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On the implementation of vibrational cold pilger pipes rolling

Vyshinsky V.T.[1], Rakhmanov S.R.[2]

1NMETAU (DNEPROPETROVSK, UKRAINE)
2LLC "VOSTOK PLUS"

Abstract
The analysis of the roll pass dynamic model of the cold pilger pipes rolling was carried out. The substantiation and the scheme of the vibrational cold pilger pipes rolling at the CPM (cold-pilgering mill).
Keywords: PIPE, ROLL PASS, COLD ROLLING OF PIPES, MANDREL, DYNAMIC MODEL, PLASTIC WAVE, ELASTIC WAVE, WAVE FRONT, RADIAL MOTION, VIBRATION, AMPLITUDE, FREQUENCY, HIGH-SPEED VIBRATOR

Problems of increasing the efficiency of the cold pilger pipes rolling put forward a number of topical tasks as following: technological advancement as well as modernization of the main elements of technological equipment [1-3].

Ascertainment of some concealed possibilities of rolling vibration existing technologies requires the establishment of correct mathematical models adequately reflected the characteristics of the process at CPM mills.

The basis for the development of a number of dynamic models and mechanisms for vibration loading of the metal are put in some fundamental developments of V. M. Klimenko, V. Shapoval, V. Poturaeva, M. G. Zeitlin and others. The analysis of these developments is generalized and best presented in [4].

Most investigators confirm the fact that the application of high-speed vibrations when metal-forming processing (MFP) leads to a decrease in yield strength of the material and consequently result in a significant reduction in energy and power parameters of the roll pass. The factor of formation of rational volume deformation of the metal and reducing the external and internal contact forces of friction play an important role.

In the early 60-ies of XX century the first semiproduction experimental plants for activation of metalforming processes (MFP) using high-speed ultrasonic vibrations were built by «Uniform Tubes» and «Aero projects» (USA). Then, at the plant of «Aero projects» company for the production of seamless pipes the press with the supply of high-speed ultrasonic vibrations directly to the matrix was created. An application of ultrasonic vibrations allowed to increase the reduction per die degree and the workpiece deformation rate, to reduce the number of operations of annealing and pickling and also the amount of waste.

These issues further found its solution in the production of seamless pipes at the plant of the «Stainless Tube Division» (USA) company, where the pipe workpiece from corrosion-resistant steel is deformed in the extrusion press with the supply of high-ultrasonic vibrations directly to the technological tools [5, 6].

Industrial technology of the production of seamless pipes at extrusion presses of pre-drilled workpieces using ultrasonic vibration energy is also mastered by the firms «Levy» and «Kolambia Jammeril» (England). [5]

Similar pipe section press for the production of seamless pipes with ultrasonic vibrations supply directly to the mandrel via the core works in firm «Kobe» (Japan) [6].

For Pipe Rolling Plants in Ukraine and Russia are mostly working CPR mills in the design of «EZTM» (Russia) and of the foreign production («SMS MEER», Germany) and equipped with modern machinery. However, for a number of groundless reasons they are not equipped with devices for the implementation of technology vibration action on the workpiece.

Investigation of dynamic processes in the metal forming ascertains the dependence of deformation conditions from the parameters of the active vibration. To achieve steady vibration state of the workpiece deformation is necessary to define dependence between the frequency, amplitude and power parameters of the technological process. Amplitude-frequency response characteristic of basic technological tools (mandrels and rolls) exert a significant influence on the efficiency of the cold pilger pipe rolling. It should form the necessary and sufficient conditions for the implementation of vibration deformation activation of the workpiece.

In order to establish hidden reserves of existing processes, development of new technological ones of cold pilger pipe rolling with high-speed vibrations and dynamic model that adequately reflects the conditions for the formation of bloom (billets) we use the basic scheme of the cold periodic pilger pipes rolling (Fig. 1), the distinguishing feature of which is a mandrel having an ability to generate the active high-speed vibration. It is an absolutely solid axisymmetric body with some given narrowing of the generant, which interacts with a homogeneous semi-infinite medium (deformable material) occupying a half-space of the roll pass normally to its free surface. Disturbed motion of the rolled metal (solid medium) induced by technological tools (mandrel and the rolls) in the cold pipes rolling in all sections of the roll pass (the entire length of rolling cone) is considered axisymmetric (Fig. 2).

