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Концепція універсального косовалкового стана

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The concept of a universal cross-rolling mill

Анотація. *Запропоновано концепцію універсального косовалкового стана (УКБ) пілігримового агрегату для вирішення його технологічних можливостей шляхом отримання гільз та товстостінних труб при прокатці на коротких та довгих оправках. Запропоновано нову конструкцію обкатного пристрою передніх кінців гільз у процесі прошивки на УКБ, що розміщується на окремій станині, що з'єднується з кліттю та напрямною проводкою. Запропонована концепція УКБ може бути використана для модернізації стана елонгатору пілігримового агрегату 5-12 ПАТ "Інтерпайп НТЗ".*
Ключові слова: *універсальний косовалковий стан, пілігримовий агрегат, гільза, труба, обкатний пристрій, упорно-регулювальний механізм, приводні шпинделі, коротка та довга оправки, центрувальники стрижня та гільзи.*

Abstract. *The concept of a universal oblique rolling mill (UBM) of a pilgrim unit is proposed to solve its technological capabilities by obtaining shells and thick-walled pipes when rolling on short and long mandrels. A new design of a running-in device for the front ends of shells during the piercing process on the UBM is proposed, which is placed on a separate frame connected to the cage and guide block. The proposed UBM concept can be used to modernize the elongator mill of the pilgrim unit 5-12 of PJSC "Interpipe NTZ".*
Keywords: *universal oblique rolling mill, pilgrim unit, sleeve, pipe, running-in device, stop-adjustment mechanism, drive spindles, short and long mandrels, guide block, core and shell centering devices.*

In memory of V.M. Druyan and V.V. Perchanik (Druyan Volodymyr Mykhailovych (06/19/1932 – 04/22/2004) - famous scientist, Doctor of Technical Sciences, Professor, Head of the Department of Technological Design of the National Metallurgical Academy of Ukraine; Perchanik Viktor Volfovich (10/30/1934 – 08/04/2018) – a well-known scientist and specialist in pipe production, Ph.D. , senior researcher at the National Metallurgical Academy of Ukraine)

Introduction. The 5-12" pipe rolling unit (TPA) with pilgrim mills of PJSC "Interpipe NTZ" was put into operation in December 1968. Pipe rolling shop No. 4 with this unit was built according to the design of UkrDI-PROMEZ in accordance with the technological task of VNITI.

On the 5-12" TPA with pilgrim mills, a design scheme for obtaining a sleeve is used by threading the initial billet into a cup on a hydraulic horizontal press with subsequent heating of the cup and rolling it into a sleeve with threading the bottom on a two-roll screw rolling mill - elongator [1].

With the launch of the Interpipe Steel electric steelmaking complex in 2012 and the transition of TPA 5-12" to continuously cast billets (BLZ) of round cross-section with a maximum diameter of up to 500 mm, the issue of significantly improving technical and economic indicators as a result of improving the quality of the initial billets was resolved. World experience shows that when using BLZ of round cross-section as the initial billet, the trend in technology development is to switch to direct flashing of BLZ on a slanting rolling mill. At the same time, the hydraulic press and ring heating furnace are being decommissioned. At the same time, a known technological scheme is used when part of the liner assortment is produced by direct flashing from BLZ, and a heavier liner assortment is produced according to the old scheme: preliminary flashing of BLZ into a cup with its subsequent heating and rolling into a liner on a slanting rolling mill with flashing of the bottom. In addition, when using the old Ingots cast in a mold with a wavy surface can be used for the production of sleeves.

Thus, the technological scheme with a two-stage production of a sleeve with intermediate heating is more universal in terms of the type of starting material used.

In the case of TPA 5-12" of PJSC "Interpipe NTZ", in order to use resource- and energy-saving technology when rolling the entire range of pipes by diameter (168-426 mm), it is necessary to replace the existing elongator mill with a more powerful mill, which will operate in the mode of direct threading of sleeves from a round NLS, as well as in the elongation mode when rolling out cups obtained on the press after their heating.

