ISSN 1028-2335 (Print)
Теорія і практика металургії, 2025, № 3
Theory and Practice of Metallurgy, 2025, No. 3

https://doi.org/10.15802/tpm.3.2025.06

UDC 621.774.36

Балакін В.Ф., Угрюмов Д.Ю., Добряк В.Д., Угрюмов Ю.Д., Николаєнко Ю.М.

Удосконалення гарячої пілігримової прокатки труб

Balakin V.F., Ugryumov D.Yu., Dobryak V.D., Ugryumov Yu.D., Nykolaienko Yu.M.

Improvement of hot pilgrim pipe rolling

Аннотація. *Розглянуто основні методи поліпшення затравочного режиму з урахуванням відношення D/S труб, що прокатуються. Запропоновано здійснювати прокатку труб у затравочному режимі зі змінною величиною подачі по заданій програмі, а також нові рішення з прокатки гільз встик. Розглянуто два нових напрямки підготовки передніх кінців гільз на чотирьохбойковому гідравлічному пресі та на обкатній машині планетарного типу. Запропоновані нові методи підготовки задніх кінців гільз за рахунок потоншення стінки на задньому кінці гільзи в процесі прошивання заготовки на косовалковому стані за рахунок переміщення оправки, а також – обтиснення заднього кінця гільзи на дорні на двобойковому гідравлічному пресі. Запропоновано комбіноване використання розглянутих методів поліпшення затравочного режиму, що підвищить продуктивність і зменшить витрати металу в обріз.*

Ключові слова: *пілігримова прокатка, пілігримовий стан, труба, гільза, несталий затравочний режим, подавальний апарат, дорн, подача, коефіцієнт витяжки, валки, витратний коефіцієнт металу, підготовка передніх і задніх кінців гільз, продуктивність.*

Abstract. *The main methods of improving the feeding mode taking into account the D/S ratio of rolled pipes are considered. It is proposed to carry out rolling of pipes in the with variable feed rate according to a given program, as well as new solutions for butt shell rolling. Two new directions for the preparation of the front ends of the sleeve liners on a four-row hydraulic press and on a planetary type reeling machine are considered. New methods of preparing the rear ends of the sleeves by thinning the wall at the rear end of the sleeve in the process of piercing the workpiece on the rotary piercer mill by moving the mandrel, as well as by crimping the rear end of the sleeve on the mandrel on a two-punch hydraulic press. The combined use of the considered methods of improving the inoculation mode is proposed, which will increase productivity and reduce metal consumption in the cut.*

Keywords: *pilgrim rolling, pilgrim mill, pipe, sleeve, unsteady inoculation mode, feeder, mandrel, feed, draw ratio, rolls, metal consumption ratio, preparation of the front and rear ends of sleeves, productivity.*

To the 90th anniversary of the birth of V.V. Perchanik (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 hot pilgrim pipe rolling process is used worldwide for the production of oil and gas, oil pipeline, boiler, and special purpose pipes of a wide range of sizes and grades. Currently, about 40 pilgrim units are in operation worldwide. In Ukraine, a 5-12" TPA is currently operating at the Nizhnyodneprovsk Pipe Rolling Plant (NTZ). The hot pilgrim pipe rolling process has the following advantages: the possibility of producing pipes of considerable length, as well as thick-walled ones, which cannot be obtained by other methods, except for pressing; the possibility of significantly improving the structure of the initial cast material due to significant total deformations on the pilgrim mill; a short duration of transition to another pipe size; the possibility of using a continuously cast round billet as an inexpensive initial material with a diameter of up to 500 mm; the feasibility of producing small-tonnage batches of pipes. From the analysis of the main performance indicators of various TPAs, it follows that the production of pipes on pilgrim units has higher metal consumption factors (MCF) by 100-150 kg per ton compared to other units, which is due to inevitable technological losses of metal on the seed and the pilger head. The value of MCF during the rolling of thick-walled and especially thick-walled pipes can be compared with VKM on other units due to the use of metal-saving technology of rolling sleeves end -to-end onto mandrels with rolls, which minimizes the final cut of pipes.

Features of the hot pilgrim pipe rolling process: The hot pilgrim pipe rolling process is characterized by the presence of steady-state and non-steady-state processes, which include the seeding mode and the finishing mode. pilgrim head. Unsteady processes are characterized by the instability of such pilgrim rolling parameters as feed, rollback, canting angle, compression by diameter and wall thickness, and draw ratio [1-4]. Unsteady seeding mode is the most difficult rolling mode due to the instability of the conditions of metal capture by the rolls, increased transverse flow of metal in the roll caliber outlet. In this case, there is an increase in the cut of the front defective ends of the pipes, as well as a decrease in the mill productivity due to the duration of the seeding mode, which is 5-15% of the machine rolling time. Difficult conditions of the seeding mode are due to significant draws (up to 15) and deformations of pipes with a front support from the side of the feeder. Metal losses in the seeding front end of the pipe reach a length of 500-700 mm or more and increase with increasing draw. The greatest metal losses occur during the rolling of thin-walled pipes with a ratio of D/S=12.5-40.0 and especially thin-walled pipes with D/S> 40 - the main assortment of TPA 5-12" NTZ. A feature of the process of hot pilgrim rolling of pipes is the presence of a pilgrim head at the rear end of the roll, which is due to the stop of the rear end of the sleeve in the mandrel ring, as a result of which rolling occurs with a constant front support on the sleeve from the side of the feeding apparatus. The formed undercut of the rear end of the sleeve is called the pilgrim head and goes into the cut, increasing the metal consumption coefficient.

