https://doi.org/10.15407/scine19.06.040

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# PRODUCTION EFFICIENCY OF RIBBON-TYPE SECTIONS BY THE DRAWING METHOD IN DOUBLED-ROLL ROLLER DIES

***Introduction.*** *The process of drawing is used to produce a wide range of fashion sections of complex configuration, including thin-walled, ribbon-type, and periodical section profiles.*

***Problem Statement.*** *Because of the complexity of steel ribbon production with flattening machines and high capital intensity of flattening production, since the second half of last century, the manufacturers have been trying to use alternative methods of flattening, in particular drawing in monolithic and double-roll roller dies.*

***Purpose.*** *The purpose of this research is to establish regularities of the influence of different sizing systems and process parameters on the regularities of shape change and energy-force parameters of the drawing process in double-roll roller dies and to determine the most effective schemes for achieving the maximal metal expansion while producing ribbon-type sections.*

***Material and Methods.*** *The materials used are as follows: round billets of 5.9 mm in diameter, made of steel brand St.08A; the methods used are as follows: cool billet processing with varying crimping in the double-roll roller die with different gauge systems.*

***Results.*** *The regularities of metal shape change and energy-force parameters alternation of the ribbon-type section drawing process in doubled double-roll roller dies by using different gauge systems have been established. Marginal conditions of the deformation in double-roll dies, which provide stable and smooth drawing process according to the criterion of deformed metal safety factor, have been studied experimentally. The most efficient gauge system of doubled roller dies, which provides maximal metal expansion while producing ribbon-type sections have been determined experimentally.*

***Conclusions.*** *It has been proposed to use the metal drawing technology in doubled double-roll roller dies with "bullhead-accelerated gauge" system while producing ribbon-type sections with a width-to-thickness ratio of more than 2, for achieving the maximal metal expansion per transition. In addition, such a process is energy efficient as the force of pulling through the roller die decreases.*

*Keywords: drawing, efficiency, steel ribbons, double-roll roller dies/dies.*

Citation: Razdobreev, V. G., Kluychnikov, K. Yu., Leschenko, A. I., Palamar, D. G., and Vorobei, S. O. (2023). Production Efficiency of Ribbon-Type Sections by the Drawing Method in Doubled-Roll Roller Dies. *Sci. innov.*, 19(6), 40—50. https://doi.org/10.15407/scine19.06.040

The use of high-precision sections in modern engineering and instrumentation is of utmost importance in terms of improving the quality of produced ware and considerably reducing the cost of its production [1–3]. Thus, for example, the use of steel piston rings instead of conventional cast iron ones allows considerably increasing the machine and aggregate motor service life, simplifying and automating the process of ring production to a great extent as well as reducing laborious and ecologically harmful foundry production [4, 5].

At present, in Ukraine, high-precise section production is extremely limited, and that of steel cold-formed ribbon is practically absent, in general. Production of such ware that is in high demand for a wide size and brand assortment are relatively small [6, 7].

Creating a specialized production of high-precision and steel ribbon-type sections in these conditions (the equipment cost is up to USD 20 thousand per a ton) is economically impractical and the import orientation of such production makes the economic and technological safety of the above fields of Ukraine's economy dependent on foreign suppliers.

The most efficient of the well-known alternative methods for high-precision section and flattened ribbon production, both technologically and economically, is considered metal drawing in roller dies in cold state. Unlike drawing in monolithic roller dies when the die is still, drawing in roller dies is made when the rolls rotate freely around their axes, which makes this process similar to rolling. However, due to the presence of pulling force with high deformation unevenness when transitioning from a round billet to a rectangular or fashion section by this method, it is considered impractical to produce strip sections with the width-to-thickness ratio of more than 1.5—2.0 [1—3, 6, 8]. It is connected with the destruction of their side edges.

Iron and Steel Institute of Z. I. Nekrasov of the National Academy of Sciences of Ukraine (ISI NASU), traditionally deals with fundamental and applied research of the drawing process in roller dies to produce ribbon-type sections. The results of this research have allowed developing and putting into production the flattened ribbon drawing technology to produce piston rings as well as developing and working out the technology of metal preparation for cold work in simple and complex profile sections in conditions of unspecialized types of production [4, 5, 9—12].

Both the drawing and flattening processes are also applied to produce various size range ribbons, including the narrow ones. In practice, accelerated gauges are used to produce narrow ribbons for the ribbon width increase in relation to the initial billet diameter. At the same time, the actual task is the use of such a gauge system and processing technological modes that prevent dangerous high tensions stretching the ribbon edge due to uneven deformation from appearing [10—12] as well as from its further destruction.