Elongator stand. The type of stand is two-roll with a removable cover and a cassette system for changing the feed and rolling angles. The rolls are located in a horizontal plane, and two guide rails in a vertical plane. The angle of inclination of the roll axes in a horizontal plane (rolling angle) is ±1.5°. The angle of inclination of the roll axes in a vertical plane (feed angle) is currently not adjustable and is 4°.

The existing state-of- the- art elongator is physically and morally obsolete and requires replacement, which is especially relevant in connection with the feasibility of switching to the energy-saving technology of direct threading of sleeves from a round NLS.

A feature of the hot pilgrim pipe rolling process is the presence of a seed rolling mode for the front end of the sleeve, which increases the machine rolling time and reduces productivity, and also reduces the yield of usable material due to the separation of the front end of the pipe of increased length into waste [1].

It has been established that the maximum improvement of the seeding mode of pilgrim rolling, especially of thin-walled pipes, is possible due to the preliminary preparation of the front ends of the sleeves. It is especially effective to carry out such preparation of sleeves in the process of their piercing on a cross-roll mill [2]. In pipe production, two- and three-roll piercing mills are used. At the same time, two-roll mills are the most common.

Problem statement. The current state of pipe production on pilgrim units requires finding ways to increase their loading, which is possible by expanding the technological capabilities of obtaining a wide range of pipes in the "piercing press - elongator - pilgrim mill" system when using different types of initial billets: stationary casting ingots, round-section BLZ, octagonal-section BLZ, rolled, forged and electroslag remelting.

Basic material. Let us consider the feasibility of using three-roll piercing screw rolling mills.

In works [3-6], the following advantages of three-roll piercing mills compared to two-roll equipped with rulers are noted: a more favorable scheme of the metal stress state in the deformation zone, which ensures high quality of the inner surface of the sleeves; the absence of a tool (rulers), which wears out quickly, which must be changed when changing the size and whose presence worsens the conditions for secondary gripping of the workpiece; better conditions for gripping the workpiece, a higher coefficient of axial slip and, as a result, a shorter machine piercing time; lower energy consumption; the possibility of rolling at large feed angles, which on two-roll mills is limited by the stability of the rulers.

The use of long-roll piercing mills can be considered appropriate when using cheap billets obtained by continuous casting, which are characterized by low core strength and are therefore less suitable for two-roll piercing. According to most researchers, the tendency to metal destruction when piercing by the long-roll scheme is much lower than by the two-roll one [5].

One of the disadvantages of the three-roller flashing scheme is the increased wall difference of the sleeves (compared to the two-roller flashing scheme), which places higher demands on the centering of the mandrel along the flashing axis [7].

The presence of axial looseness in round NLS should facilitate the direction of the mandrel along the axis of the workpiece.

Assel rolling mill and continuous mill is known. However, the use of long-roll piercing mills on TPA with pilgrim mills has not yet been implemented, with the exception of a piercing mill with a shifted axis (two drive rolls and one idle) on TPA 8-16" of the MDM company (Germany). Such a piercing mill occupies an intermediate position between two- and long-rolling mills in creating a stressed-deformed state in the middle of the workpiece during piercing.

The use of the technology of through-threading of the BLZ on a horizontal hydraulic press of a pilgrim unit opens up opportunities for rolling hollow billets (without a bottom) on a long mandrel in a cross-rolling mill. It is known that in foreign pilgrim units, through-threading of the BLZ into a hollow billet or cutting off the bottom of the cup is carried out. Rolling hollow billets into a sleeve on a long delivery allows you to increase the accuracy of pipes by reducing the transverse wall difference [8]. For through-hole piercing of BLZ on a horizontal hydraulic press TPA 5-12" NTZ, its modernization is necessary. The use of the technology of obtaining sleeves with preliminary piercing of ingots into a cup with a bottom on the press was appropriate only when using as the initial workpiece an open-hearth ingot cast in a mold, which has a developed shrinkage cavity in the head part. Piercing of such an ingot on the press from the bottom part led to the sinking of metal at its top, which reduced metal losses from the pilger needles that go to the edge.

