УДК 621.983.07.669.017

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SYSTEM-MODULAR APPROACH TO UPGRADING EQUIPMENT FOR ROLLING MILLS

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СИСТЕМНО-МОДУЛЬНЫЙ ПОДХОД ПРИ МОДЕРНИЗАЦИИ ОБОРУДОВАНИЯ ДЛЯ ХОЛОДНОЙ ПРОКАТКИ ТРУБ

Purpose. Modernization of cold-rolled pipes mills in order to increase functionality, regardless of their physical wear and tear.
Design/methodology/approach. Constantly increasing demands on the pipe geometry and properties of materials perfectly satisfied by cold rolling (HPT), which evolves by optimizing the modes of deformation and improvement of equipment for its implementation. It offers system-modular approach to modernize the equipment of cold rolling mills, realizing one of the few non-waste technologies for the production of products with high consumer characteristics. The main producers of cold-rolled pipes mills (company SMS Meer and NGOs EZTM) more than a 80 year period of existence and development of technology HPT released about a thousand mill pipe diameters from 4 to 450 mm.
Findings. System-modular approach to the unit that implements the method of production of goods HPT, based on the analysis of both technological and regime of the functioning of its mechanisms, and design options for their execution and layout, allows efficient use of the existing equipment and, if necessary, to expand its capabilities.
The growing demand for cold-rolled tube can be satisfied both by the modernization of existing units and replacing them with new ones. For the design and manufacture of advanced mill HPT Ukraine has not only technical capabilities but also professionals able to offer solutions at the level of the best world standards.
Originality/value. As part of undergoing a painful restructuring of the Ukrainian pipe production is more than 200 cold rolling mills pipes of different sizes and constructive accomplishments. This production will be effective in diversification - "merging" with the production of final products (for example, the production of ball bearing steel and bearing production at factories of the company "Timken" USA; production of heat exchangers in a SMPO them. Frunze, production and sale of precision tubes stainless and alloy steels, titanium alloys and refractory metals Dnepropetrovsk plant of precision tubes and special).
Keywords: cold rolling mill tubes, the main power line, mobile working stand, twin slider-crank mechanism, the device periodically feed deformation zone, the line rotation, the control module, pressure device.

Introduction

Constantly increasing demands on the pipe geometry and properties of materials perfectly satisfied by cold rolling (HPT), which evolves by optimizing the modes of deformation and improvement of equipment for its implementation. The strains varied from 50% (extract 2) to 80% (extract 5) even at hard-rolled materials and performance - from tens to hundreds of meters per hour. His vitality and competitiveness is also determined by the fact that he belongs to one of the few non-waste technologies OMD, enabling:

- Regulation nonuniform due to the controllability of the process flow of metal in the circumferential and longitudinal directions;
- Varying small compression in different areas of calibration that allows you to control the geometry of the finished product, voltage levels and provides high levels of both the outer and inner surfaces;
- Management structure of the metal;
- Produce pipes of different sizes of billets of the same size;
- Reduction of technological operations, such as cleaning, heat treating, etching, cutting, transportation etc.

The main producers of cold-rolled pipes mills (company SMS Meer and NGOs EZTM) more than a 80 year period of existence and development of technology HPT released about a thousand mill pipe diameters from 4 to 450 mm. According to experts on the Tube, chemical and machine-building enterprises, both Ukraine and the CIS operates several hundred units for cold rolling a roller tubes and roller gauges, which have been manufactured and delivered to customers in the middle of the last century. Proposals for their modernization in order to increase functionality, regardless of their physical wear and tear, are relevant.

Research objective

Development and use the system-modular approach to upgrading equipment for cold rolling for realization of non-waste technology for producing of tubular products with better consumer characteristics

DOI: http://dx.doi.org/10.20535/2305-9001.2016.78.78686

Basic maintenance and results of research

Figure 1 shows a diagram of the mill HPT, gathered at the camp which is made almost the entire volume of cold-rolled pipes. The mill consists of the following blocks (modules): the main power line, which includes electric and dual slider-crank mechanism of the reciprocating movement of the movable stand; the device periodically feeding the workpiece in the deformation; line rotation system "pipe-blank - mandrel - finished pipe."