The goal of the experimental research is the establishment of regularities of the influence of different sizing systems and technological parameters on the regularities of shape change and energy-force parameters of a drawing process in doubled double-roll dies as well as the determination of the most efficient schemes to achieve the maximal metal expansion.

The experimental research was carried out in several stages.

At the first stage, the initial round billet deformation in double-roll die with different values of relative crimping per transition has been studied.

According to the results of the experimental research, the relative crimping per transition, at which the maximal metal expansion is achieved, has been determined.

At the second research stage, the initial round billet is deformed in the doubled double-roll die with such a total crimping per transition, according to which the first stage maximal expansion is achieved, as well as with different breaking with crimps between two double-roll dies. The gauge system "bullhead — bullhead" is employed.

While conducting all the types of research on the initial round billet deformation in all the ty-

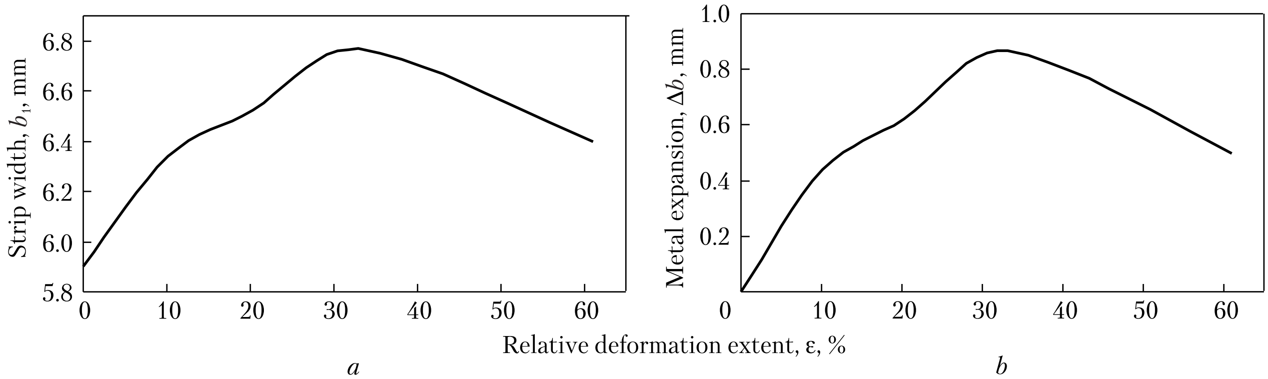


***Fig. 1.*** Changes in the shape and deformation parameters during crimping the initial 5.90 mm diameter round billet in double-roll die: *a* — strip width after deformation; *b* — metal expansion

pes of roller dies the following parameters are taken as the initial data:

- the initial billet diameter is 5.90 mm;
- the initial billet material is steel brand St.08A.
- the diameter of bullhead rolls is 145 mm.

The steel chemical structure and mechanical properties of the billet are given in Table 1.

The research has been carried out with the use of finishing stand of drawing machine UDZSA 2500/5 at a maximally acceptable pulling force of 25000 N, in the laboratory of Iron and Steel Institute of Z. I. Nekrasov of the National Academy of Sciences of Ukraine (ISI NASU).

The crimping modes during the initial round billet deformation in the double-roll die are given in Table 2.

Figure 1 features changes in the shape parameters (the strip width after deformation $b_1$) and deformation (metal expansion $\Delta b = b_1 - b_0$, which shows an increase in the ribbon width after the deformation, namely the difference between the initial $b_0$ and the final $b_1$ ribbon width) due to the relative deformation during the crimping of initial 5.90 mm diameter round billet in a double-roll die.

According to the analysis of Fig. 1a, it has been established that the maximal strip width of approximately 6.8 mm is observed at the relative deformation of nearly 30% per transition. As the relative deformation per transition further increases in the range of 40—60%, the metal expansion $\Delta b$ decreases from 0.88 to 0.5 mm (Fig. 1, *b*). It can be explained by the fact that as the crimping per transition increases, the metal pulling tension σpull increases as well. Upon reaching the fluidity limit σт ($\sigma_{pull.}/\sigma_e = 1$) by the pulling tension,

*Table 1.* **The Steel Chemical Structure and Billet Mechanical Properties**

| Content of chemical elements, % | | | | | Mechanical properties | | |
|---|---|---|---|---|---|---|---|
| C | Mn | Si | S | P | $\sigma_e$, N/mm$^2$ | $\sigma_m$, N/mm$^2$ | $\delta_5$, % |
| 0.09 | 0.42 | 0.028 | 0.023 | 0.010 | 480 | 518 | 20 |

