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

https://doi.org/10.15802/tpm.3.2025.01

UDC 621.774.3

Балакін В.Ф., Стасевський С.Л., Угрюмов Ю.Д., Угрюмов Д.Ю., Николаєнко Ю.М.

Нові металозберігаючі технології прокатки труб

Balakin V.F., Stasevsky S.L., Uhriumov Yu.D., Uhriumov D.Yu., Nykolaienko Yu.M.

New metal-saving technologies of pipe rolling

Аннотація. *Прокатка тонкостінних труб з D/S=12,5-40 на пілігрімовому стані супроводжується значними витратами металу в технологічний обріз, так звану пілігрімову головку, що суттєво збільшує витратний коефіцієнт металу зрівняно з іншими станами (безперервним, автоматичним та ін.). Виконаний аналіз відомих методів зменшення маси пільгерголовки дозволив запропонувати нові комбіновані металозберігаючі технології пілігрімової прокатки, які суттєво зменшують витрати металу. Вперше запропонована і обґрунтована нова металозберігаюча технологія часткової розкатки пільгерголовки на тонкостінних трубах з D/S=12,5-40, що дозволяє зняття труби з дорна за допомогою шибера. Це дозволить зменшити масу пільгерголовки до 50%.*
Ключові слова: *труба, пілігрімовий стан, пілігрімова головка, гільза, дорн, дорновий пристрій, металозберігаюча технологія, витратний коефіцієнт металу.*

Abstract. *Rolling of thin-walled pipes with D/S=12.5-40 on a pilgrim mill is accompanied by significant metal consumption in the process cut, the so-called pilgrim head, which significantly increases the metal consumption factor compared this other mills (continuous, automatic, etc.). The analysis of known methods for reducing the mass of the pilgrim head allowed us this propose a new combined metal-saving technologies of pilgrim rolling, which significantly reduce metal consumption. For the first time, a new metal-saving technology of partial rolling of the pilger head on thin-walled pipes with D/S=12.5-40 was proposed and substantiated, which allows the pipe this be removed from the mandrel using a gate valve. This will allow reducing the mass of the pilger head by up to 50%.*
Keywords: *pipe, pilgrim mill, pilgrim head, sleeve, mandrel, mandrel device, metal-saving technology, metal consumption coefficient.*

Стаття присвячується пам'яті відомого вченого, д.т.н., професора, зав. кафедрою технологічного проектування Національної металургійної академії України Друяна Володимира Михайловича (19.06.1932-22.04.2004)

Introduction. The main production of hot-rolled seamless pipes is focused on 3 types of hot-rolled pipes: with pilgrim, continuous and automatic mills.

Reducing metal consumption is relevant for all pipe rolling units, where metal losses are ≥15% of the usable rolled stock. This problem is especially relevant for TPA with pilgrim mills, which is associated with metal losses and technological scrap of the seed end and the pilger head, which constitute 6-10% and more of the mass of the initial billet. At the same time, the share of metal losses in the pilger head is 75-77%, and in the seed end 23-25% [1].

When using BLZ, the quality of the pilger head does not differ from the quality of the main part of the sleeve, which makes it necessary to reduce metal losses in both the pilger head and the seed. Metal losses in the pilger head and seed are primarily related to the peculiarities of the pilgering process in rolls of a periodic profile of caliber with large drafts, reaching ≤15 and the presence of support on the sleeve from the side of the feeding apparatus.

The issue of reducing metal losses in the seed is considered in works [2, 3] and others.

Ukrdipromez calculations, reducing the cut of the seed end of the sleeve and reducing the duration of the seeding regime can increase production by about 12 thousand tons per year on the TPA 5-12" NTZ (in the 1974 range) with an annual production volume of at least 330 thousand tons per year.

The main problem of pipe rolling on TPA with pilgrim mills is significant metal losses in the pilgrim head, which is 100-150 kg per ton of pipe more than on other TPAs.

Let us consider existing methods for reducing metal consumption in the pilger head [4].