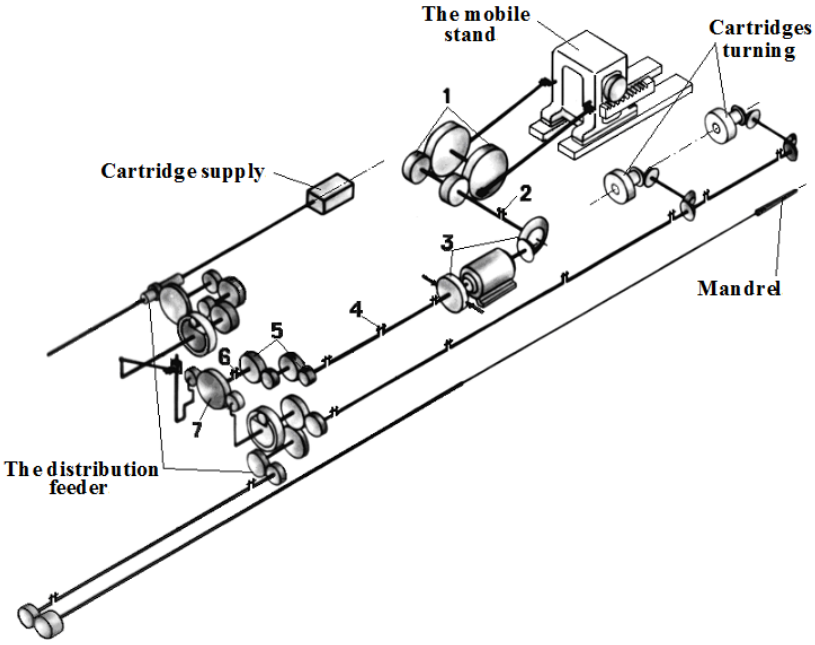

Fig. 1. Kinematic scheme mills HPT basic sizes of NPO EZTM

From the technological features of HPT it follows that mill mechanisms operate in various operating conditions, which necessitates the existence of the account of the functioning of each of them. So on the basis of statistical data collected for more than three decades of observing the formation of modes of operation of mills HPT in various pipe-rolling factory in Ukraine and Russia, it is determined that the downtime average statistical mill HPT repairs due to accidental failure of the only parts of the propulsion the line was about 400 hours a year. And this is in addition to material damage associated with the elimination of accident consequences, resulting in the loss of more than 30 thousand. Meters of pipes.

The cold-rolled pipes mills should be regarded as a system created by specialized units (modules), which is determined by a set of specific conditions and objectives of the operation.

The main power line. The main power line company mills SMS Meer uses classical scheme aligning torque on the shaft of the crank and partial balancing of inertia forces reciprocating mass of the working stand. This solution is not optimal, since in the process of balancing the forces of inertia of the moving cage and leveling points on the crank shaft involved mass balances and counterweight, the total weight exceeds the weight of reciprocating cage.

A radical solution to the problem of improving the functioning of the main power line is the use of pneumatic balancing device (PBD) [1] (Figure 2). Dynamic loads due to the specifics of functioning of slider-crank mechanism, with the help of this device are located in the area of their origin. This significantly reduces energy consumption, since the flow of the power transmitted from the engine to the deformation in the processed product excluded components at the movement of the masses, ensuring the formation of the deformation zone.

PBD consist of double-acting pneumatic cylinder mounted on the racks. The working cylinder cavity air is constantly supplied, whereby the pistons in the cylinders always pressurized. Cylinder rod is pivotally connected to the working cage. Balancing force created by compressed air in the cylinder located in front of the pistons at the approach of the working stand to its end position (dead center). During acceleration and deceleration of the main drive both cavity of each cylinder are automatically connected with a special valve.

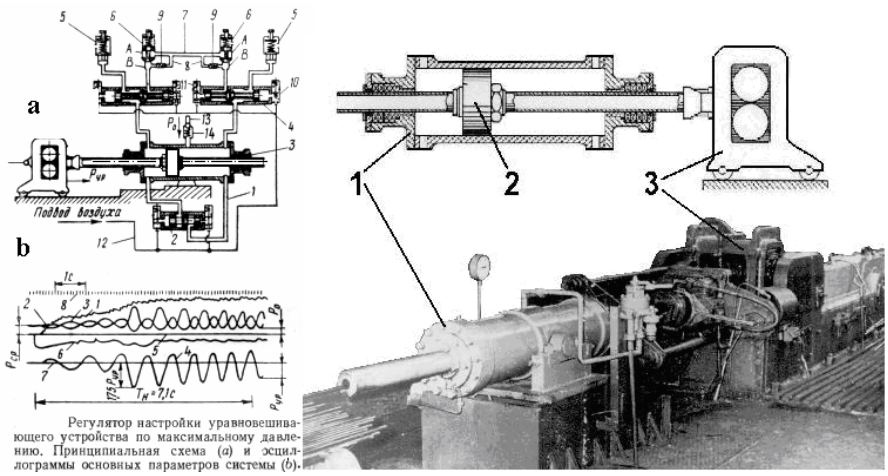

Fig. 2. Detail ofthe main power line mill HPT-32-2: 1-cylinder balancing device; 2-the piston(plunger); 3-mobile work stand

Long-term operation of PBD showed that their use in the mills HPT can speed rolling mills for HPT-32 and 200 ... 220; for mills HPT-55 and 140 ... 150 for mills HPT-90 and 110 ... 120 double strokes per minute stand, respectively. Thus the load of the main drive elements are sharply reduced, and electric power consumption is reduced by 30% ... 60%. Describing the SCPs of metal, it should be noted that the weight of the device with reference to a part of the mill HPT-32 is about 1.0 tons, mills HPT-55 and the HPT-90 1.5 ... 1.6 and 2.0 tonnes.