*Table 2.* **The Modes of Crimping the Initial 5.90 mm Diameter Round Billet in Double-Roll Die**

| | | | | | | |
|---|---|---|---|---|---|---|
| Relative crimping per transition, ε,% | 10 | 20 | 30 | 40 | 50 | 60 |
| The ribbon height after crimping, $h_1$, mm | 5.30 | 4.70 | 4.10 | 3.50 | 2.90 | 2.30 |

the metal deformation proceeds mainly towards the extraction, instead of expanding (the extraction effect).

Figure 2 shows changes in the force parameters and marginal conditions of the deformation process of the initial 5.90 mm diameter round billet in a bullhead double-roll die.

As a result of the analysis of Fig. 2, *a*, it has been determined that with an increase in the relative metal crimping per transition from 10 to 60%, the metal pulling tension increases starting with approximately 500 N/mm$^2$ up to the metal fluidity limit and reaches it with a relative crimping per transition of around 50% that corresponds to approximately 700 N/mm$^2$. Further increase in the pulling tension leads to the fact that the initial round billet deformation process in the roller die with a bullhead proceeds without metal expansion, which can also cause metal breakout in the deformation cell.

Figure 2, *b* features the change of safety factor $K^* = \sigma_e/\sigma_{pull.}$, which guarantees a stable process without a breakout and geometrical section size violation [13], while crimping the initial 5.90 mm diameter round billet in a roller die with a bullhead, depending on the relative deformation per transition.

According to the analysis of chart represented in Fig. 2, *b*, it has been established that during the deformation of the initial 5.90 mm diameter round billet, the safety factor equal to 0.625 runs out at the relative deformation of approximately 40%. Thus, the operating crimping per transition range, at which the deformation process will continue steadily without destruction has been determined as equal to 5—35%.

Figure 2, *c* shows the changeable metal pulling force during the deformation of the initial 5.90 mm diameter round billet in a double-roll die with a bullhead, depending on the relative single crimping per transition. It has been determined that the pulling force in this case of deformation has been recorded in the range of 1000 to 14000 N and it does not exceed an acceptable pulling force for machine UDZSA 2500/5 on the entire range of single crimping of 10 to 60%.

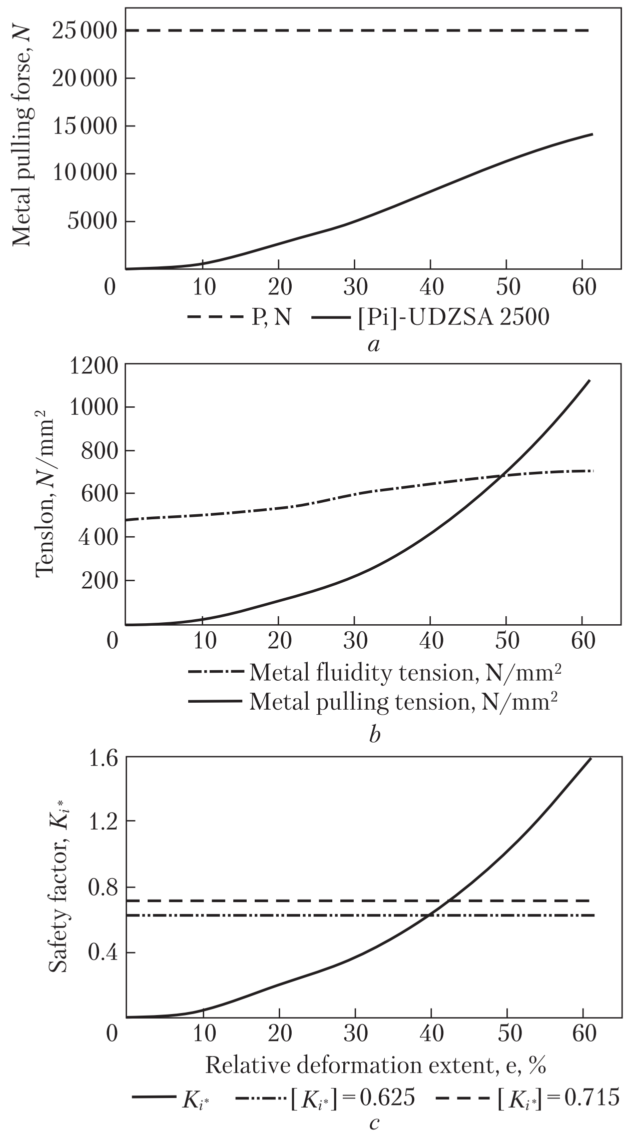


***Fig. 2.*** Changes in the force parameters and marginal conditions of the deformation of initial 5.90 mm diameter round billet in a bullhead roller die, depending on the relative deformation: *a* — pulling tension and metal fluidity limits; *b* — safety factor; *c* — metal pulling forces