Methods for reducing the weight of the pilgrim head. The problem of significantly reducing the weight of the pilgrim head has not been completely solved to date, especially for rolling thin-walled pipes with a ratio of D/S=12.5-40. A number of methods are known for reducing the weight of the pilgrim head, which are currently used mainly in rolling thick-walled pipes with D/S=6-12.5. The problem of reducing the weight of the pilgrim head when rolling thin-walled pipes is due to the features of the existing rolling technology and removing the rolling from the mandrel by a sliding device. In practice, the following methods are currently used: rolling sleeves end-to-end ; reducing undercuts pilger heads ; use of special calibration of the mandrel shank under the pilger head ; rolling of the pilger head on the free area of the mandrel.

Butt-rolling method of sleeves. This method consists of the sequential joining of an unrolled sleeve and the next sleeve on the mandrel. After rolling the pipe on the mandrel, the rear end of the sleeve remains unrolled. Then the mandrel is removed from the rolling mill and the next sleeve is fed onto a new mandrel, which is joined to the end of the previous sleeve, with subsequent rolling of the pilgrim head. In this case, the pilgrim head is completely rolled out, and the rear end of the pipe is cut to a length of 50-70 mm.

The features of the method of rolling sleeves butt - to-butt are: rolling the joint of sleeves with different metal temperatures: the first sleeve has a lower temperature compared to the second, which can lead to an excessive increase in metal pressure on the rolls; uneven feed from cycle to cycle leads to uneven metal pressure on the rolls; the possibility of uncoupling the sleeves when rolling them together, which is dangerous from the point of view of equipment strength; the need to use a special calibration of rolls designed for rolling thick-walled pipes, which is characterized by a decrease in the sharpness of the roll strikers and a more uniform distribution of metal pressure on the rolls along the length of the crimping section. When the "second" sleeve is delayed on the piercing mill due to the temperature difference between the two sleeves, the docking process proceeds unsatisfactorily due to strong cooling of the "first" sleeve.

Reducing defects Pilger heads. This method is used in conjunction with a mandrel ring design, which allows for more complete rolling. Pilger head without the mandrel ring getting into the rolls of the pilger mill. For trouble-free rolling of the head, a system for notifying the rolling operator about the extreme position of the sleeve with the mandrel in the rolls of the mill or a system for automatic feed shutdown is required.

Special calibration of the mandrel shank. The method consists in increasing the diameter of the mandrel under the pilger head. With an unchanged caliber size (distance in the gap between the rolls), this ensures a reduction in the volume and mass of the pilger head, and also increases the adhesion of the sleeve to the mandrel during seeding, which allows to intensify this process and reduce the cut of the seed ends of the pipes, as well as increase the critical rolling speed under the conditions of adhesion of the sleeve to the mandrel. The maximum increase in the diameter of the mandrel shank compared to its main part should not exceed the gap between the sleeve and the mandrel, which is due to the need for stable charging of the mandrel into the sleeve both in the pilger line and outside it.

Method of rolling a pilger head on a free section of the mandrel. After rolling the pipe on the mandrel, the rear end of the sleeve (pilger head) remains unrolled. The rolling process is stopped and the mandrel is pulled out of the roll by a value of l=1.2-1.5 m using a slide device. Then the pilger head is rolled out on the mandrel without support from the side of the feeding device. As a result, the pilger head is rolled into a pipe with a volume of $V_т$. Further pulling of the mandrel from the pipe is carried out using the same slide device. The length l_m of the pipe obtained from the pilger head is determined from the equality of the volumes of the pilger head V_{nr} and sections $V_т$. In this case, this method is mainly used for rolling the pilger head on the last sleeve in the batch, the rest are rolled using the butt method. In the process of rolling the pilger head, a moment comes when an increase in the feed m leads to a decrease in the rollback and disruption of the synchronization of the process as a result of a sharp decrease in the cross-sectional area of the workpiece.