Through-hole insertion of the BLZ on the press of the pilgrim unit also allows for quick control of the transverse wall difference of the rear part of the hollow workpiece for press adjustment.

Problem statement. It is necessary to propose a concept of a universal cross-rolling mill for the modernization of the 5-12" NTZ pilgrim mill by replacing the existing cross-rolling mill- elongator.

The new cross-rolling mill should be universal for performing the following operations:

- threading of a round cross-section BLZ into a sleeve on a short conical mandrel; to improve the quality of the inner surface of the sleeve, the mill stand must be long-rolled;
- elongation (rolling) of glasses obtained on a press with intermediate heating in a ring furnace;
- preparation of the front ends of the sleeves in the process of flashing (rolling) taking into account the existing experience of operating the running-in device on the TPA 5-12" NTZ elongator mill [2];
- rolling of hollow blanks on a long mandrel after through-hole piercing of the BLZ on a horizontal hydraulic press with intermediate heating of a ring furnace.

It is known that obtaining liners with pre-threading of ingots on a press expands technological capabilities by using various types of starting blanks: stationary casting ingots, round and octagonal BLZ, electroslag remelting ingots, centrifugally cast billets, hollow BLZ, etc. The use of a universal slanting rolling mill of a pilgrim unit increases these capabilities, and also allows switching to an energy-saving technology for obtaining liners in the absence of additional heating of the metal before rolling on a slanting rolling mill.

The preparation of the front ends of the sleeves on a cross-roller mill during the process of threading (elongation) is proposed to be carried out using a new technology, which consists in reducing the front end of the sleeve without compression along the wall, which eliminates the use of a cylindrical mandrel. The size of the reduction along the outer diameter is up to 20 mm. At the same time, the inner diameter of the sleeve at the front end is reduced (the change in wall thickness is not taken into account). This contributes to the centering of the front end of the sleeve on the mandrel after it is loaded. The new technology for preparing the front ends of the sleeves together with the centering of the rear end of the sleeve on the conical shank of the mandrel ensures a reduction in the transverse wall difference of the pipes during pilgrim rolling and reduces the metal consumption factor.

In the 1980s, for the modernization of the 5-12” TPA with pilgrim mills of PJSC “Interpipe NTZ” with the replacement of the existing two-roll elongator with guide rails, the concept of a three-roll stitching mill with a universal running-in device has been proposed [9-11].

The project was implemented by employees of the Dnipropetrovsk Metallurgical Institute: V.M. Druyan, V.V. Perchanik, O.M. Komarov, VNDTI: O.A. Plyatskovsky, Y.G. Pavlovsky with the participation of UkrDipromez, NTZ and Chepel Metallurgical Plant.

The general view of a three-roll stitching mill is shown in Figure 1.