Features of the seeding mode of pilgrim rolling [1-4]: during seeding The pilger mill does not produce a finished pipe, but forms a pilger head on the sleeve; metal waste during cutting the seed end of the pipe reaches 30% of the total technological cutting on the pilger mill; the conditions for gripping the sleeve by the rolls are complicated, since the metal meets the roll before the line of the roll centers; the impact of the roll crest on the metal causes increased dynamic loads in the working line of the mill; there is no synchronization (especially in the initial period of seeding) of the operation of the feeding apparatus with the rotation of the working rolls due to the variable length of the rollback and the undercutting of the sleeve; the high-speed rolling mode is limited by the conditions of the sleeve's adhesion to the mandrel and inertial forces at the moment of braking of the feeding apparatus; the feed amount is limited by the uneven deformation along the perimeter of the sleeve in the absence of a rigid front end of the pipe; increased wall unevenness in the seed area and further in some part of the finished pipe for the same reasons.

After the start of deformation of the sleeve on the mandrel by the rolls in the seeding mode, the feed rate is important, which is determined by the movement of the sleeve in the rolls in each cycle. In practice, they strive to carry out the seeding mode of pilgrim rolling with small feeds, since it is not controlled and a situation of mill overload due to a large feed is possible. In practice, the feed rate during the seeding mode does not exceed the feed rate in the steady mode. This prolongs the seeding process and increases the machine time of rolling with a corresponding decrease in the productivity of the mill. The process of the seeding mode of pilgrim rolling is influenced by the capabilities of the applied feeders. The unmodernized feeders operated in Ukraine significantly complicate the seeding process, especially during the rolling of thin-walled pipes. Thus, improving the seeding conditions, their maximum possible approximation to the steady process is an important reserve in increasing productivity and improving the technological performance of pilgrim units.

Problem statement. The unstable seeding mode of pilgrim rolling reduces productivity and increases metal consumption in the final cut. Given the complexity of the problem, it has received only a partial solution mainly for rolling thick-walled D/S= 6.0-12.5 and especially thick -walled D/S<6 pipes. The current work is devoted to the development of new technological solutions for improving the seeding mode when obtaining both thick-walled and thin-walled D/S= 12.5-40.0 and especially thin-walled D/S>40 pipes.

The main part

A.O. Chernyavsky proposed dividing the seeding process into two separate stages [1]. The first stage of seeding is characterized by the meeting of the sleeve with the rolls in front of the line of their centers (Fig. 1a). Due to the fact that the rolls are ahead of the sleeve, friction forces arise in the contact area formed as a result of the initial interaction of the sleeve with the rolls, directed in the direction of rotation of the rolls. The first period of seeding lasts until the preliminary seeding end is formed, which makes it possible to feed the sleeve beyond the line of the centers of the rolls without the risk of excessive overloading of the mill due to a sudden increase in the feed. During this period, not rolling takes place, but forging of the sleeve, which is periodically fed into the rolls.

At the second stage of seeding, the sleeve with the previous seed end is set behind the line of the centers of the rolls and a portion of the metal is squeezed out by the rolls with its subsequent rolling (Fig. 1b). If at the first stage the support contributed to the implementation of the seed, then at the second stage its value decreases, and in practice during the second stage the force Q_n reduced by bleeding air from the acceleration chamber of the feeder. This helps reduce transverse deformation of the metal in the caliber, which reduces the duration of forming the seed end and improves its quality.

The size of the cut of the seed end of the pipe is influenced by many factors, the main of which are: the size of the pipes being rolled (diameter and wall thickness); the quality of the starting metal of the billet; the steel grade and the temperature regime of rolling; the design of the feeding apparatus; the feeding regime during seeding; the extraction coefficient during seeding; the gap between the mandrel and the sleeve, etc. [5, 6]. The cut of the seed end conventionally consists of two parts. The first part is due to significant unevenness of the deformation along the rolling perimeter, and the second - to increased pipe wall heterogeneity. Significant unevenness of the deformation along the rolling perimeter occurs due to the absence of a rigid front end of the pipe during seeding, which leads to the pulling of individual portions of metal along the side walls of the caliber independently of each other and, accordingly, to the violation of the continuity of the metal. The reason for the increased pipe wall difference is the presence of a gap between the sleeve and the mandrel, which, due to the uneven deformation of the sleeve along the perimeter, leads to asymmetric clamping of the sleeve on the mandrel by the rolls. In the general technological cut on the pilger mill seeding is 23-30%, and in some cases more. The duration of seeding is subject to the influence of many factors that act with different intensity in different conditions. Moreover, these factors are partly subjective and random in nature. Rolling of thick-walled pipes (D/S<10) requires no more than two roll strokes for seeding. The performed analysis of the features of the seeding mode allows us to consider the main methods of its improvement from new positions, taking into account both previously performed works [1-4] and recent publications [5, 6].