Development of rolling technology To ensure a reduction in the mass of the pilger head, it is advisable to carry out a final rolling the pilgrim's head is practically without a cylindrical section [4].

In practice, it is known to use rings 1 made of carbon steel when rolling high-alloy thick-walled pipes 3, which are located on the mandrel between the mandrel ring 2 and the rear end of the sleeve (Fig. 1 a). This allows for complete rolling Pilger head, with removal of carbon ring 1.

One of the most frequently used methods in practice to reduce the mass of the pilger head when rolling thin-walled pipes is the use of special mandrels rings, allowing for more complete rolling When rolling a small batch of pipes from high-alloy steel grades, the rear end of the sleeve 1 is rolled out using a disposable special mandrel ring 2 (Fig. 1).

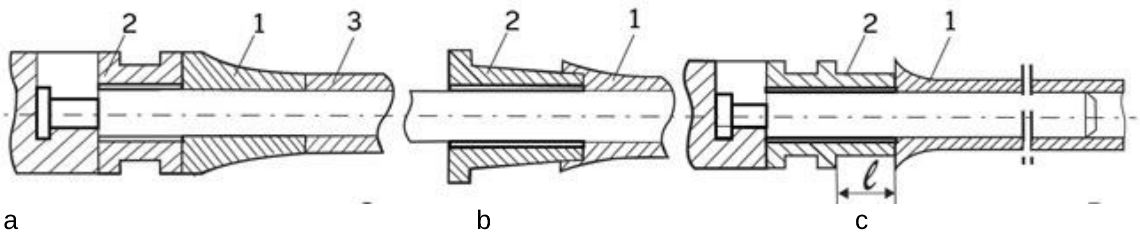


Fig. 1. Methods (a, b and c) of more complete rolling Pilger heads: 1 – pilger head, 2 – mandrel ring, 3 – alloy steel pipe

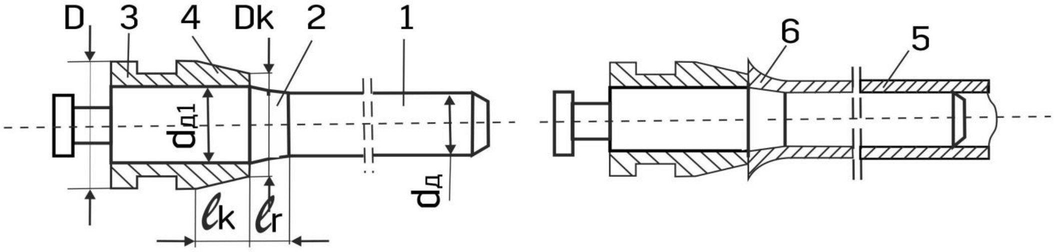
To conduct industrial research on rolling pipes measuring 245×10 mm on a 5-12" TPA, PJSC "Interpipe NTZ" proposed a special mandrel ring for finishing. pilger heads without a cylindrical section (Fig. 1). Special mandrel ring 2 has an additional cylindrical section with a length of l_1=150 mm with an outer diameter equal to ~0.8 of the sleeve diameter D_r. As a result of a comparative analysis of

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

the rolling of pipes measuring 245x10 mm with ordinary and finished It was found that the weight reduction of pilger heads when rolling using the new technology is approximately 30 kg per sleeve or 9-14 kg per ton.

Main part. Based on the conducted industrial research, we have proposed two new technologies that allow more effectively reducing the mass of the pilger head by combining solutions to eliminate defects and reduce the mass of the profile part of the pilger head.

Combined technologies for reducing pill head [5]. The first technology involves the use of an improved design of the mandrel device of the pilgrim mill (Fig. 2), which has the following differences: the mandrel ring 3 on the sleeve side contains an additional section in the form of a truncated cone 4 with a decrease in the outer diameter in the direction of the sleeve, and the mandrel section under the pilger head is made conical with a maximum diameter $d_{Д1} = d_Д + \Delta$ [6].



a b

Fig. 2. New mandrel device (a) and rolled pipe (b): 1 – mandrel; 2 – conical shank; 3 – mandrel ring; 4 – front end of the ring; 5 – pipe; 6 – pilger head

This design of the mandrel device ensures a reduction in the mass of the pilger head both by reducing the sleeve ΔG_1 undercuts and by increasing the diameter of the mandrel under the pilger head ΔG_2.