It follows from the above that for this type of deformation of the initial 5.90 mm diameter round billet in a double-roll die with a bullhead, the operating crimping range, at which the steadiness of metal expansion and metal deformation process is observed, makes up 5—30%. The maximal metal expansion during the deformation of initial

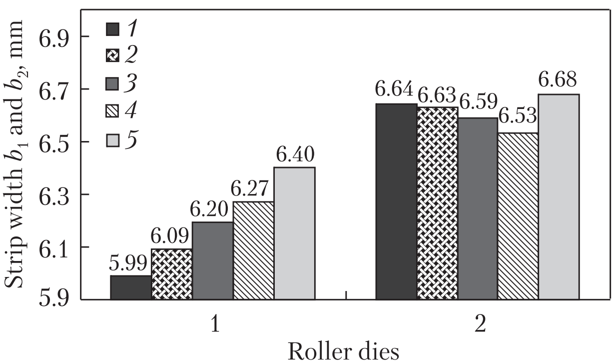


***Fig. 3.*** Changes in the strip width during the experimental research of crimping the initial 5.90 mm dimeter round billet in doubled double roll die with "bullhead — bullhead" gauge system

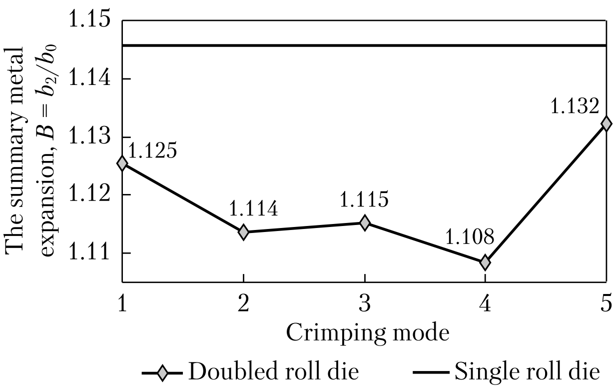


***Fig. 4.*** The comparison of the total metal expansion after the deformation of initial 5.90 mm diameter round billet in the doubled double-roll die and in the second separate double-roll die with a bullhead

5.90 mm diameter round billet is equal to approximately 0.9 mm, with the relative single deformation being nearly 30%.

Based on the results obtained, the second stage of research deals with studying the deformation of initial 5.90 mm diameter round billet in a doubled double-roll die with "bullhead — bullhead" gauge system, at a total crimping $\varepsilon_\Sigma$ equal to 30%, with different variants of crimping distribution between two double-roll dies (Table 3).

At the same time, with the purpose of evaluating the efficiency of scheme of the deformation of initial 5.90 mm diameter round billet in a doubled double-roll die with "bullhead — bullhead" gauge system, we have made the experimental research according to the classical scheme of the deformation of initial 5.90 mm diameter round billet: separate deformation in the first double-roll die with a bullhead and separate deformation in the second double-roll die with a bullhead. During the additional experiments, the total crimping $\varepsilon_\Sigma$ after the deformation in the separate first and the second roller dies with a bullhead makes 30%, with the strip width $b_2$ after the crimping in the second separate roller die amounting to 6.76 mm.

The results of drawing the initial 5.90 mm diameter round billet in the doubled double-roll die with "bullhead — bullhead" gauge system, according to the modes shown in Table 3 are presented in Fig. 3.

As a result of the chart analysis represented in Fig. 3, it has been determined that the maximal output strip width $b_2$ from the second doubled double-roll die is received during the deformation of initial 5.90 mm diameter round billet in crimping mode 5 and it makes up 6.68 mm.