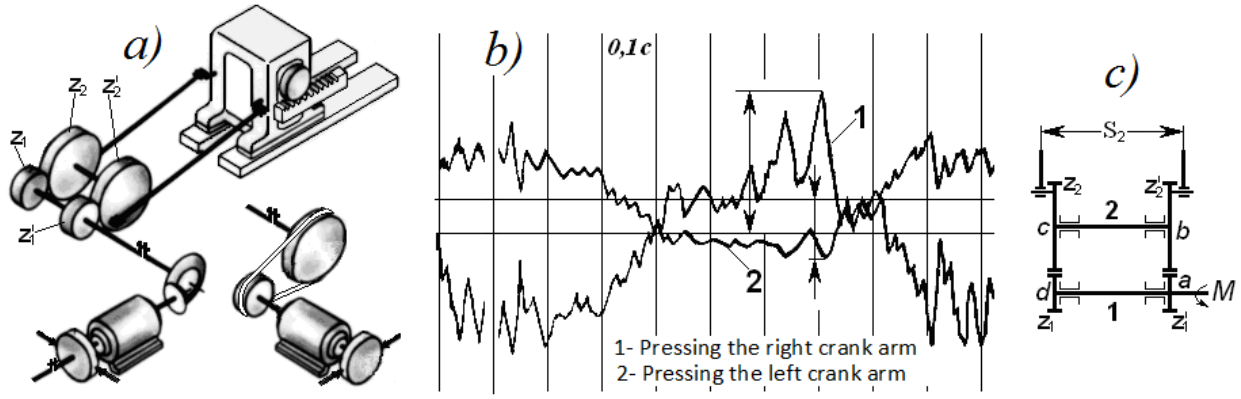

Fig. 3. Kinematic diagram of the main drive of the mill HPT-32 efforts in the waveform diagram of a rod and torque transmission from the drive gears coupled to the cranks.

During continuous operation PBD it held a large amount of research peculiarities of their functioning in the lines of the main drives of different sizes mills. It was possible to identify a number of shortcomings, set objectives, the results of which decisions to:

- Identify the optimum design parameters for the mill HPT PBD all sizes in the steady-state and transient operating conditions;
- Offer support structure, nodes connected to the cage to ensure their insensitivity to change the path of the cage as a result of wear of the guide and meet the conditions laid-back assembly;
- provides new material for the guide and sealing elements SCPs to ensure their reliable and durable operation.
- Cold rolling mill stand pipe, being driven member coupled crank mechanism is driven by the main motor through a gearbox or belt drive through a gear z_1 and z_1' (Figure 3 a). These mechanisms, forming a closed circuit, is a statically indeterminate system, the number of redundant connections is determined not only by the number of repetitive kinematic joints, but also their views. This forces the analysis of the drive units, and to consider the deformation elements of the kinematic joints.

As the shafts 1 and 2 can be elastically deformed due to the asymmetry of the power supply transmission power flow can occur both in the direction of abcd and adcb direction (Fig. 3c). Establishing the direction of torque transmission drives become different sizes due to their individual characteristics.