The results of the calculations showed a significant reduction in the mass of the pilger head both by eliminating the imperfections (diagram 1) and by increasing the diameter of the mandrel under the pilger head (diagram 2). The total reduction in the mass of the pilger head reaches 22% (Fig. 3).

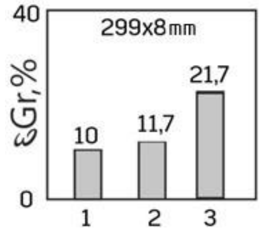
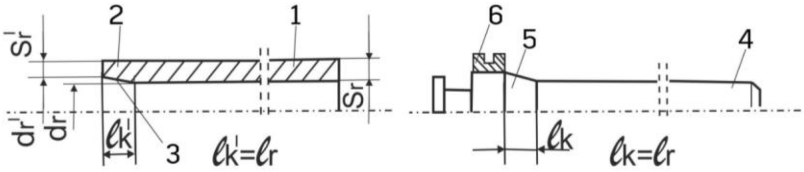


Fig. 3. Savings in the mass of the pilger head εGr when rolling according to the first technology at L_n=30 mm and Δ=20 mm: 1 – ΔG_1 (L_n=0); 2 – ΔG_2 ($dg_1 > dg$);
3 – $\varepsilon Gr = -\Delta G_1 + \Delta G_2$

The second technology [7, 8] is that the blank is pierced with a thinning of the rear end of the sleeve from the side of the inner diameter (Fig. 4 a), and the sleeve is rolled into a rough pipe with profile rolls on a mandrel (Fig. 4 b), the generatrix of the shank of which under the pilgrim head and the generatrix of the rear end of the sleeve with an increased inner diameter are congruent and made in a straight line (Fig. 5). The amount of thinning of the sleeve wall varies within 10-30%. The angle of inclination β_1 of the generatrix of the conical shank of the mandrel is determined by the expression:

$$\beta_1 = arct\frac{\Delta/_2 + \Delta S_Г}{l_Г}, \qquad (1)$$

$$\ell_к = \frac{\ell_г \cdot \Delta S_г}{\frac{\Delta}{2} + \Delta S_г} \qquad (2)$$



a b

Fig. 4. New technology with prepared rear end of the sleeve: 1 – sleeve; 2 – rear end of the sleeve; 3 – conical section of the sleeve; 4 – mandrel; 5 – conical shank; 6 – mandrel ring

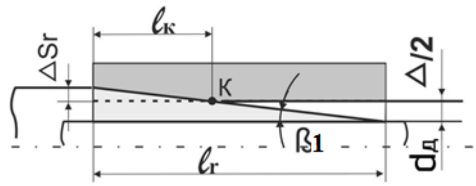


Fig. 5. Determination of the parameters of the prepared rear end of the sleeve

Fig. 6 shows a diagram of the mandrel shank under the pilger head. for three options: option 1 – mandrel diameter dq, determined from the rolling table for a given pipe size; option 2 with diameter $d_{q1} = d_q + \Delta$, where Δ – the gap between the sleeve and the mandrel before rolling; option 3 – with the maximum mandrel diameter

$d_{q2} = d_q + \Delta + 2\Delta Sr$,

where ΔSr– the thinning of the sleeve wall at the rear end. Metal savings are determined by the difference in the volumes of the mandrel shanks for different options 1, 2 and 3 (Fig. 6).