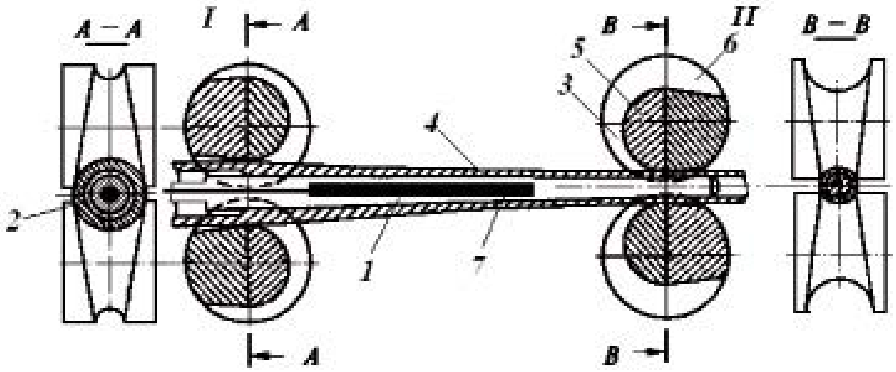

Figure 1. Scheme of the cold pilger pipe rolling (I - front and II - back working stand position): 1 - conical mandrel; 2 – annular space; 3 - die type; 4 - rolled pipes; 5 - gauge; 6 - working rolls; 7 – high-speed vibrator

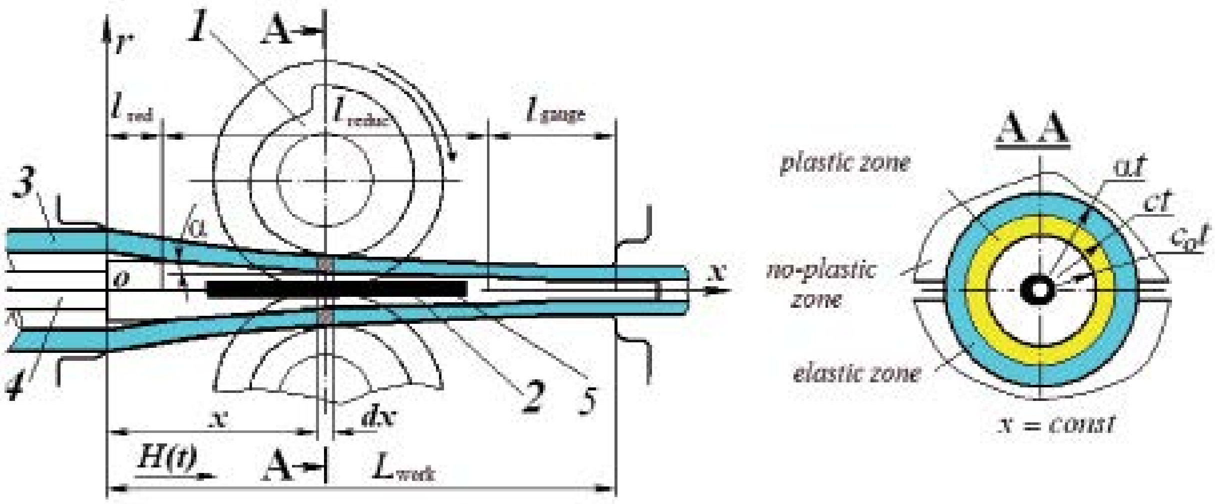

Figure 2. The calculation scheme of dynamic processes in the roll pass when cold rolling on the CRM mill: 1 – working rolls; 2 – mandrel; 3 - hollow billet; 4 – draw bar; 5 – high-speed vibrator

The solution of the motion problem of a continuous medium (of metal) mathematicaly based on the use of sufficiently rigorous non-linear differential equations which take place due to large deformation is currently difficult. At this stage of investigation process approximate methods which have a certain error are more acceptable but nevertheless they embrace the essence of physical phenomena occurring in the process of transformation of the hollow billets into a finished product.

This approach consists of the following: it is considered that each layer of metal billet in a conventionally fixed plane $x = const$ moves dependently of other layers, wherein the motion starts from the time when the surface of the mandrel is located in this plane. At the same time the original formulation of the production process in a closed space of the roll pass is reduced to the problem of motion of a cylindrical wave (caverne) in a solid medium (in the hollow billet).

Such adopted dynamic model is a problem of the propagation of one-dimensional radial waves in a layer perpendicular to the direction of motion of the metal pipe during rolling. Then the proposed approach is based on the slab method and represent the development of theoretical process propositions of the periodic pipe rolling by technological equipment.

Analysis of stress-strain state of the metal shows that at the current pace of rolling in a cylindrical bloom (billet) except for the zone of elastic state, primarily a zone of plastic state and in some cases zone of destruction of the metal. Therefore, initially separately defined zones are considered and the adopted approximation for solving dynamic problems is given for each of them.

A number of experimental researches [3-6] show the need for a phased research of strain state of the rolled metal into a tight roll pass and the active control of stress-strain state in the implementation of the technological operations of cold pilger pipe rolling.