The main methods for improving the seeding mode: reducing the draw ratio on the pilger mill; increasing the adhesion of the sleeve to the mandrel before rolling; using special rings; rolling the sleeves end-to- end; forcing the sleeve to be tilted by 90° during seeding; choosing a rational feed mode during seeding; choosing a high-speed rolling mode; preliminary preparation of the front (rear) ends of the sleeves.

1. Reducing the draw ratio on the pilger mill. This method is widely used in practice when rolling thin-walled and especially thin-walled pipes (with a pipe wall thickness on the pilger mill S=5-7 mm). When the rolls make 8-10 revolutions from the beginning of the seed, the upper roll is smoothly lowered. Under the existing conditions, only this method makes it possible to roll pipes with S=5-7 mm. The existing thickening of the pipe wall during the lifting of the upper roll is then removed into the cut along with the defective end, which increases the mass of the total cut. In order to increase the yield, in the work [7] it is proposed to deform the front end of the sleeve during the separation of the rolls of the pilger mill by 1.02-1.15 times greater than the separation of the rolls set during the rolling of the middle part of the sleeve. After that, the separation of the rolls is set in accordance with the rolling mode of the middle part of the sleeve and deform it from beginning to end. To reduce the technological cut on the pilger mill, a combined technology for rolling thin-walled pipes on a pilgrim installation is proposed, which includes a slanting roll rolling mill with a short mandrel. The essence of the new technology is that on the pilger mill the front and rear ends of the pipe, corresponding to the seed and the pilger head, are rolled with an increased wall thickness, subsequently the wall thickness is equalized along the length of the pipe on the rolling mill [1]. The wall thickening at the ends (compared to its middle part) should not exceed the maximum value of the wall crimp on the rolling mill.

2. Increasing the sleeve-mandrel adhesion before rolling. Increasing the sleeve-mandrel adhesion allows you to intensify the pilgering process, especially at the initial moment of rolling in the seeding mode. This method allows you to choose a more optimal rolling speed mode along the length of the pipe. The gap between the sleeve and the mandrel during seeding increases the flattening of the roll due to reduction, and this prevents canting. In addition, the presence of a gap between the sleeve and the mandrel during the seeding period leads to an increase in the unevenness of deformation across the caliber width and, as a result, to the appearance of cracks and additional cutting of the front end of the pipe. Reducing the gap to the minimum required values (10-12 mm), which ensure stable loading of the mandrel into the sleeve, is in practice carried out by improving the quality of the sleeve piercing on the cross- rolling mill. To ensure a minimum gap between the mandrel and the sleeve, the latter must have minimal curvature and a stable (within the permissible limits) inner diameter along the length of the sleeve, which is achieved mainly by the correct setting of the cross-rolling mill.

Thus, to reduce the final cut during seeding, it is necessary to strive to reduce the gap between the sleeve and the mandrel along the entire length of the sleeve or at its front end. On the 6-12" NT3 TPA, it was found that reducing the gap Δbetween the sleeve and the mandrel leads to a reduction in seeding duration by 11.6-18.2%, other things being equal [8].

3. Use of special rings. This method has been used during the rolling of pipes from high-alloy and special steels and consists in the use of additional rings from carbon steel, which are put on the mandrel and joined to the front end of the sleeve. As a result of rolling into the edge, the defective end from carbon steel is removed, which makes it possible to significantly reduce the consumption of alloyed and special steels. The most widespread method is welding a special ring to a hollow workpiece with subsequent heating to the deformation temperature and rolling directly on a pilger mill. It is possible to join a heated special ring and a hollow workpiece on a mandrel and compress the ring on a press to increase adhesion.

4. Butt-rolling of sleeves. The method has found wide application during rolling of thick-walled pipes with D/S=6-12.5 and especially thick-walled pipes with D/S<6 [1]. It provides reduction of the cutting of the front and rear ends of the pipes due to a more uniform distribution of deformation over the width of the caliber due to the presence of "hard ends". For rolling of pipes with thinner walls it was proposed to reduce the section of the sleeve joint before the main deformation along the wall thickness (Fig. 1). In this case, the draw ratio during reduction of the sleeve wall is μ_1 =1.03-1.15, and the elongation coefficient during deformation along the wall μ_2 = 4-9 [9]. The second option for implementing the technological capabilities of the butt-rolling method of sleeves is the use of carbon steel rings between the sleeves joined by mandrels (Fig. 2).

5. Forced tilting of sleeves by 90° during seeding. In conventional air cylinders of a forgoler, the rotation of the sleeve by an angle of 90-120 degrees is carried out using a drill. Part of the plunger is made with a thread that works in conjunction with a nut. The nut engages with the threaded part of the plunger during its movement towards the rollers. The angle of rotation depends on the size of the plunger stroke and is not a constant value. In the air cylinder of the company " Mannesmann-Demag " (Germany), in addition to the drill, a device for forced tilting of the sleeve is provided. The optimal tilting angle is set, which is 90 degrees. In this case, the drill is made in such a way that the tilting always occurs at an angle less than 90 degrees, and the forced tilting device turns the sleeve to 90+(5-10) degrees. [10]. The forced canting device is also designed to reduce the number of seed blows, which is currently 11-12, and sometimes increases to 18. This is due to the lack of canting in the initial rolling period.