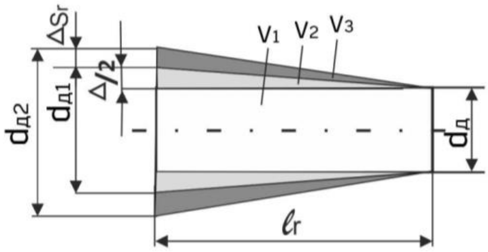


Fig. 6. Scheme for determining the metal savings of the pilger head

From the above analysis it follows that when rolling thin-walled pipes, the new technology is quite effective in terms of reducing the mass of the pilger head, which reaches 29% with an increase in the diameter of the mandrel shank both due to the gap Δ and the permissible thinning of the sleeve wall εSr (Fig. 7).

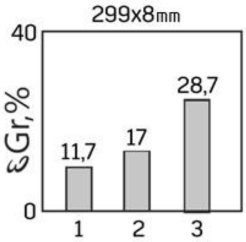


Fig. 7. Reducing the mass of the pilger head εGr:
1 – (V_2-V_1); 2 – (V_3–V_2); 3 – (V_3–V_1) at Δ=20 mm and εSr=20%

New metal-saving technology for rolling the pilger head. For thin-walled pipes with D/S=12.5-40, we have developed a new technology [9], which consists in partial rolling of the pilger head due to the impossibility of removing the thin-walled pipe from the mandrel using a sliding device.

According to the new technology, the pilger head in Fig. 8 is represented as composed of two parts 1 and 2 (Fig. 9), while

$$\ell_r = \ell_{rk} + \Delta\ell_r \qquad (3)$$

$$\Delta\ell_r = \ell_r \frac{\mu_\kappa - 1}{\mu_s - 1} \qquad (4)$$

where $\mu_k = S_r/S_к$, $\mu_s = S_r/S_к$, ℓ_r is the length of the pilger head before rolling, $\ell_{rк}$ and $\Delta\ell_r$ are the unrolled and rolled parts of the head, S_r is the thickness of the sleeve wall, $S_n$is the thickness of the pipe wall on the pilgrim mill, $S_к$ is the “critical” wall thickness at the end of the partially rolled pilger head.

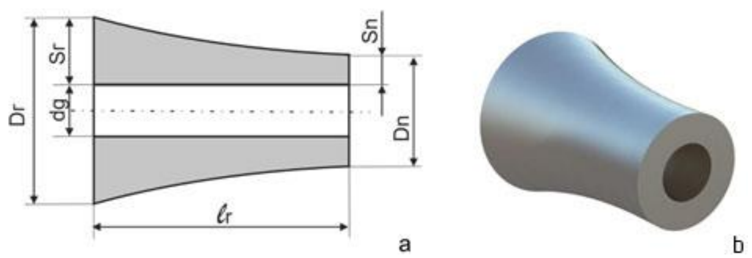


Fig. 8. Longitudinal section (a) of the pilger head and its three-dimensional image (b)

The division of the pilger head into two parts 1 and 2 (Fig. 9) is carried out in such a way that the wall thickness $S_к$, which we have called "critical", allows the mandrel to be removed from the rolling mill using a sliding device, which can be determined experimentally.

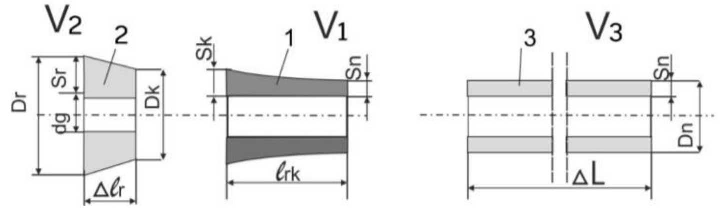


Fig. 9. New technology for rolling a pilger head on the free section of a mandrel for pipes (D/S=12.5-40)

Part 1 of the pilger head with a length ℓ_{rk} remains after its partial rolling, while the length of the head ℓ_r decreases by the value $\Delta\ell_r$.