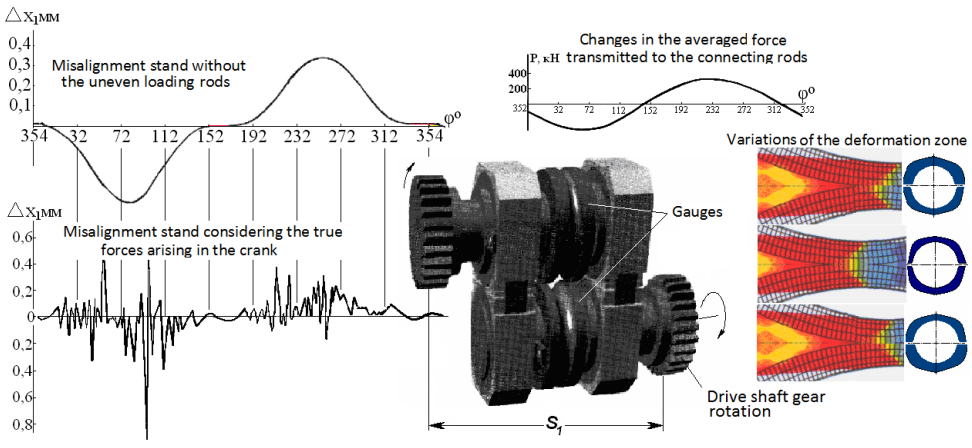

Fig. 4. Distortion stand and distortion of the roll gap during rolling

In [2] shows the relationship twisting of the shaft 2 with the relative movement of the connecting rods (right rod relative to the left). Misalignment of the cage to determine if the known coordinates of the meeting planes of symmetry axes of the connecting rods with the movable finger joints of their connection to the cage. The additional movement of the center of the leading roller gear will be larger as the distance between the gears S_1 is greater than the distance between the rods S_2.

The dependence of the magnitude Δx_1, taking into account the differences in distance between the plane of symmetry of the crank pin and the leading gear drive rollers are shown in Figure 4. From these graphs it is clear that if the resistance movement of the cage varies smoothly, and the bias (yaw) would take place smoothly, as it follows from

the graph skew averaged effort. However, experimental studies have shown that resistance to movement of the cage varies far from smooth: in particular there is a sharp change efforts at the opening of the front or rear "throat" of the rolls (periods of supply and tilting of the "blank - finished pipe").

As a result of the sharp increase or decrease the load and moment of unilateral application to the driving gear starts to stand oscillates around the vertical axis. The summation of all these processes and leads to a significant difference between modules of practical indicators skew from their theoretical values.

There are a number of proposals the organization more uniform loading of rods. Thus decision [3] includes setting one of the crank wheel is rotatable about the crank shaft. According to [4] to the drive hub proximal end of the crank shaft gear wheels and hollow elongate performed with respect to the crown gear and the other side is connected to the shaft at the location of the crank wheel toothing via a bearing mounted in the cavity, and an elongated end rigidly. It should be noted that with this decision you must also control the amount of stiffness branches which transfer the rotation to the crank gear wheel.

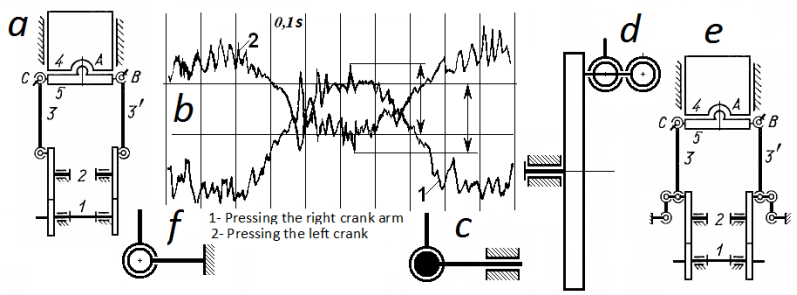

Fig. 5. Statically determinate crank mill HPT-32 waveform efforts rods and amplification circuit reference node cranks

Close to the optimal solution is presented in Figure 5a [5], according to which the gear wheels, which are mounted on cranks, mounted cantilevered on the support of individual nodes 2 and 4 carrier rolls mill associated with rods 3 and 3′ with intermediary 5. The implementation of this solution has been tested in a production environment [6], showing a number of positive effects (improving product quality, increasing the lifetime of the crank of the group). However, the constraints imposed by the peculiarities of the implementation of maintenance solutions, forcing the improvement of the structure.

To increase the load capacity of supports 2 crank pin provided with additional spherical bearing assemblies that allow to form a second support of the crank assembly to the frame forming a statically determinate group consisting of either a single unit (option f in Figure 5), or two-link connection (option c on Figure 5).

In view of the above, the options available solutions (Figure 6) in the modernization of the main drive line mill HPT-32 with the installation of rods weight reduction made by precision molded from high-strength aluminum alloys.