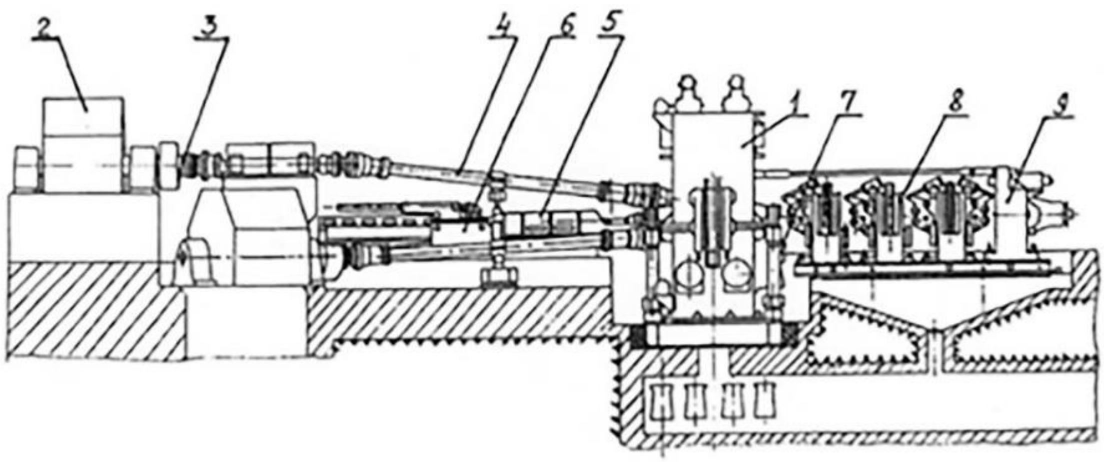


Figure 1 – Scheme of a three-roll piercing mill [9]: 1 - piercing mill stand; 2 – drive electric motor; 3 – coupling; 4 – universal spindle; 5 – receiving chute; 6 – workpiece pusher ; 7 – idle rolls for running in the sleeve end; 8 – rod centering devices ; 9 - thrust -adjusting mechanism

The technical characteristics of the long-roll stitching mill are given in [10].

The previously proposed concept of a long-roll stitching mill [9-10] is taken in this work as a basis for developing the basic provisions of the UKS design, while taking into account new tasks, the concept of the known mill is subject to certain changes and additions.

The purpose of this work is to expand the technological capabilities of the cross-roller mill as part of the 5-12” pilgrim unit and select a rational type of this mill for various technological schemes for producing sleeves.

Universal cross-rolling mill for modernization of the pilgrim unit.

Working stand. Working stand 1 contains a frame, working drive rolls with bearings, a pressure and balancing device for the rolls (see Fig. 1).

Each working roll of the mill receives rotation from the electric motor 2 through the coupling 3 and universal spindles 4. The spindle of the upper roll is connected to the coupling 3 through a horizontal intermediate shaft. To unload the spindle hinges in the geometric center of each, a support with hydraulic balancing and spring shock absorbers of dynamic loads is installed. To receive the workpieces and direct them to the mill rolls, a receiving chute 5 is installed between the spindles, the height of which is adjusted using spacers. To set the workpiece into the rolls, a hydraulic pusher 6 is installed.

Three working rolls are placed in the frame at an angle of 120° to each other (with one roll positioned at the top and the other two at the bottom), and three idle rolls 7 are installed at the rear end of the frame for running in the front end of the sleeve, offset by 60° relative to the working rolls.

The input side of the mill contains three electric drive motors for individual drive of the work rolls, clutches, universal and intermediate spindles, a receiving chute and a billet pusher .

Figure 2 shows a diagram of the input side of the mill with three main spindles 1, 2 and 3 and one intermediate spindle 4 and three drive electric motors 5, 6 and 7. The permissible skew angle of the spindles is no more than 8°.

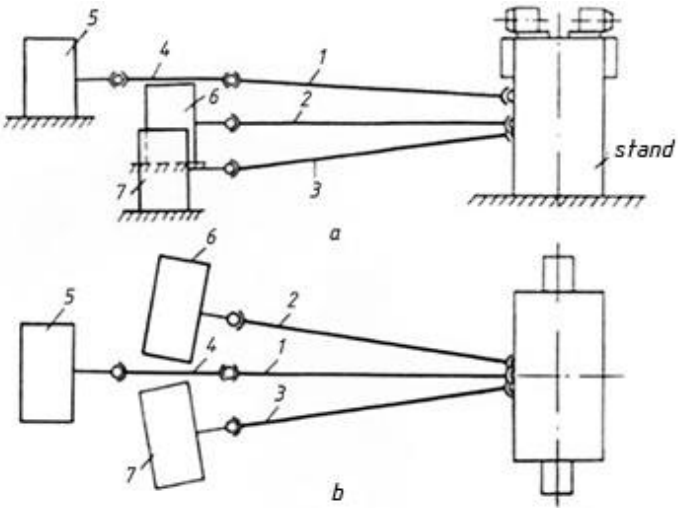


Figure 2 – Scheme of the input side of the mill: a – main view; b – top view; 1-3 – main universal spindles; 4 – intermediate horizontal spindle; 5-7 – drive electric motors

Drive spindles of the working rolls of the mill [11]. The use of ball spindles on a long-roll mill will ensure reliable centering, reduce spindle runout, reduce vibrations of the working line and inertial forces. This project is one of the design options for the drive of the working rolls of a long-roll mill, which provides the transmission of torque with minimal unevenness of angular velocity during one revolution.