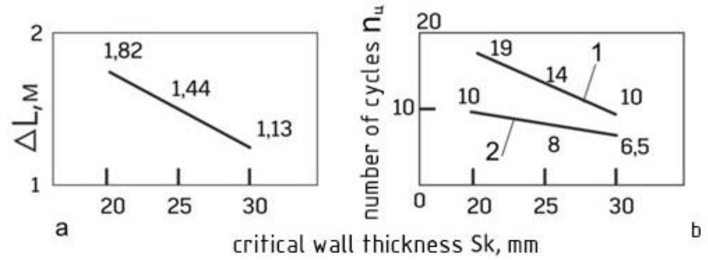


Fig. 10. Change $\Delta L = f(S_k)$ – a and $n_ц$=$f(S_k)$ – b when rolling pipes 299×12 mm:
1 - $m = m_y$; 2 - m at $V = const$

The required number of rolling cycles of the second part of the head is determined by the formula

$$N=\frac{\Delta\ell_r}{m}, \quad (5)$$

where m– is the feed rate in steady state (feed rate $m = m_Y$). The required number of rolling cycles n $_Y$ in variable feed rate from the condition $V_n = const$is determined by the formula:

$$n_ц = \frac{\Delta l_r}{m l_n \mu_k}\left(1 - \frac{1}{\mu_k}\right), \quad (6)$$

which reduces the number of rolling cycles and their duration.

The rolled part 2 of the head increases the length of the rough pipe by the value ΔL, while the elongation $\Delta L$is determined from the equality of volumes $V_2 = V_3$ (Fig. 9):

$$\Delta L = \frac{4V_2}{\pi(D_n^2 - d_q^2)} \quad (7)$$

Fig. 10,a for a 299×12 mm pipe shows the change ΔL depending on the value of the critical wall thickness $S_к$. An increase $S_к$ leads to a decrease ΔL, due to a decrease in the volume V_2.

Fig. 10,b for the same pipe size shows the change in the number of cycles n_{ts} of rolling part 2 of the head with a length $\Delta\ell_r$ depending on $S_к$ the two modes (1 and 2). The first mode is characterized by a constant feed rate $m = m_y$, where $m_y$is the feed rate in a steady state. The second mode is characterized by a variable feed rate with its increase as the head is rolled to maintain the condition V_n=const, which allows to reduce $n_ц$ by 1.5-1.9 times and accordingly the duration of the rolling process. The decrease in n $_ц$ depending on $S_к$is associated with the decrease in $\Delta\ell_r$.

Conclusions

Pipe rolling on TPA with pilgrim mills has significantly higher metal losses in the technological cut compared to other units (continuous, automatic and others), which is due to the presence of the so-called pilgrim head. This is an important reserve for reducing the metal consumption coefficient on the pilgrim mill and is especially relevant and cost-effective when using a continuous billet of circular cross-section as the starting material.

The analysis of known methods for reducing the pilger head allowed us to propose two new combined metal-saving technologies that do not require significant equipment reconstruction.

The research of the first new technology on the TPA 5-12" of JSC "Interpipe NTZ" using a special mandrel device allowed to achieve metal savings of about 30 kg per sleeve. The second new technology reduces the mass of the pilger head by up to 29% due to the use of a sleeve with a thinned rear end and a corresponding increase in the taper of the mandrel shank under the pilger head.

a new metal-saving technology for rolling a pilger head on the free part of the mandrel has been proposed and substantiated, which involves partial rolling of the head on thin-walled pipes (D/S=12.5-40), which will allow reducing its mass by up to 50%.