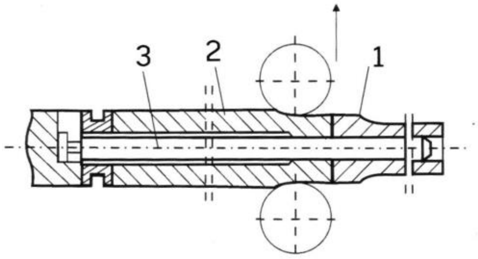

Fig. 1. Stage of reducing the joint of the sleeves: 1 and 2 - the previous and next sleeves, respectively, 3 - mandrel

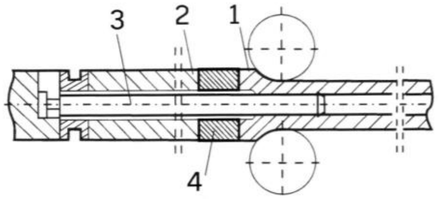

Fig. 2. Rolling of sleeves end-to-end with a ring between them: 1 and 2 - previous and next sleeves respectively, 3 - mandrel, 4 – ring

6. Choosing a rational feed mode during seeding. In practice, it is known to use two feed modes during seeding. The difference between them is that the first mode is carried out at a feed equal to its value in a steady state. The second feed mode is characterized by the fact that at the beginning of the seeding process (in its first cycles) the feed value significantly (2.5-3 times) exceeds its value in a steady state. This feed mode is used in practice more often, since it allows you to reduce the duration of the unstable seeding mode by 50-70% compared to the first mode, which, in turn, provides a reduction in the final cut due to less uneven deformation of the metal in the caliber, which makes it possible to use it during the rolling of special (expensive) steels.

There are known proposals for improving the feed mode during seeding, and according to the first of them, the next volume of metal is fed when a signal is received about the complete rolling of the previous metal feed, which should contribute to reducing the unevenness of metal deformation in the caliber, and should also make the automation of the seeding mode more realistic. According to the second proposal, it is recommended that the metal feed into the rolls during seeding (as well as during the rolling of the entire sleeve) be carried out according to a pre- set program, which will allow you to more rationally choose the required feed mode and quickly change it [2].

To achieve the exact optimal feed rate, mechanisms are provided that combine the hydraulic drive of the carriage movement with a mechanical device for precise dosing of the amount of this movement [10]. During the seeding of the sleeve into the rolls, the nut of the feed dispenser moves according to a given program. The carriage of the feeding device is pressed against the nut, which thus determines the feed rate. Later, during a stable process, the nut moves by a constant value *m* with a frequency corresponding to the frequency of rotation of the pilger mill rolls. This ensures the exact volume of metal that is given into the rolls.

Currently, during seeding, feed mode 1 is used, when the feed $m$is equal to the feed my in the steady rolling mode (Fig. 3), which increases the seeding duration to approximately 20 s. In the case of using a sleeve with a prepared front end and in the presence of a feeding device with a mechanical feed dispenser, a variable feed mode 2 can be implemented, which reduces the seeding duration to 10 s. The third feed mode is used for rolling heavily deformed steel grades.

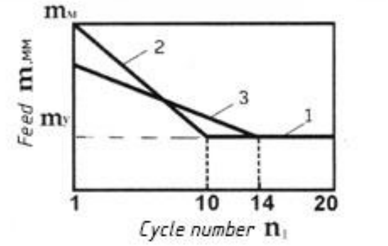

Fig. 3. Feed modes 1, 2 and 3 *m* during casing priming

7. Selection of the rolling speed mode. Currently, the rolling is carried out at a constant speed of rotation of the rolls and the minimum permissible feed. The possible number of revolutions of the rolls is calculated from the condition of the permissible acceleration of braking of the feeder during its approach to the rolls during the idling period. The maximum permissible acceleration of braking, which depends on the force of adhesion of the sleeve to the mandrel, is determined from the condition of the absence of slipping of the sleeve from the mandrel during the rolling period [1 1]. In the initial rolling period (during seeding), the adhesion of the sleeve to the mandrel is minimal, and then increases as rolling progresses. Therefore, to increase the rolling speed during seeding, it is necessary to increase the adhesion of the sleeve to the mandrel. This can be done by preliminary preparation of the front or rear end of the sleeve on the mandrel;

8. Preliminary preparation of the front (rear) ends of the sleeves [12]. The use of a pre-sharpened sleeve end immediately eliminates the first stage of the seeding, which reduces its duration and ensures the sleeve is set beyond the line of the roll centers. Due to a significant increase in the feed (not exceeding the critical one), a significant reduction in the duration of the second stage can be achieved, which, with a length of the pointed end equal to half the pilger head, should ensure a reduction in the seeding duration by 50%. In the case of synchronization of the roll-feeder system with a length of the pointed end of the sleeve equal to half the length of the pilger head, the seeding duration could be significantly reduced. The length of the end section and its profile correspond to the length of the pilger head and the shape of the pilger roll striker. However, obtaining such a profile of the end section from the point of view of sharpening technology is irrational due to the deterioration of quality due to significant intercellular deformation and the acceleration of the end section of the sleeve before the pilgrim rolling. As a result of our research, the shape of the end section was recommended, in which the length of the sharpened end of the sleeve is approximately half the length of the pilger head.