The efficiency of the metal deformation process in a doubled double-roll die with the "bullhead — bullhead" gauge system at different crimping modes

*Table 3.* **The Modes of Crimping the Initial 5.90 mm Diameter Round Billet in Doubled Double-Roll Die with "Bullhead — Bullhead" Gauge System at the Second Stage of Experimental Research**

| Total crimping, $\varepsilon_\Sigma$, % | 30 | | | | |
|---|---|---|---|---|---|
| Crimping mode | 1 | 2 | 3 | 4 | 5 |
| Relative crimping in the 1st roller die, $\varepsilon_1$, % | 5 | 10 | 15 | 20 | 25 |
| Relative crimping in the 2nd roller die, $\varepsilon_2$, % | 25 | 20 | 15 | 10 | 5 |
| Ribbon height after the 1st roller die, $h_1$, mm | 5.60 | 5.30 | 5.00 | 4.70 | 4.40 |
| Ribbon height after the 2nd roller die, $h_2$, mm | 4.10 | 4.10 | 4.10 | 4.10 | 4.10 |

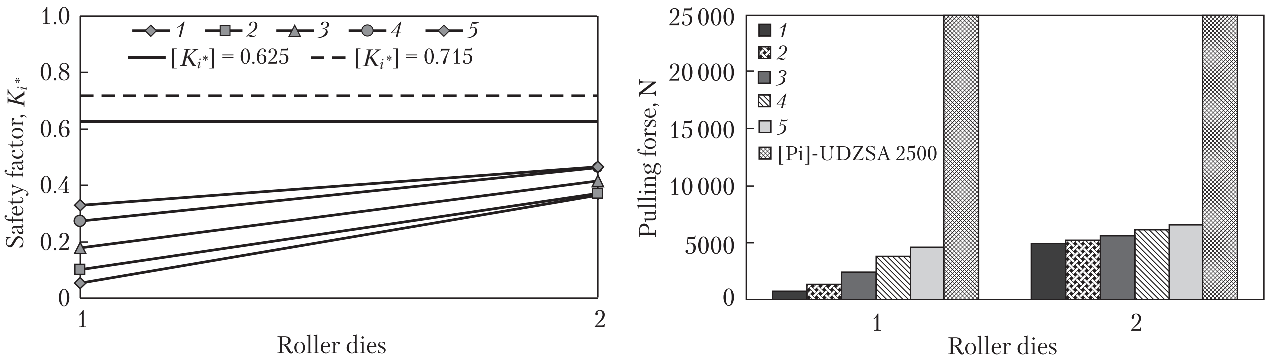


***Fig. 5.*** The height of output strip from the doubled double-roll die and from the second double-roll die: *a* — safety factor; *b* — pulling force

as compared with the deformation process according to the classical scheme (separate drawing in the first and in second double-roll dies) has been evaluated with the use of the calculated value of total metal expansion $K_{Btotal}$ = = $b_2/b_0$ (Fig. 4).

The strip width $b_2$ during the metal deformation in a doubled double-roll die with "bullhead — bullhead" gauge system at different crimping modes *1—5* changes from 6.53 to 6.68 mm (see Fig. 3). The strip width $b_2$ after the billet deformation in the second separate double-roll die with a bullhead made up 6.72 mm. Thus, the strip width $b_2$ achieved at modes *1—5* during the metal deformation in a doubled double-roll die with "bullhead — bullhead" gauge system is less than the strip width $b_2$ obtained after the initial round billet deformation in the second separate double-roll die with a bullhead. The comparison of the total metal expansion $K_{Btotal}$ after the deformation of initial 5.90 mm diameter round billet in a doubled double-roll die with the "bullhead — bullhead" gauge system and in the second separate double-roll die with a bullhead has shown that the total metal expansion after the metal deformation in a doubled double-roll die with the "bullhead — bullhead" gauge system at modes *1—5* is less than the total metal expansion after the initial round billet deformation in the second separate double-roll die with a bullhead (Fig. 4).

We have evaluated different strip width $b_2$ (the width varies within 6.53—6.68 mm) during the metal deformation in a doubled double-roll die with gauge system "bullhead — bullhead" at different crimping modes (modes *1—5*) as compared with the strip width ($b_2$ = 6.72 mm) after the billet deformation in the second separate double-roll die with a bullhead. The total metal expansion ($K_{Btotal}$ = $b_2/b_0$) or the strip width obtained after the initial round billet in a doubled double-roll die with the "bullhead — bullhead" gauge system at modes *1—5* is less than the strip width obtained after the initial round billet deformation in the second separate double-roll die with a bullhead (Fig. 4).

Accordingly, it can be concluded that the use of doubled double-roll die with the "bullhead — bullhead" gauge system is inefficient for achieving the maximal metal expansion while producing ribbon-type sections with the width-to-thickness ratio more than 2.