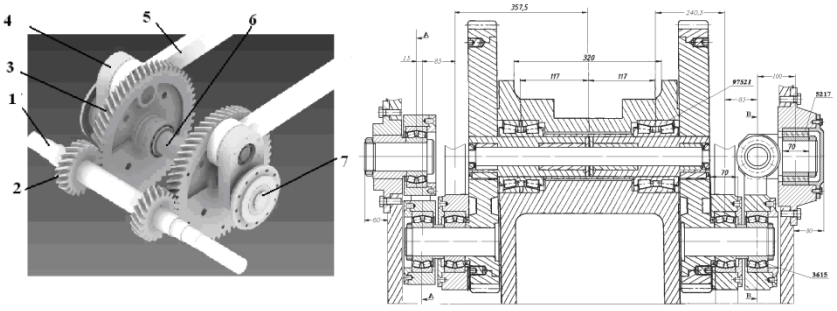

Fig. 6. Upgrading the main drive of the mill HPT-32:
1 drive shaft; 2-gear drive; 3-wheel crank; 5 - an aluminum rod;
6 - forked shaft of the crank wheel; 7 - an additional support unit

Module rolling deformation zone. It is established that during the rolling deformation zone in the movable contacting system "rolls - workpiece" is formed such that in addition to vertical displacement determined pliability system "rolls - cage frame", and they carry out horizontal (along the axis) displacement. Making these movements, rolls distort instantaneous cross-section of the deformation zone. This has led to critically assess the schemes of the deformation zone. Having identified a number of shortcomings and using the provisions of the bases of structural synthesis of mechanisms designed rational pressure device, the optimum geometry of the cage and carried out their testing on mills HPT different sizes.

The mobile stand. To avoid large dynamic loads movable frame stand cold rolling tubes should be extremely easy and at the same time durable. Typically, the frame is made of closed type with fins and cross struts to reduce weight. Calculate the frame in the usual way, but the allowable stresses are received higher than is usual in the rolling production. This significantly reduces the service life of the base.

During loading of the frame configuration by the action of the process load is deformed as a result of its elements are not only subject to the action of tensile stress but also a greater or lesser extent subjected to bending. In order to minimize this phenomenon, it is necessary to select a certain way forming rack frame mill HPT. The problem is reduced

to finding the conditions for an extremum of the integral bending moment $\Phi = \int_0^{l_1} \bar{y} dl_1$, where l_1 - the length of the rack frame;

$\bar{y}$ - coordinate the reporting section of the rack (Fig. 7).

Among all curves schematically depicting rack frame of the working stand, it is required to find the use of which results in a minimum value and in comparison with the other, assuming that the boundary point coupling cross member and the rack of the frame (point B1) is fixed, and the second - is selected from the conditions minimizing considered functional. The proposed method of determining the configuration and location of the rack frame is not very easy, but in this case, is very effective. The main results of theoretical and experimental studies of rational frame that combines high strength and minimum weight, were the basis for the design of new working mill stand.

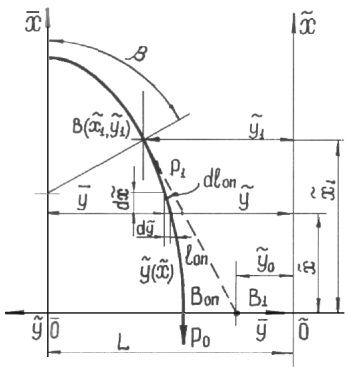

Fig. 7. Choice of rational configuration of the rack frame

Working millstand HPT [7] (Fig. 8) consists of the oval-shaped frame (frame) 1, which are mounted in the pressing means 2, the work rolls are mounted on bearings in the cushions 3 and 4.

The frame 1 is a spatial structure comprising two connected links oval-shaped frame rational form, each of which is formed by the inner 7 and outer 8 shells paired vertical longitudinal webs 9 of variable thickness, including at the sector angles of 120 ° the upper and lower cross members, articulated between themselves racks. At the level of the axis of the rolling rack frame has a sampling wedge groove with holes 10 for connecting the actuator rods and the rods of the counterbalancing apparatus. At the bottom of the frame support 11 is to set the working stand, designed as a reference and side rails along the entire length, thereby increasing maintainability, stability and smoothness of motion stand, reduced wear on the support rails, which are attached to textolite patchs 12. The guide support working stand combined with a lower frame coupled to the spatial grid system - supports and ribs are connected by transverse connection stiffeners.

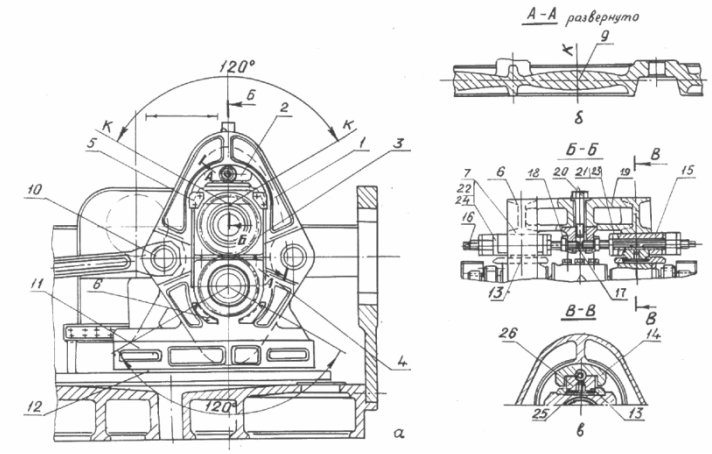

Fig. 8. Rational working mill stand HPT

With this construction working implement HPT mill stand has a reduced weight and ability to withstand high static and dynamic loads. The top link side frames made taking into account the possibility of its use in mounting screw-in unit labor millstand HPT.