Guide wire. It is installed directly near the mill rolls. One of the main provisions for reducing eccentricity during oblique roll threading is to ensure that the axes of the workpiece, threading, and sleeve coincide.

Therefore, a guide (input) wire is installed on the input side of the mill, the axis of the working channel of which must coincide with the axes of the firmware and the sleeve at the exit from the rolls.

The guide wire operates in quite difficult conditions: hot metal, dynamic impacts when the workpiece rotates with the rolls. The length of the guide part of the wire is important, which should be slightly less than the minimum length in the workpiece assortment. For example, with a minimum workpiece length of 1200 mm, the wire length can be 800-900 mm. Usually the gap between the workpiece and the working channel of the wire is 20 mm. However, it is necessary to strive to reduce this gap to 10-12 mm, while the wire should not interfere with the free movement of the workpiece in the mill rolls. It is also necessary to take into account the curvature of the workpiece and fluctuations in its diameter.

As noted by the company "SMS MEER" (Germany), pipe eccentricity is the main problem in the production of seamless pipes. This problem is mainly associated with failures in the operation of the cross-roller piercing mill. In conditions of high competition among pipe manufacturers, the requirement for product quality can only be met by limiting the eccentricity. The size of the eccentricity of seamless pipes (from 8% and above) is almost twice as large as the deviation in the wall thickness of pipes manufactured on highly automated multi-cell and reduction -stretching mills. Reducing the eccentricity by 1% provides cost savings of 1% of the annual production volume (in tons).

On a number of slant-roll piercing mills of the company "SMS MEER" a certain reduction of eccentricity has been achieved due to the new design of the inlet section. Figure 3 shows the guide wiring at the inlet of the rolling mill, which illustrates the possibility of precise direction of the rolled material to the work rolls. This block is successfully used on several rolling mills. The main element of this block is a guide sleeve of a rather significant length (as follows from Fig. 3), which changes when the diameter of the initial workpiece changes. The sleeve is fixed in the block by means of bolted connections.

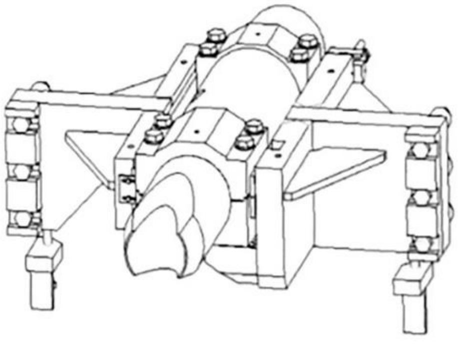


Figure 3 – Directional wiring of the company "SMS MEER"

We have proposed a new design of the guide wire of the cross- rolling mill, which is shown in Figure 4.

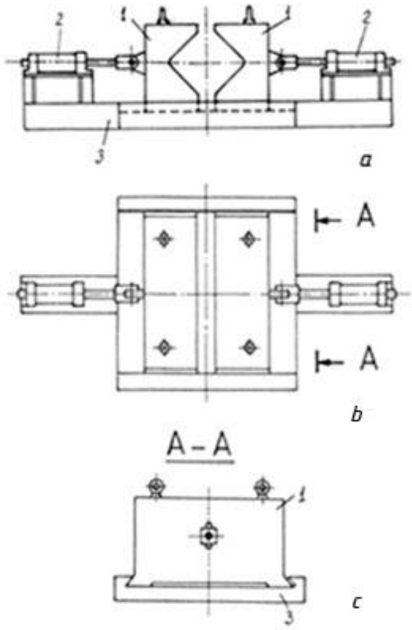


Figure 4 – Guide wire of a cross- rolling mill: a – general view; b – top view; c – section A-A in Fig. 1b; 1 – figured slider; 2 – hydraulic drive; 3 – frame base