Let us consider a refined classification of methods for preparing the front ends of sleeves on a pilgrim unit with a piercing press and an elongator mill (Fig. 4).

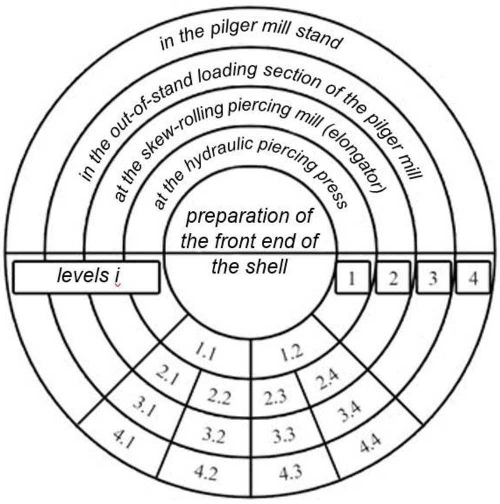

Fig. 4. Classification of methods for preparing the front ends of sleeves on a pilgrim unit with a piercing press and a cross-roller elongator mill

Preparation of the front ends of the sleeves before pilgrim rolling is possible at each of the four technological levels. The first level is the piercing press, the second level is the piercing cross-roller mill (elongator), the third level is the off-stand charging section of the pilgrim mill, and the fourth level is the pilgrim mill stand.

On the unit with a piercing hydraulic press, the following basic preparation methods are possible. At the first level: 1.1 - in the process of piercing the workpiece into the sleeve with a mandrel with subsequent rolling of the sleeves into pipes on the pilger mill, and the profiling of the front ends of the sleeve is carried out with support punches with a change of the profile sleeve; 1.2 - first, the profiling of the front end of the workpiece is carried out, and then the compression in diameter and wall thickness is carried out by moving the matrix along the workpiece to its rear end. At the second level, the following basic preparation methods of the front ends of the sleeves are possible during the rolling of the cups after the press on the oblique roll elongator mill : 2.1 - in the process of rolling on the output side of the elongator mill stand with idle rolls; 2.2 - the same with profiled matrices; 2.3 - changing the rolling angle of the working rolls of the elongator mill; 2.4 - change in the spacing of the working rolls under the load of the elongator.

At the third level, the following basic methods of preparing the front ends of the sleeves are possible: 3.1 - by pressing with the punches of a hydraulic press on the mandrel; 3.2 - on a planetary-type rolling machine or cross-screw flattening; 3.3 - by longitudinal flattening in stream rolls; 4.4 - pushing the sleeve onto the mandrel in the idle roll or matrix. At the fourth level, the following basic methods of preparing the front ends of the sleeves are possible: 4.1 - by preliminary pressing with pilgrim rolls with increased roll spacing; 4.2 -

by pressing with press matrices in front of the stand; 4.3 - by pressing the sleeve end behind the stand with press matrices under the condition of the rolled rolls being spaced; 4.4 - limiting the position of the front end of the sleeve in front of the rolls using profile sectors placed in the mill stand [13].

A feature of the preparation of the front end of the sleeve with idle rolls on a piercing mill (elongator) is the presence of deformation of the sleeve section between the drive and idle rolls, which is subjected to the forces of axial support and twisting. In this case, the increase in the diameter of the sleeve should not exceed 2%, so as not to complicate the process of pilgrim rolling. Studies of pilgrim rolling of pipes from sleeves with prepared front ends have established a decrease in metal consumption by 5-14 kg/t due to a decrease in the front end cut and the duration of the seeding process by 25-30% (depending on the pipe assortment). The experience of using the TPA 5-12" elongator mill with pilgrim mills for running in the front end of the sleeve with idle rolls allowed us to determine the advantages and disadvantages of this technology, which should be used to improve it. The second most realistic way to prepare the front ends of the sleeves is to crimp the front end of the sleeve on a mandrel with profiled half-matrixes on a hydraulic press.

Further development of the technology of preparing the front ends of the sleeve in the area of off-station loading is the work [5], which proposed two new solutions for preparing the sleeve in a four-jaw press with the sleeve canting at 45° between two compressions by longitudinal jabs (Fig. 5) and on a planetary-type rolling machine (Fig. 6). A feature of the new solutions is that the preparation of the front ends of the sleeves is carried out in both the first and second cases on equipment placed between two pilgrim stands, which reduces the equipment park. In this case, the preparation of the front ends of the sleeves is carried out on a temporary short mandrel, the diameter of which is equal to the diameter of the pilger mandrel.

The objectives of preparing the rear ends of the sleeves before pilgrim rolling are to facilitate the conditions for loading the mandrel into the sleeve, improve the conditions of the seeding and steady-state processes by reducing the gap between the sleeve and the mandrel, increase the adhesion of the sleeve to the mandrel before rolling to reduce the cutting of the seeded ends of the pipes and reduce the seeding time, increase the rolling speed on the pilger mill without the sleeve slipping off the mandrel during the period of sleeve braking when it rolls into the rolls. Reducing the gap between the sleeve and the mandrel was proposed by increasing the inner diameter of the sleeve at its rear end on the cross-rolling piercing mill by moving the short conical mandrel of the mill against the direction of rolling from the moment the rear end of the workpiece approaches the rolls by a distance ΔLx so that the thinning of the sleeve wall at the rear end was within 2-6 mm [14].