Бібліографічний опис

1. Совершенствование процессов горячей прокатки труб / В.Ф. Балакин, Ю.С. Кривченко, В.В. Перчаник, Г.Н. Кущинский, Ю.Д. Угрюмов, Д.Ю. Угрюмов. *Сталь*. 2006. №9, С. 73-79.
2. Особенности затравочного режима горячей пилигримовой прокатки труб и пути его совершенствования / Балакин В.Ф., Угрюмов Д.Ю., Потемкин О.В., Угрюмов Ю.Д. *Черная металлургия: бюл. НТИ*. 2011. №11, С. 53-56.
3. Балакин В.Ф., Угрюмов Ю.Д., Угрюмов Д.Ю. Методы подготовки передних концов гильз перед прокаткой труб. *Теория и практика металлургии*. 2012. №1-2, С. 16-20.
4. Балакин В.Ф., Угрюмов Ю.Д., Угрюмов Д.Ю. Пути снижения массы пильгерголовки при горячей прокатке труб. *Теория и практика металлургии*. 2012. №1-2, С. 32-36.
5. Балакин В.Ф., Стасевский С.Л., Угрюмов Ю.Д. Новые металлосберегающие технологии прокатки труб на пилигримовых агрегатах. *Системные технологии*. – 2020. - №6 (131), С. 149-162.
6. Дорновий пристрій пілігрімового стану: пат. 91209 Украна: МПК B21B 25/00, B21B 21/00 (2014.01). №u201400695; заявл. 24.01.2014; опубл. 25.06.2014, Бюл. №12. 8 с.
7. Спосіб прокатки труб на агрегаті з пілігрімовим станом: пат. 88265 Україна: МПК B21B 21/00 (2014.01). №u201311005; заявл. 16.09.2013; опубл. 11.03.2014, Бюл. №5. 6 с.
8. Спосіб прокатки труб на трубопрокатному агрегаті з пілігрімовими станами: пат. 88524 Україна: МПК B21B 21/00 (2014.01). №u201309695; заявл. 05.08.2013; опубл. 25.03.2014, Бюл. №6. 8 с.
9. Спосіб гарячої пілігрімової прокатки тонкостінних труб: пат. 129752 Україна, МПК B21B 21/00 (2018.01). №u201805077; заявл. 08.05.2018; опубл. 12.11.2018; Бюл. №21. 9 с.

References

10. Balakin, V. F. Krivchenko, Yu. S., Perchanik, V. V., Kuschinskiy, G. N., Ugryumov, Yu. D., & Ugryumov, D. Yu. (2006). Sovershenstvovanie protsessov goryachey prokatki trub. *Stal*, 9, 73-79.
11. Balakin, V. F., Ugryumov, D. Yu., Potemkin, O. V., & Ugryumov, Yu. D. (2011). Osobennosti zatravochnogo rezhima goryachey piligrimovoy prokatki trub i puti ego sovershenstvovaniya. *Chernaya metallurgiya: byul. NTI*, 11, 53-56.
12. Balakin, V. F., Ugryumov, Yu. D., & Ugryumov, D. Yu. (2012). Metodyi podgotovki perednih kontsov gilz pered prokatkoy trub. *Teoriya i praktika metallurgii*, 1-2, 16-20.
13. Balakin, V. F., Ugryumov, Yu. D., & Ugryumov, D. Yu. (2012). Puti snizheniya massyi pilgergolovki pri goryachey prokatke trub. *Teoriya i praktika metallurgii*, 1-2, 32-36.
14. Balakin, V. F., Stasevskiy, S. L., & Ugryumov, Yu. D. (2020). Novyie metallosberegayuschie tehnologii prokatki trub na piligrimovyih agregatah. *Sistemnyie tehnologii*, 6 (131), 149-162.
15. Dornoviy pristrIy pIlIgrImovogo stanu: (Patent No. 91209 Ukraine) (2014). Bulletin No 12. 8 p.
16. SposIb prokatki trub na agregatI z pIlIgrImovim stanu: (Patent No. 88265 Ukraine) (2014). Bulletin No 5. 6 p.
17. SposIb prokatki trub na truboprokatnomu agregatI z pIlIgrImovimi stanami: (Patent No. 88524 Ukraine) (2014). Bulletin No 6. 8 p.
18. Sposib hariachoi pilihrimovoi prokatky tonkostinnykh trub: (Patent No. 129752 Ukraine) (2018). Bulletin No 21. 9 p.

Надіслано до редакції / Received: 12.04.2025
Прийнято до друку / Accepted: 30.08.2025