On the frame base are two figured sliders that move perpendicularly to the mill axis using hydraulic cylinders. In cross-section, the sliders in the working position form an internal channel (of a square profile) for the passage of the initial workpiece of a round cross-section. The channel formed by the sliders 1 serves to direct the workpiece into the mill rolls along the insertion axis. This shape of the figured sliders 1 ensures centering of several standard sizes of workpieces in diameter due to the expansion-contraction of the sliders 1, which must move synchronously to stabilize the workpiece axis relative to the insertion axis (Fig. 5).

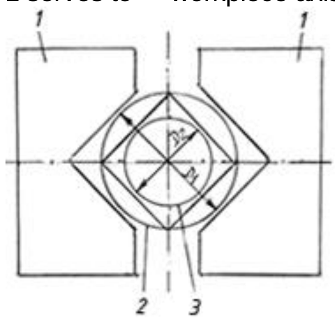


Figure 5 – Scheme of centering a workpiece of circular cross-section with diameters D1 and D2 using figured sliders: 1 – figured sliders; 2 – workpiece with diameter D1; 3 – workpiece with diameter D2

To reduce the eccentricity of the front ends of the sleeves, it is necessary to accurately center the front end of the workpiece with the formation of a hole of the required diameter and depth of the corresponding mandrel toe.

The output side of the mill. Contains a device for running in the front ends of the sleeves during the insertion process, a centering and transporting device; a thrust -adjusting mechanism (RUM), etc.

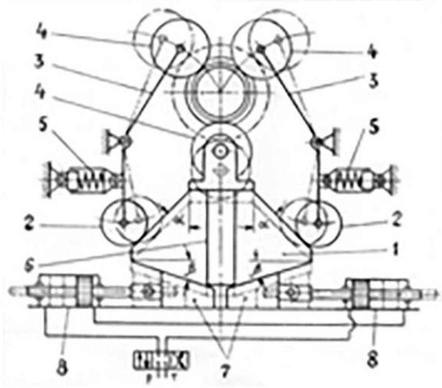
Device for running-in of the front ends of sleeves. In work [10] it was proposed to place a universal device for running-in (sharpening) of the front ends of sleeves on the input side of the long-roller piercing mill, which, in our opinion, is complex and, as a result, insufficiently reliable (see Fig. 1).

We propose a new design of a device for running-in (sharpening) the front ends of sleeves during the flashing process, working in tandem with the UKS cage, devoid of the above-mentioned disadvantages.

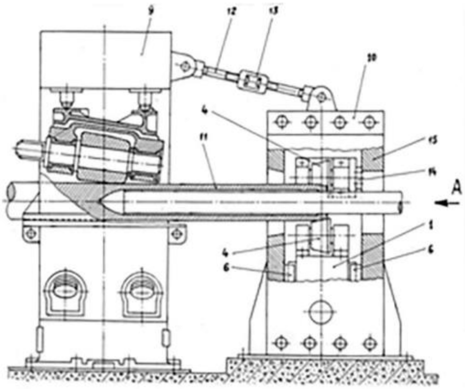
The kinematic diagram of the new device at the moment of the end of the sleeve sharpening is shown in Fig. 6a.

The device is a combination of two pairs of simple mechanisms: a cam-lever and a wedge-lever. The cam -lever mechanism consists of a cam 1, which contacts two symmetrically arranged rollers 2, hingedly mounted on the lower ends of two double-arm levers 3. Deforming non-driven rollers 4 of conical shape are hingedly mounted on the upper ends of the levers 3. The third deforming roller 4 is hingedly mounted on the upper platform of the cam 1. The αcam inclination angles are chosen such that when the cam is moved from the upper position to the lower position, the deforming rollers 4, mounted on the upper ends of the levers 3, move synchronously from the small contact circle to the larger contact circle. The small contact circle corresponds to a small diameter sleeve, and the large contact circle corresponds to a large diameter sleeve. Since the segments connecting the center of the sleeve with the centers of rotation of the rollers 4 always converge at one fixed point, namely at the center of the sleeve, such a device performs an additional self-centering function. The force locking of the cam 1 and the rollers 2 is carried out by means of compression springs 5, which constantly press the rollers 2 to the cam 1.