Rational pressure device. Pressing means (Fig. 9) comprises a wedge and a screw mechanism. Wedge mechanism is provided with wedges 13, moving along the inclined contact surfaces of the cushions 3, two pairs of compensating inserts cylindrical surfaces, the axis of one of them 14 mounted on the wedges are parallel to the longitudinal axis of the frame, and the axis of the other 15 in contact with the bed, parallel to the axis of the roll.

Setting mechanism wedges comprises a screw 16 rigidly fixed to the frame (its fixation in the housing 17 is carried nuts 18 retained by a screw 20 fitted to the top connection 19) whose axis is parallel to the roll axis, the two nuts 21, 22 and the respective spherical washers 23 and 24 interacting with the wedge inserts compensating mechanism.

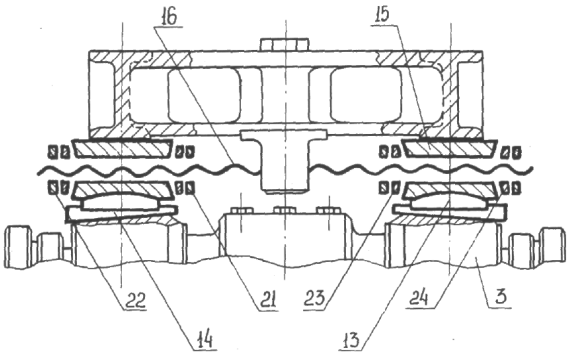

Fig. 9. Kinematic scheme of the optimum pressure device

Due to such a rational structure of the pressing device has acquired the property to adapt to all possible inaccuracies of manufacturing and installation, as well as deformation elements, which appear as a result of misalignment and base surfaces. If rigidly mounted in the frame 16 during the screw assembly to be installed parallel to the roll axis, then the system will adjust by rotation of the spherical washers 23 and 24 relative to the liner 15 (a prerequisite for this is the presence of a guaranteed clearance between the screw 16 and the hole in the liner 15). If the result of installation working cage axis of the cylindrical inner surface of the window frame will not parallel to the roll axis, the system also adapts a result of

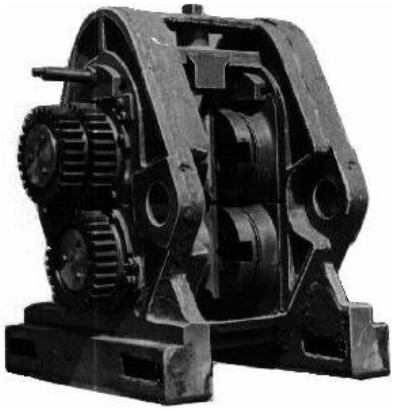

Fig. 10. Rational working millstand HPT-32

relative rotation of the inserts 14 and 15 (if the misalignment results in the vertical plane) or as a result of displacement of the wedge 13 on the supporting surface of the upper pads (if misalignment appears in the horizontal plane).

In this system guaranteed no additional load on the elements of the kinematic pairs. Self-adjustment of the supports of the upper roll, above all, ensures uniform loading of bearings and the upper cushion on the extent of wear of the last roller are displaced axially towards each - other under the action of horizontal component reactions of wedges providing selection gaps appearing. This also reduces the axial displacement of the rollers relative to each other and the distortion of the profile gauge.

The practice of a rational working stand on mills HPT-32 (Fig. 10) shows the high reliability and efficiency at which the following figures: an increase in mill production by 7%; weight reduction of the working stand at 14%; saving energy consumption by 9%; increase service life of the rolling mill at trudnodeformiruemyh steels and alloys actually 3.6 times; improving the quality of the finished product by increasing the rigidity of the working stand; decrease in marriage "roll forward" at 5%; expansion of technological capabilities mill (rolling a special assortment of pipes - thin-walled, change existing routes rolling to reduce the cyclical processing).

Tilt-and-supply modules of the complex. The device periodically feeding the workpiece in the deformation and rotation of the line of the "blank - finished pipe" shall ensure, in particular, the following basic requirements:

• Consistency of operation with a predetermined position of the stand, providing not only filling the deformation, but given the level of axial forces;

• Software defined displacements in a wide range of rates of the mill;

• the possibility of continuous or discrete variation amount of displacement over a wide range without disturbing the maintaining process;

• indifference complex functioning with respect to the dynamic characteristics of the process.