In [7] the following scheme of formulating and solving problems in theoretical terms is offered. First we consider the problem in assuming that the disturbed area of the roll pass during cold pipe rolling consists of plastic zone and fractured zone. At first the equation is solved to determine the relative velocity of the plasticity wave (the parameter of wave propagation) and then the true stresses $\sigma_\theta > -\sigma_0$ and velocities fields are restored. After checking the implementation of the necessary and sufficient conditions for the formation of stresses throughout the disturbed area of the roll pass. If this condition is met, the given solution of the problem is limited.

Then, a certain initial and boundary conditions are given for the implementation of the active high-speed forced harmonic motion with intended frequency by technological tools (vibrator inside the mandrel) in the formula $f(r) = R(t)\sin(\omega t)$ and $F(r) = R'(t)\omega\cos(\omega t)$ through mathematical modeling the effective parameters are determined by vibration bloom rolling when the design stage and appointment of conditions of the CPM process.

It should be underlined that since the processes of deformation of the workpiece within the selected dynamic model of roll pass in the transverse direction as to the axis of the mandrel represents the wave processes, then by applying the active external control actions technology process can be activated.

For example, applying a high-speed vibrations of the definite frequency $\omega = 0{,}5 - 15$ kHz from the mandrel the efficiency of the cold pipe rolling process can be achieved without the formation of fracture zones in the metal.

Fig. 3 shows the structure of the CPR mandrel mill, constructively implementing the proposed solution of the problem.

Is necessary to note that since the vibration exciter 3 is integrated directly into the mandrel 1 and stored in the working cone. The cold pipe rolling must be forcibly and rapidly cooled inter alia for protecting

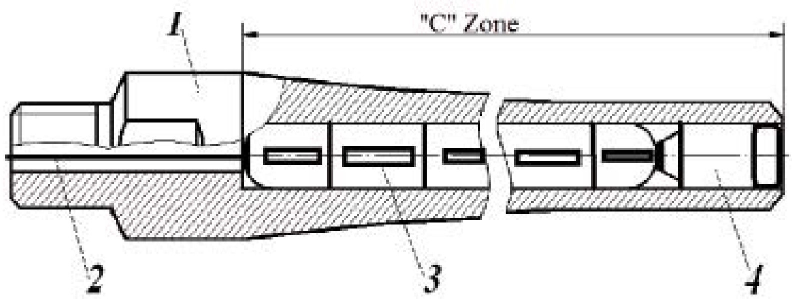

Figure 3. The CPR mill 75 mandrel with built-in high-speed vibrator: 1 - mandrel; 2 - a flexible shaft; 3 – high-speed vibrator; 4 - plug

against thermal effects. This part of the problem can be solved with existing technology of a modern system of the rolling lubrication.

Stabilizing the parametrs of the three-dimention stress-strain state of the metal when the intense cold pipes rolling, for example, stainless steel blooms 10X17H13M2T with a diameter of 89,0 × 5,0 mm → for the pipe of 63 × 3,5 on the CPM mill 75 can achieve lower rolling force by 28% (initial rolling force of 570 kN). The diameter of the vibrating element is 30 mm. The value of the working frequency of the vibrator is adjustable from 7,000 Hz to 12,000 Hz. The length of the vibrating element positioned in the corresponding working zone of cone mandrel "C" and roll pass reaches 380 mm. Working voltage of the generation system of high-speed vibrations at a frequency corresponding to the current frequency of 400 Hz is 42 V.

The implementation of the required modes of the vibrational pipes rolling is carried out directly from the control desk of CPR mill.

As a result, by reducing the considerable forces of contact friction we obtain a significant increase in the durability of the mandrels (in triple) and rolls (in twice). Sustainability of the mandrel bar and changes the deformation of the basic elements of the working stand are achieved by reducing power parameters (axial component of the rolling pressure). This leads to a significant reduction in both the transverse and longitudinal wall thickness deviation and improved pipes quality.

Conclusion

Under the influence of control active high-speed vibrationss a significant reduction in the limits of elastic strength and yield tensile strength of the rolled metal can be achieved which reduces the rolling preassure and increases the efficiency of the process. Required rational amplitude-frequency characteristics of forced vibrations technological tools (required vibration activity of the vibrator inside the mandrel) ensures the stabilization of power parameters of the roll pass and can be determined by mathematical modeling. It is necessary to emphasize the fact that with the use of high-speed active vibrations significantly increases expansion rate of the plastic zone border.

Research methods of the billets cold rolling processing from different steel grades and their alloys on the proposed scheme significantly expands the optimization possibilities of the stress-strain state of the roll pass in cold pilger pipes rolling under conditions of high-speed vibrations application.

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