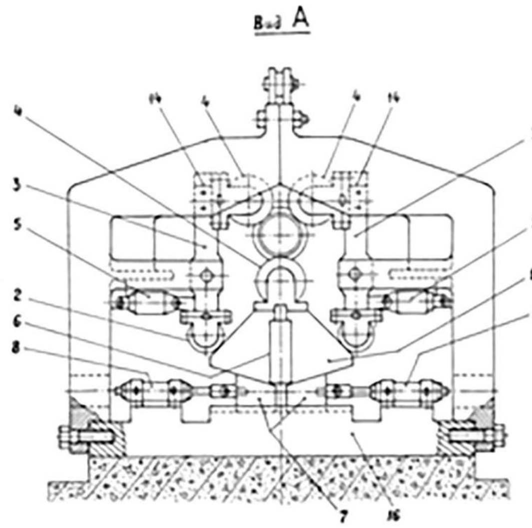
The vertical movement of the cam 1 in the guides 6 is carried out using wedges 7, which must be, on the one hand, large enough so that the stroke of the wedges for raising and lowering the cam is small, and on the other hand, not too small so that there is no jamming. We recommend an angle of β=15°. The wedges must converge or diverge synchronously. This is achieved by the fact that each hydraulic cylinder 8, in addition to the working rod, has a false rod, and the connection of the pipelines must be made as shown in Figure 6a. Since the deforming rollers 4 after sharpening the sleeve must quickly move away from it, the time of rapid action of the hydraulic cylinders 8 must be minimal, which is achieved by minimizing the working volume of the rod cavities of the hydraulic cylinders. For this, the diameter of the hydraulic cylinders must be minimal, and the diameter of the rods maximum, of course, while ensuring a given force on the working rod.



A



b



c

Figure 6 - Stand of a long-roll mill and a device for sharpening a sleeve: a - kinematic diagram of a device for sharpening a sleeve; b - main side view; c - view from the arrow in Fig. 6b; 1 - cam; 2 - roller; 3 - lever; 4 - deforming roller; 5 - compression spring; 6 - guide; 7 - wedge; 8 - hydraulic cylinder; 9 - piercing mill; 10 - device for sharpening a sleeve; 11 - sleeve; 12 - tie; 13 - tie nut; 14 - support plate; 15 – housing

Figure 6b shows a sketch of the UKS 9 in tandem with the device 10 for sharpening the sleeve 11. The moment of the end of sharpening and the beginning of the departure of the deforming rollers 4 from the sleeve is shown. The distance between the axes of the mill 9 and the device 10 should be selected from the condition of preventing the loss of longitudinal stability of the sleeve from the resistance force of the device and taking into account the necessary space for servicing both the UKS and the running-in device. The force closure between the mill 9 and the device 10 is carried out using a tie 12 with a tie nut 13. Fig. 6b shows the deforming rollers 4, the cam 1, and the cam guides 6. To relieve the levers 3 from bending, support plates 14 are fixed to them, which transfer the load to the housing 15. The plates are made of textolite. The lower deforming roller 4 of the device 10 transmits the force from the sleeve 11 to the rear guide 6 of the cam and then to the housing.

Figure 6c shows a view from arrow A in Figure 6b (conditionally without the rear wall of the housing), from which it can be seen that the housing consists of at least two parts, resting at the bottom on the base 16, fixed to the foundation, and connected at the top with bolts. On the base 16, guide grooves for wedges 7 and seats for the hydraulic cylinder 8 are made.

