:

$$\Delta R_{tot.fc} = (\Delta R_{abs.beg} \cdot e^{-\alpha\varepsilon_{\Sigma1}} \cdot e^{-\alpha\varepsilon_{\Sigma2}} \cdot ... \cdot e^{-\alpha\varepsilon_{\Sigma n}}) + n \cdot R_{dir} \qquad (2)$$

where $\Delta S_{abs.beg}$- initial variation in wall thickness of billet; α – coefficient of reduction of absolute transverse variation in wall thickness; ε_{Σ} – total deformation on pipe wall thickness, %; $e^{-A\varepsilon_{\Sigma1}}$ – reduction of variation in wall thickness when first rolling; $e^{-A\varepsilon_{\Sigma2}}$ – reduction of variation in wall thickness when second rolling; $e^{-A\varepsilon_{\Sigma n}}$ – reduction of variation in wall thickness when n-th rolling; R – directed variation in wall thickness.

The use of developed forecasting method of transverse variation in wall thickness allows us to determine a transverse final variation in wall thickness of a pipe at schedule development stage under industrial conditions of the modern enterprise.

Conclusion

Influence of level of initial variation in wall thickness on the nature of its change in process of the design analysis of deformation samples with different thickness made of titanium alloys was analyzed. Results show that for great values of initial variation in wall thickness, the level of reduction is higher, but at the same time value of coefficient of intensity of change of variation in thickness is identical.

The obtained dependence of change of absolute variation in wall thickness along the length of zone of wall drafting when rolling on the mill HPT-55 showed that the dependences obtained in course of design analysis and in case of experiment on rolling on the industrial mill HPT show the sameness.

The use of the developed forecasting method of transverse variation in wall thickness in case of multipass rolling of pipes from titanium alloys allows us to analyze quickly production processes and to calculate technological operations for the purpose of reduction of costs in case of production.

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