Taking into account the specifics of their influence on the process HPT supply line and turning and it is advisable to perform separate sets the minimum at a distance from the roll gap. When creating mechanisms lines subject to the following conditions of their synthesis:

• minimizing the number of units and values of the masses involved in the process of periodic translational and rotational movements;

• combination of unproductive operations connected with the preparation of feed lines and rotation, with the work of other mechanisms in the function sequence of functioning which the enslavement of the "blank - finished pipe";

• mobility control operation parameters feed and turn.

On the basis of the use of materials AS USSR number 532 413, AS USSR number 818 683, AS USSR number 1409359 designed unified technical documentation for the modernization of the cold rolling mills pipes HPT-32, HPT-55, HPT-75 and the HPT-90 second and third EZTM models with tilt-and-feed systems (PPK) with epicyclic converters.The high level of technological development has provided the opportunity to implement a comprehensive supply with a high degree of readiness of assembly units that make up the complex, for installation on the mills.

The delivery device comprises a mechanism batch and the associated converter continuous rotation of the drive shaft into intermittent axial movement of the chuck sleeve. The mechanism of periodic action (Fig. 11) is designed as a pulley block brake and pneumatic system of its management, cinematically connected with the line of the main drive of the camp, and the converter of rotation of the drive shaft in the form of epitsiklicheskog mechanism.

Continuous rotational movement drive (not shown) through the coupling 1, a high-speed shaft 2 is transmitted to the sun gear 3 and through the satellite 4 reported cage, where rigidly fixed brake disc 5. When the alarm drum brake 6, the impact of which through the brake pads on the disc 5 are pneumatic control system via pneumatic cylinder 7, the carrier is stopped and the rotary motion of the shaft controlled electric drive is transmitted through the ring gear internal gear unit 8 on the ring gear with external engagement and then a system of wheels shaft 9 connected to the shaft nut feed screw (stroke). The angle of rotation of the shaft 9 during the stopping of the carrier can be varied by changing the rotor speed controlled drive and, accordingly, the rotational speed of the sun gear 3.

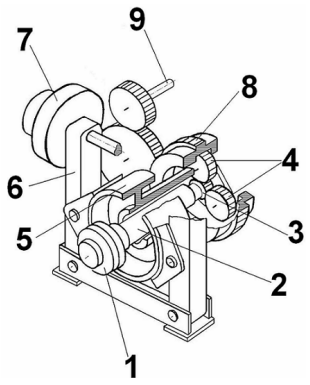

Fig. 11. The mechanism of periodic action

A device that provides a periodic rotation of the "blank - finished pipe - mandrel rod", performed similarly, with the only difference being that the continuous rotation of its drive shaft is converted into intermittent rotation of the elements of the line of rotation (Fig. 12).

Pneumatic control system includes a valve mechanism AUC and candy bars,

which provide:

• synchronization trigger supply lines and turning to the position of the working stand;

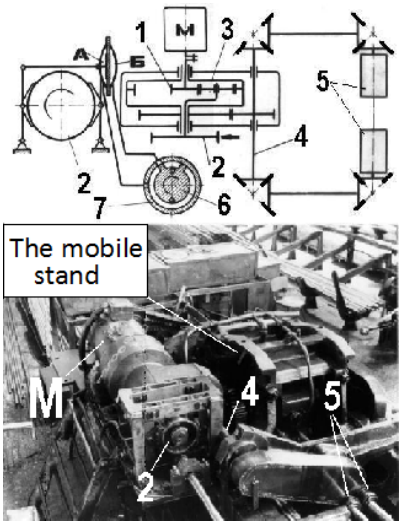

Fig. 12. The mechanism of rotation of the workpiece with the epiciclic module (basic sheme and set the mill, to modernize two-stand rolling

• management of the epicyclic mechanisms in the process of rolling tubes;

• opening and closing of feed and turn in the stopping and starting of the main drive of the camp;

• management of the epicyclic arrangements when recharging the camp.

Experience in long-term operation revealed a number of advantages of using a tilt-feeding complexes with epicyclic converters:

• the ability to control the feed rate and the angle of rotation of the workpiece in a wide range without stopping the mill;

• availability of feedback on the electromotive force with massive rotor drive motor allowed the process to feed;

• possible to use the flexible technology of rolling pipe mill, which allows rolling of a pipe joint in the optimal mode for each case;

• controlled scatter of the angle of rotation of the workpiece (the spread does not exceed 15%) provide increased lifetime caliber.

Currently, the different plants of Ukraine and Russia are operated for more than 20 mills HPT different sizes and designs, equipped with epicyclic AUC converters.