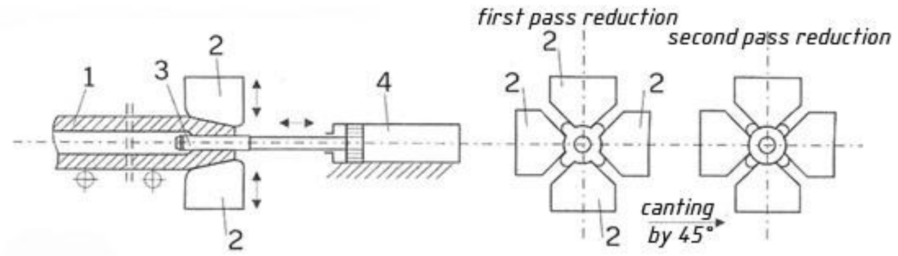

Fig. 5. Scheme of preparation of the front end of the sleeve on a four-jaw hydraulic press: 1- sleeve, 2- press jaws, 3- mandrel, 4- mandrel hydraulic drive

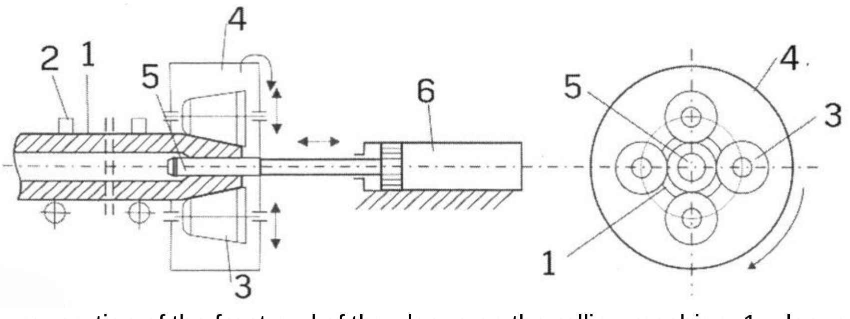

Fig. 6. Scheme of preparation of the front end of the sleeve on the rolling machine: 1- sleeve, 2- clamp, 3- idle rollers, 4- faceplate, 5- mandrel, 6—mandrel hydraulic drive

To increase the adhesion of the sleeve to the mandrel, it is proposed to prepare the rear end of the sleeve before pilgrim rolling by pressing it on a two-hammer horizontal hydraulic press with the deforming faces of the hammers arranged at an angle of 90° (Fig. 7).

The condition for holding the sleeve on the mandrel during its insertion into the rolls is

$P_{тр} \geq P_{ін}$,

where $P_{тр}$ is the friction force at the contact of the sleeve with the mandrel; $P_{ін}$– inertial force applied to the sleeve.

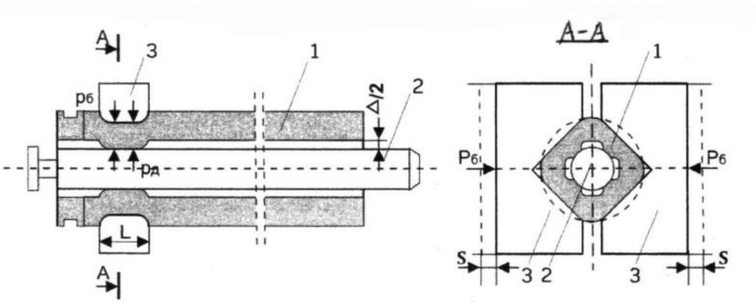

Fig. 7. Scheme of crimping the rear end of the sleeve on a two-jaw horizontal press: 1-sleeve, 2 – mandrel, 3 – press jabs

Analysis of known processes of preparation of front ends of sleeves shows that a common drawback for them is the acceleration of the front prepared end of the sleeve. This is due to the cooling of the sleeve, starting from the piercing mill (elongator) during its movement to the pilger mills. It should be noted that the sleeve after the elongator loses almost 100°C, to this it is necessary to add movement on the roller table and movement in the area of out-of-station loading. All this leads to a significant acceleration of the thinned end of the sleeve, which worsens the conditions of the seeding, primarily with an increase in the load on the rolls, deterioration of the quality of their working surface and increased risk of accidents.

To reduce these disadvantages: the elongator roller table must be made heat-shielding, a heated thermostat must be located in the off-stand charging area to stabilize the sleeve temperature not lower than the critical one, and a metal temperature monitoring system must function on the rolling mill both on the mills and between the mills.

Combined use of methods for improving the seeding regime. The greatest deterioration in the technical and economic indicators of pilgrim rolling occurs during the production of thin-walled D/S=12.5-40.0 and especially thin-walled D/S>40 pipes due to the features mentioned above. The seeding conditions during the production of thick-walled D/S=6.0-12.5 and especially thick-walled pipes D/S<6 are much better, however, even in this case there is a solution to improve the production of these pipes.