Figure 5 features changes in the marginal conditions of the deformation of initial 5.90 mm diameter round billet in doubled double-roll die with "bullhead — bullhead" gauge system as compared with the deformation process separately in the first and in the second double-roll dies with a bullhead.

It has been established that the safety factor during the deformation of initial 5.90 mm diameter round billet in doubled double-roll die with "bullhead — bullhead" gauge system at all the crimping modes is less than the safety factor during the deformation separately in the first and in the second

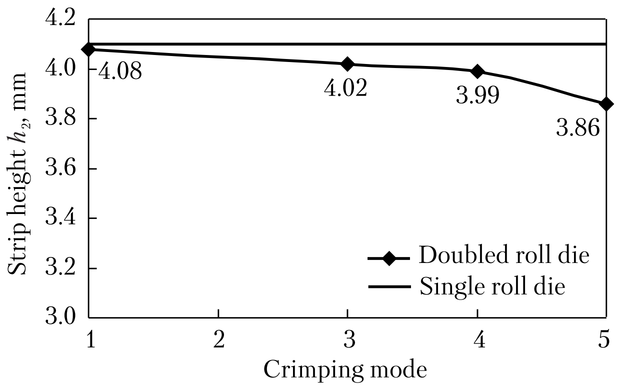


***Fig. 6.*** The strip height on its way out of the doubled double-roll die and out of the second double-roll die

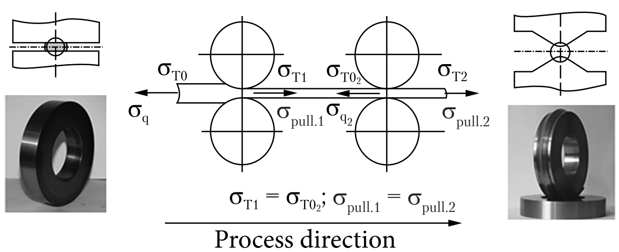


***Fig. 7.*** Deformation scheme of the initial 5.90 mm diameter round billet in the doubled double-roll die with "bullhead – accelerated gauge" system

double-roll dies with a bullhead. It has been proven that the safety factor of the metal deformation in the doubled double-roll die with "bullhead — bullhead" gauge system at all the crimping modes does not run out as compared with the classical billet deformation process in separate double-roll dies with a bullhead. It can be explained by the fact that in the second doubled double-roll die, the following process parameters influence the stability of the metal deformation process continuation: the back tension created in the first doubled double-roll die and the relative crimping in the second doubled double-roll die. It has been established that the pulling force for all crimping modes does not exceed the maximal acceptable pulling force for machine UDZSA 2500/5 (Fig. 5, *b*).

The results of the experimental research on crimping the initial 5.90 mm diameter round billet in the doubled double-roll die with "bullhead — bullhead" gauge system have shown that as the crimping increases in the first double-roll die, on the way out of the second double-roll die, there is observed the effect of high-altitude metal tightening. This effect is illustrated in Fig. 6.

Due to the fact that the use of doubled double-roll die with "bullhead — bullhead" gauge system is inefficient for achieving the maximal metal expansion while producing the ribbon-type sections with a width-to-thickness ratio more than 2, it has been decided to use "bullhead — accelerated gauge" system in the doubled double-roll die while conducting the experimental research on the initial 5.90 mm diameter round billet.

The deformation scheme and modes of the initial billet crimping in the doubled double-roll die with "bullhead — accelerated gauge" system are presented in Fig. 7 and in Table 4, accordingly.

It should be noted that during the research on the initial round billet deformation in the doubled double-roll crusher with "bullhead — accelerated gauge" system, the relative crimping in the first double-roll die made up no less than 15%. It is connected with the fact that for the stable con-

*Table 4.* **Modes of Crimping the Initial 5.90 mm Diameter Round Billet in Doubled Double-Roll Die with "Bullhead — Accelerated Gauge" System in the Experimental Research**

| Total crimping, $\varepsilon_\Sigma$,% | 30—40 | | | | | |
|---|---|---|---|---|---|---|
| Crimping mode | 1 | 2 | 3 | 4 | 5 | 6 |
| Relative crimping in the 1st roller die $\varepsilon_1$,% | 15 | 15 | 15 | 20 | 20 | 20 |
| Relative crimping in the 2nd roller die $\varepsilon_2$,% | 15 | 20 | 25 | 10 | 15 | 20 |
| Strip height after the 1st roller die $h_1$, mm | 5.00 | 5.00 | 5.00 | 4.70 | 4.70 | 4.70 |
| Strip height after the 2nd roller die $h_2$, mm | 4.25 | 4.00 | 3.75 | 4.20 | 4.00 | 3.80 |

tinuation of the metal deformation process in the accelerated gauge, it is necessary to create an appropriately sized flat ground (Fig. 7 on the left) during the initial round billet deformation in the first double-roll die.