It should be noted that the replacement of the distribution feeder with complex epicyclic converters transformed cold pilgerovaniya unit (Fig. 13) in a multi-system providing an independent implementation of all process steps of the process without losing their qualitative characteristics throughout the range of operating pace. Implemented terms of regulatory independence quantities feed and turn without stopping the mill, possible interference of the variable components of the transmission rate of job displacement stand and slave units supply lines and rotation.

The control module. In recent decades, a growing trend towards the introduction of the automatic control of process parameters on the basis of OMD use the highest standards of reliability compact siloizmeritelej included in a single system containing a microprocessor signal processing blocks for a variety of algorithms. Widespread application of such hardware significantly increases the observability processes. Since the process of HPT is characterized by considerable inertia, the inclusion in the logic of the control circuit values of the angles of rotation and movement of the workpiece flow of information on the loading roller bearings and conveying elements of the feeder creates the preconditions for the formation of the automatic control of output parameters. This allows you to assign tasks, decisions which are aimed at changing the substantial level of the "mill HPT", ie its transformation from a technical view in the cybernetic.

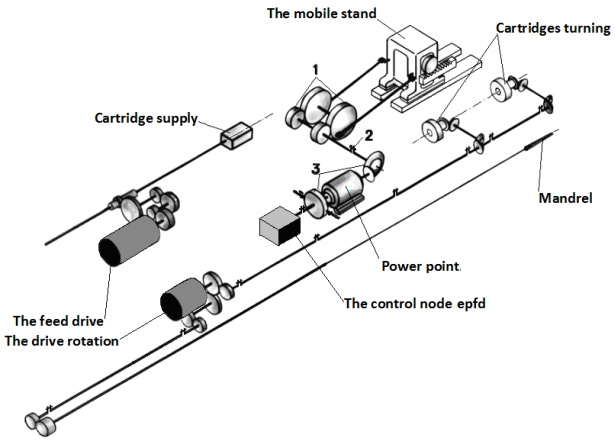

Fig. 13. Kinematic scheme of acold rolling mill equipped with a rotatory-feeding complex being equipped epicyclic conwerters

As part of undergoing a painful restructuring of the Ukrainian pipe production is more than 200 cold rolling mills pipes of different sizes and constructive accomplishments. This production will be effective in diversification - "merging" with the production of final products (for example, the production of ball bearing steel and bearing production at factories of the company "Timken" USA; production of heat exchangers in a SMPO them. Frunze, production and sale of precision tubes stainless and alloy steels, titanium alloys and refractory metals Dnepropetrovsk plant of precision tubes and special).

Summary

System-modular approach to the unit that implements the method of production of goods HPT, based on the analysis of both technological and regime of the functioning of its mechanisms, and design options for their execution and layout, allows efficient use of the existing equipment and, if necessary, to expand its capabilities.

The growing demand for cold-rolled tube can be satisfied both by the modernization of existing units and replacing them with new ones. For the design and manufacture of advanced mill HPT Ukraine has not only technical capabilities but also professionals able to offer solutions at the level of the best world standards.

Анотація. *За оцінками фахівців на трубопрокатних, хімічних і машинобудівних підприємствах, як України, так і СНД функціонує кілька сотень агрегатів для холодної прокатки труб валковими і роликовими калібрами, які були виготовлені та поставлені замовникам в другій половині минулого століття. Пропонується системно-модульний підхід при модернізації агрегатів холодної прокатки труб, що реалізують одну з небагатьох безвідходних технологій отримання виробів з високими споживчими характеристиками. Наведено приклади реалізації підходу.*
Ключові слова: стан холодної прокатки труб; головна силова лінія; рухлива робоча кліть; спарений кривошипно-повзунний механізм; пристрій періодичної подачі; осередок деформації; лінія повороту; керуючий модуль; натискний пристрій

Анотация. *По оценкам специалистов на трубопрокатных, химических и машиностроительных предприятиях, как Украины, так и СНГ функционирует несколько сотен агрегатов для холодной прокатки труб валковыми и роликовыми калибрами, которые были изготовлены и поставлены заказчикам во второй половине прошлого века. Предлагается системно-модульный подход при модернизации агрегатов холодной прокатки труб, реализующих одну из немногих безотходных технологий получения изделий с высокими потребительскими характеристиками. Приведены примеры реализации подхода.*
Ключевые слова: стан холодной прокатки труб; главная силовая линия; подвижная рабочая клеть; спаренный кривошипно-ползунный механизм; устройство периодической подачи; очаг деформации; линия поворота; управляющий модуль; нажимное устройство.

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Подана до редакції 29.09.2016