For an axisymmetric position of the sleeve on the mandrel before rolling on a pilgrim mill, a combined preparation of the front and rear ends of the sleeves is proposed, which will ensure uniformity of the gap between the sleeve and the mandrel and thereby increase the accuracy of the pipes in terms of wall thickness by reducing the transverse wall difference. This measure is effective in obtaining pipes of the entire assortment. Several options are possible for this. According to the first option, the front and rear ends of the sleeve are crimped on the mandrel in the area of out-of-the-mill charging. According to the second option, a mandrel with a conical belt near the shank is used, which will allow the rear end of the mandrel to be distributed and the gap to be eliminated.

Possible combinations of methods 1-8 are given in Table 1, taking into account the ratio D/S, steel grade, use of old or modernized feeders. For a modernized pilgrim unit, the task of choosing a set of methods to improve the seeding regime is solved from the point of view of economic feasibility, taking into account the above factors and production volumes.

Table 1. Combined use of basic methods for improving the seeding regime

No. s/n	Method	Method number							
		1	2	3	4	5	6	7	8
1	Reducing the extraction coefficient on the pilger mill	AND	AND			AND	AND	AND	
2	Increasing the adhesion of the sleeve to the mandrel before rolling	AND	AND			AND	AND		
3	Using special rings		B	B		B			
4	Butt-rolling of sleeves	B			B			B	
5	Forced 90° tilting of sleeves during seeding	AND				AND			AND
6	Choosing a rational feeding regime during seeding	AND	AND				AND		
7	Selecting the rolling speed mode		AND		B			AND	
8	Preliminary preparation of the front (rear) ends of the sleeves					AND	AND	AND	AND
A - thin-walled pipes D/S= 12.5 – 40.0 (especially thin-walled pipes D/S>40) B - thick-walled pipes D/S= 6.0 - 12.5 (especially thick-walled pipes D/S> 6)									

Conclusions

1. The presence of an unstable seeding mode of hot pilgrim rolling of pipes reduces the technical and economic indicators of pilgrim rolling, especially of thin-walled pipes, which leads to a decrease in the productivity of the pilgrim mill by 1.2 - 1.5% and an increase in the metal consumption factor by 2-3%.

2. An analysis of known methods for improving the conditions of the seeding regime was carried out and the prospects for their use for thin-walled and thick-walled pipes were determined.

3. The maximum positive impact on the conditions

of the seeding mode is made by the preparation of the ends of the sleeves before the pilgrim rolling. Two new technologies for preparing the front ends of the sleeves on a four-punch press and on a planetary-type rolling machine are proposed, as well as two new technologies for preparing the rear ends of the sleeves, the first of which is carried out on a cross-roller piercing mill due to the movement of the mandrel, which thins the wall of the rear end of the sleeve and helps reduce the gap between the sleeve and the mandrel. The second technology consists in pressing the rear end of the sleeve on the mandrel in order to increase the adhesion between them at the beginning of rolling, which improves the conditions of the seeding mode and increases the rolling speed.

4. The most effective is the combined use of the considered methods of improving the seeding regime, taking into account the specific composition of the equipment of the pilgrim unit, the assortment of pipes being rolled, the tonnage of a specific order. The D/S parameter of the pipes being rolled is of particular importance, since the choice of certain methods of improving the seeding process depends on it.

Бібліографічний опис

1. Чернявський А.О., Березовський В.В., Угрюмов Ю.Д.. Економія металу при виробництві труб нафтового сортаменту. М:. Металургія 1987. 304.с
2. Особливості затравочного режиму гарячої пілігримової прокатки труб і шляхи його вдосконалення / В.Ф. Балакін, Ю.Д. Угрюмов, О.В. Потьомкін, Д.Ю. Угрюмов. *Чорна металургія*: Бюл. ін-ту «Черметінформація». 2011. №11, С. 53-65.
3. Удосконалення технології прокатки труб на установках з пілігримовими станами / Я.Л. Ваткін, Г.О. Бібік, В.В. Перчанік та ін. *Металургійна і гірничорудна промисловість*. 1971. №.3, С.27.
4. Шубик М.А., Ломма В.К., Гріншпун М.Ш. Інтенсифікація процесу затравки під час розкочування гільз на пілігримовому стані: У зб. «Виробництво зварних і безшовних труб (УралНІТІ)». Вип. 11. М:. Металургія, 1969. С. 61-67.
5. Проєктування нових технологічних процесів підготовки передніх кінців гільз до пілігримової прокатки / Балакін В.Ф., Стасевський С.Л., Угрюмов Ю.Д., Добряк В.Д., Гриньов А.Ф. *Металургійна та гірничорудна промисловість*. 2018. №2, С. 45-51.
6. Удосконалення підготовки гільзи до прокатки на пілігримовому стані / В.Ф. Балакін, С.Л. Стасевський, Ю.Д. Угрюмов, В.Д. Добряк. *Металургійна та гірничорудна промисловість.* 2018. №4, С. 39-44.
7. Спосіб прокатки труб на пілігримовому стані: а.с. 1528589 СРСР. В21 В 21/00. 1989.
8. Чернявський А.О., Ламін Л.Б. Підвищення продуктивності пілігримового стану за рахунок скорочення часу затравки гільзи. *Металургійна і гірничорудна промисловість*. 1963. С.35-37.
9. Балакін В.Ф., Стасевський С.Л., Угрюмов Ю.Д. Нові матеріалозберігаючі технології прокатки труб на пілігримових агрегатах. *Системні технології*. 2020. №6 (131), С. 149-162.
10. Технологічні процеси, обладнання та інформаційно-керуючі системи, що застосовуються фірмою «Меннесманн-Демаг», ФРН, під час прокатки труб на агрегатах з пілігримовим станом / Ю.Г. Крупман, І.Б. Лейбман, О.С. Кагарлицький та ін. *Чорна металургія.* Бюл. Ін-ту «Черметінформація». 1987. №10, С. 15-31.
11. Устаткування цехів з пілігримовими трубопрокатними установками / Кожевников С.Н., Праздников А.В., Іоффе А.М., Бібік Г.О., Пешат В.Ф. М.: Металлургия, 1974. 256 с.
12. Балакін В.Ф., Угрюмов Ю.Д., Угрюмов Д.Ю. Методи підготовки передніх кінців гільз перед прокаткою труб. *Теорія і практика металургії*. 2012. №1-2, С. 16-20.
13. Спосіб пілігримової прокатки труб і пристрій для його здійснення: заявка ФРН, кл. В21 В 21/00, №3008820, заявл. 6.03.80, опубл. 17.09.81.
14. Тартаковський Б.І. Геометричні, кінематичні та силові параметри перехідного процесу при переміщенні оправки у прошивному стані. *Производство проката*. 2010. №12, С. 28-36.