Figure 8 shows changes in the strip width during the experimental research on crimping the initial 5.90 mm diameter round billet in the doubled double-roll die with "bullhead — accelerated gauge" system.

According to the results in Fig. 8, it can be seen that as the total crimping per transition in doubled double-roll die with the "bullhead — accelerated gauge" system increases, so does the strip width. It has also been established that the pulling force during the deformation in the doubled double-roll die with "bullhead — accelerated gauge" system at all the crimping modes made up approximately 5500 N and does it not exceed the maximal acceptable pulling force for machine UDZSA 2500/5.

Figure 9 features the comparison of the metal expansion during the initial round billet crimping by three stages.

The comparative analysis of the three schemes of initial round billet deformation has shown the following:

- during the initial billet deformation in the separate double-roll die with a bullhead after the relative crimping per transition equal to 30%, the metal expansion decreases;
- the initial billet crimping in the doubled double-roll die with "bullhead — bullhead" gauge system has shown the inefficiency of the "bullhead — bullhead" gauge system, as in the entire crimping range, the metal expansion is less than during similar crimping in the separate double-roll die with a bullhead;
- the use of the doubled double-roll die with the gauge system "bullhead — accelerated gauge" during the initial billet deformation has shown sufficient efficiency concerning the maximal metal expansion obtaining. In the entire crimping range, the metal expansion, i.e. the strip width, increases. For producing the ribbon-type sections with a width-to-thickness ratio of more than 2, it is recommended to carryout the cold work process by using the doubled double-roll die with "bullhead — accelerated gauge" system. At the same time, this process is energy efficient due to a decrease in the force of pulling through the roller die.

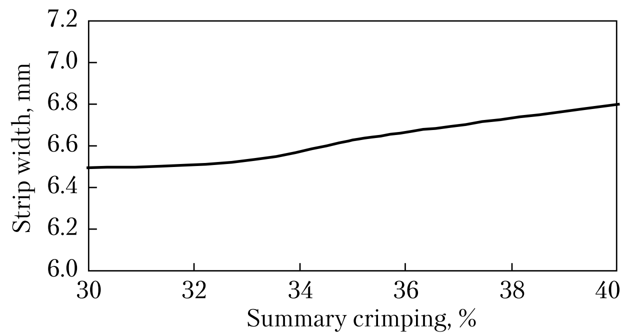


***Fig. 8.*** Changes in the section width during the deformation of initial 5.90 mm diameter round billet in doubled double-roll die with "bullhead — accelerated gauge" system

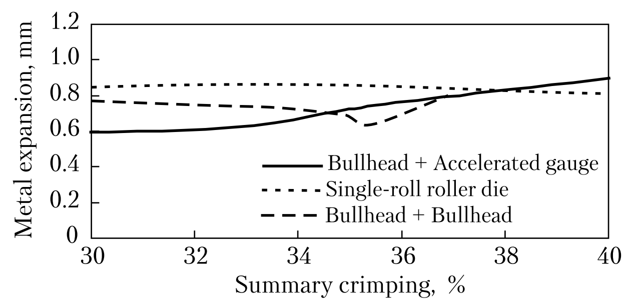


***Fig. 9.*** The metal expansion during crimping the initial 5.90 mm diameter round billet according to the three research stages of the deformation process: in the separate double-roll die with a bullhead; in the doubled double-roll die with "bullhead — bullhead" gauge system; and in the doubled double-roll die with "bullhead — accelerated gauge" system

## CONCLUSIONS

1. In engineering and instrumentation, high-precision sections, including ribbon-type ones of a wide brand and size assortment are used. However, ribbon-type section production is practically absent in Ukraine.

2. Iron and Steel Institute of Z. I. Nekrasov of the National Academy of Sciences of Ukraine (ISI NASU)

deals with fundamental and applied research of the drawing process in roller dies to produce ribbon-type sections from carbon steel brands of different sizes.