It is advisable to equip the output side of a long-roller UKS for sleeve insertion as follows:

- after the mill stand, a running-in device is installed, and between them the first centering device for the mandrel rod and the sleeve;
- immediately after the stop -adjustment mechanism, a second rod centering device is installed, which performs the rod centering operation before insertion [10];
- it is possible to install a third centering device between the running-in device and the second centering device;
- after the running-in device, a ramming device is installed, which ensures that the sleeve exits the zone of action of the running-in device when the lock is closed;
- the required number of oscillating rollers with individual drives are installed between the centering devices, which perform the operations of holding the sleeve with the rod along the axis of the insertion and transporting it after the running-in device fixes the position of the rod and the lock opens;
- for rolling blanks on a long mandrel, appropriate equipment is installed, including for holding the long mandrel during the rolling process.

Thrust -adjusting mechanism (TAM). In the proposed concept of the mill, the TAM corresponds to modern trends in influencing the geometric parameters of rolled sleeves by moving the mandrel during the flashing process [12], which allows obtaining a sleeve at the rear end with an increased inner diameter. This solves the problem of loading the mandrel into the sleeve with minimal gaps between them, as well as removing the sleeve from the rod after flashing with rolling its front end.

Technological schemes of rolling on short and long mandrels. In work [13], a universal cross-rolling mill (UKM) for rolling on short and long mandrels is proposed.

This mill provides rolling according to the following technological schemes: rolling of sleeves on a long floating mandrel; rolling of sleeves with support; rolling of sleeves with tension; rolling of sleeves on a held, partially held and mandrel that is pulled out during the rolling process; piercing of blanks on a short mandrel and rolling of sleeves on a short mandrel.

The individual technical solutions presented in [13] can be used to design a new UCS as part of a pilgrim unit.

For rolling on a UKS using short and long mandrels, it is necessary to provide for operations for cooling and lubricating these mandrels. The installation [14] can be taken as the basic option for solving this problem.

The operations of cooling and lubricating the mandrels are conveniently carried out on a special installation with lateral delivery of sleeves from the UKS.

As a result of the flashing with the preparation of the front end of the sleeve before pilgrim rolling, it will have the appearance shown in Figure 7.

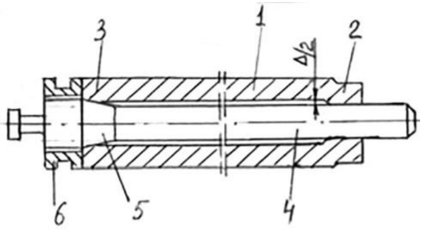


Figure 7 – Position of the sleeve with the prepared front end on the mandrel before pilgrim rolling: 1 – main part of the sleeve; 2 – prepared front end; 3 – rear end of the sleeve; 4 – main part of the mandrel; 5 – conical shank of the mandrel; 6 – mandrel ring (Δ- gap between the sleeve and the mandrel)

The use of a mandrel with a tapered shank and a sleeve with a prepared front end ensures centering of the sleeve on the mandrel before pilgrim rolling, which reduces the difference in pipes and increases the yield.

Conclusions

The concept of a long-roll UKS for the reconstruction of TPA 5-12” with pilgrim mills of PJSC “Interpipe NTZ” is proposed, which allows for threading of round-section NLS into a sleeve, rolling of cups with threading of the bottom, and rolling of hollow blanks on a long mandrel.

The main features of the proposed mill are individual drive of the work rolls; the presence on the output side of the mill's working stand of a new device for running in the front ends of the sleeves; the use of a URM to move the rod with the mandrel during the piercing process; the use of centering devices for the mandrel rod and sleeve, the use of short and long mandrels, and a new design of the guide wire.

The proposed design of the running-in device, placed on a separate frame, will ensure increased reliability of its operation and improved maintenance conditions for the UCS and the running-in device.

It is advisable to further consider the possibility of using a transformed UKS oblique roll stand for working with two and three rolls to produce thinner-walled pipes.

unevenness of the pipes and an increase in the yield during the pilgrim rolling process.

The proposed concept of the UKS can be used to develop a technical task for the design of a new cross-rolling mill to replace the existing elongator mill. pilgrim unit 5-12" NTZ.

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