References

1. Chernyavskii, A. O., Berezovskii, V. V., & Ugryumov, Yu. D. (1987). *Yekonomiya metalu pri virobnitstvi trub naftovogo sortamentu.* Metalurgiya.
2. Balakin, V. F., Ugryumov, Yu. D., Potomkin, O .V., & Ugryumov, D. Yu (2011). Osoblivosti zatravochnogo rezhimu garyachoi piligrimovoi prokatki trub i shlyakhi yogo vdoskonalennya. *Chorna metalurgiya*: *Bul. in-tu "Chermetinformatsiya"*, (11), 53-65.
3. Vatkin, Ya. L., Bibik, G. O., & Perchanik, V. V. (1971). Udoskonalennya tekhnologii prokatki trub na ustanovkakh z piligrimovimi stanami. *Metalurgiina i girnichorudna promislovist*, (3), 27.
4. Shubik, M. A., Lomma, V. K., & Grinshpun, M. Sh. (1969). Intensifikatsiya protsesu zatravki pid chas rozkochuvannya gilz na piligrimovomu stani: U zb. Virobnitstvo zvarnikh i bezshovnikh trub (UraINITI). *Metalurgiya*, 11, 61-67.
5. Balakin, V. F., Stasevskii, S. L., Ugryumov, Yu. D., Dobryak, V. D., & Grinov, A. F. (2018). Proektuvannya novikh tekhnologichnikh protsesiv pidgotovki perednikh kintsiv gilz do piligrimovoi prokatki. *Metalurgiina ta girnichorudna promislovist*, (2), 45-51.
6. Balakin, V. F., Stasevskii, S. L., Ugryumov, Yu. D., & Dobryak, V. D. (2018). Udoskonalennia pidhotovky hilzy do prokatky na pilihrymovomu stani. Metalurhiina ta hirnychorudna promyslovist. (4), 39-44.
7. Sposib prokatki trub na piligrimovomu stani: (1989) a.s. 1528589 SRSR. V21 V 21/00.
8. Chernyavskii, A. O., & Lamin, L. B. (1963). Pidvishchennya produktivnosti piligrimovogo stanu za rakhunok skorochennya chasu zatravki gilzi. *Metalurgiina i girnichorudna promislovist,* 35-37.
9. Balakin, V. F., Stasevskii, S. L., & Ugryumov, Yu. D. (2020). Novi materialozberigayuchi tekhnologii prokatki trub na piligrimovikh agregatakh. *Sistemni tekhnologii*, 6(131), 149-162.

10. Krupman, Yu. G., Leibman, I. B. & Kagarlitskii O.S. et al. (1987). Tekhnologichni protsesi, obladnannya ta informatsiino-keruyuchi sistemi, shcho zastosovuyutsya firmoyu “Mennesmann-Demag”, FRN, pid chas prokatki trub na agregatakh z piligrimovim stanom / *Chorna metalurgiya*. (10), 15-31.
11. Kozhevnikov, S. N., Prazdnikov, A. V., Ioffe, A. M., Bibik, G. O., & Peshat, V. F. (1974). *Ustatkuvannya tsekhiv z piligrimovimi truboprokatnimi ustanovkami*. Metallurgiya.
12. Balakin, V. F., Ugryumov, Yu. D., & Ugryumov D. Yu. (2012). Metodi pidgotovki perednikh kintsiv gilz pered prokatkoyu trub. *Teoriya i praktika metalurgii*, (1-2), 16-20.
13. Sposib piligrimovoi prokatki trub i pristrii dlya yogo zdiisnennya: zayavka FRN, kl. V21 V 21/00, №3008820, opubl. 17.09.81.
14. Tartakovskii, B. I. (2010). Geometrichni, kinematichni ta silovi parametri perekhidnogo protsesu pri peremishchenni opravki u proshivnomu stani. *Proizvodstvo prokata*, (12), 28-36.

Надіслано до редакції / Received: 21.05.2025
Прийнято до друку / Accepted: 30.08.2025