3. To improve the production technology of ribbon-type sections with a width-to-thickness ratio over 2, the experimental research has shown the following:

- it has been established that during the deformation of the initial steel billet ranging in 10—60% per transition in the separate double-roll die with a bullhead after the relative crimping per transition of approximately 30%, the strip width decreases, with the metal expanding. It is explained by the fact that as the crimping increases per transition, so does the metal pulling tension ($\sigma_{pull.}$). Upon reaching the fluidity limit ($\sigma_{pull.}/\sigma_T = 1$) by the pulling tension, the metal deformation proceeds mainly towards the extraction. It has been determined that with the increased relative metal crimping per transition, the metal pulling tension increases up to the metal fluidity limit and reaches it at the relative crimping of around 50% per transition. Further increase in the pulling tension leads to the fact that the initial round billet deformation process in a double-roll die with a bullhead proceeds without metal expansion, which can also cause the metal breaking out in the deformation cell.
- when using the "bullhead — bullhead" gauge system during the initial steel billet deformation in the doubled double-roll die, it has been established that with the increased crimping in the first double-roll die on the way out of the second roller die, the metal high-altitude tightening effect is observed. It has been determined that in the second double-roll die, the following process parameters influence the stability of metal deformation process continuation: the counter tension created in the first double-roll die and the relative crimping in the second double-roll die. It has been established that the pulling force at all the crimping modes does not exceed the acceptable pulling force. It has been shown that in the range of total crimping of 5—30%, the received strip width during the initial round billet deformation in the separate double-roll die with a bullhead. For this reason, the initial billet deformation in the doubled double-roll die, while using the "bullhead — bullhead" gauge system, is inefficient to obtain the maximal metal expansion, while producing ribbon-type sections with the width-to-thickness ratio more than 2.
- when using the "bullhead — accelerated gauge" system during the initial round steel billet deformation in the doubled double-roll die with the total crimping ranging within 30—40% in the first and second roller dies, it has been established that the growth of the strip width ranging in 6.5 to 6.8 mm and the strip expansion ranging in 0.6 to 0.9 mm is achieved.

Thus, it can be concluded that to obtain the maximal metal expansion per transition while producing ribbon-type sections with a width-to-thickness ratio over 2, it is quite efficient to use doubled double-roll dies with "bullhead — accelerated gauge" system.

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**Received 17.04.2023**
**Revised 05.05.2023**
**Accepted 10.05.2023**

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## ДО ПИТАННЯ ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ВИРОБНИЦТВА ПРОФІЛІВ СТРІЧКОВОГО ТИПУ МЕТОДОМ ВОЛОЧІННЯ У ЗДВОЄНИХ РОЛИКОВИХ ВОЛОКАХ

**Вступ.** Процес волочіння застосовується для виробництва цілого ряду фасонних профілів складної конфігурації, зокрема й тонкостінних, стрічкових та профілів періодичного перерізу.

**Проблематика.** Через складність процесу виробництва сталевої стрічки на плющильних станах і високою капіталомісткістю плющильних виробництв з другої половини минулого століття ведуться спроби використовувати інші способи плющення і, зокрема, волочіння у монолітних та двороликових волоках.

**Мета.** Встановлення закономірностей впливу різних систем калібрувань і технологічних параметрів на закономірності формозміни й енергосилові параметри процесу волочіння у здвоєних двороликових волоках та визначення найбільш ефективних схем для отримання максимального розширення металу при виробництві профілів стрічкового типу.

**Матеріали й методи.** Використано круглі заготовки діаметром 5,9 мм зі сталі марки Ст08А та застосовано методи холодної обробки заготовки обтисненням з різним ступенем відносного обтиснення за перехід у двороликовій волоці з різними системами калібрів.

**Результати.** Встановлено закономірності формозміни металу та зміни енергосилових параметрів процесу волочіння профілів стрічкового типу у здвоєних двороликових волоках при використанні різних систем калібрів. Експериментально досліджено граничні умови деформації у двороликових волоках, що забезпечують стабільне протікання процесу волочіння за критерієм запасу міцності деформованого металу. Експериментально визначено найбільш ефективну систему калібрів здвоєних роликових волок, що забезпечує максимальне розширення металу при виробництві профілів стрічкового типу.

**Висновки.** Запропоновано при виробництві стрічкових профілів з відношенням ширини до товщини більше двох з метою отримання максимального розширення металу за перехід застосовувати технологію волочіння металу в здвоєних двороликових волоках з системою калібрів «гладка бочка — розгінний калібр». Також такий процес є енергоефективним з точки зору зменшення величини сили протягування крізь роликові волоки.

*Ключові слова:* волочіння, ефективність, сталеві стрічки, здвоєні двороликові волоки.