New production technology of screw sections by drawing

A R Fastykovskii¹, E V Chinokalov², A N Prudnikov¹ and T N Oskolkova¹
¹Siberian State Industrial University, 42 Kirova Street, Novokuznetsk, 654007, Russia
²EVRAZ United West Siberian Metallurgical Plant, 16 Kosmicheskoe shosse, 654043, Novokuznetsk, Russia
E-mail: omd@sibsiu.ru

Abstract. The development of engineering and technology necessitates the search for new solutions related to the release of innovative products with high added value, which include long-length cold-worked screw sections. An analysis of the methods for producing long screw profiles is made, as a result of which a new method is proposed that differs from the known methods by the absence of a twisting operation for forming a helical surface. This feature of the new method for producing long screw profiles simplifies the design of the device and reduces energy consumption. The influence of the workpiece diameter and the number of passes of the helical surface on energy consumption was studied, and a comparative schedule was constructed that proves the advantages of the proposed method for producing screw sections by drawing. For the strength analysis of equipment, a dependence is proposed by which the force that occurs when drawing long screw profiles can be found, taking into account the deformation conditions and design features of the device forming the screw surface. Using the fourth theory of strength, a dependence is obtained to determine the condition that guarantees the absence of breaks in the process of drawing a screw profile.

1. Introduction

The development of engineering and technology necessitates the search for breakthrough solutions in various fields, especially in basic ones, such as metallurgy. Thanks to the development of new types of products, the greatest effect can be obtained, which, in turn, contributes to the development of machine building and construction industries. With this interaction, the development efficiency becomes more significant.

New perspective sections rightfully include screw sections, from which various products used in construction are produced. In Japan, the USA, and China, extensive work is being carried out on the industrial production of screw sections on a large scale. From the point of view of the development prospects of this area, special attention is paid to screw sections for construction purposes: reinforcing bars, nails. Constantly growing requirements for buildings and structures dictate the need to improve reinforcing sections in terms of finding optimal surface shapes, while guaranteeing high strength and reliable adhesion to concrete.

The evolutionary change in the cross-sectional shape of reinforcing sections led consumers to the conclusion that reinforcement with a helical surface obtained by cold working has optimal technological characteristics. Compared to conventional, such reinforcement with a lower mass and similar strength has a greater adhesion area to concrete. However, despite all the advantages, multi-way screw reinforcement is mastered with great difficulty by enterprises. The reason for this state of
affairs is a lack of theoretical knowledge of the process of helical surface formation, the structural complexity of the equipment, the lack of reasonable recommendations for choosing rational modes of forming. The same situation is with screw nails.

As follows from the literature, at present, cold-deformed screw profiles are obtained by drawing in a forcefully rotary die [1], by drawing, followed by twisting to obtain a given pitch of the screw surface [2]. In both cases, when forming a screw section, it is necessary to additionally apply torque. Such feature, on the one hand, increases energy costs for production, and on the other hand, complicates equipment, making it necessary to use, in addition to the drawing mill, additional devices that provide twisting at a certain angle during the drawing process. To eliminate the disadvantages of the known solutions, a new drawing method [3] and a tool [4] have been developed, the design of which, due to the application of longitudinal force, provides drawing with simultaneous rotation of the tool around an axis with a certain adjustable frequency, and a screw profile is formed on the surface of the workpiece. This process is stable and guarantees a constant pitch of the helical surface when the drawing speed changes. The geometrical parameters of the tool for obtaining screw profiles are similar to the parameters of a standard die. This feature greatly simplifies the development of screw sections on existing equipment, without requiring additional costs for reconstruction.

2. Theoretical aspects of screw sections production by drawing

It was noted above that the proposed method and equipment that implements it do not provide for the presence of an additional drive, thereby reducing energy costs for obtaining screw profiles. Let us evaluate the effectiveness of the proposed method by comparing the energy consumption for its implementation with the energy consumption of the combined drawing with twisting. Reduction in energy costs when obtaining cold worked screw sections by drawing with the help of the proposed method in comparison with combined drawing with twisting can be found using the dependence:

\[ \Delta N = N_{w1} + N_{tw} - N_{w2} - N_{rot} \],

where \( \Delta N \) is the additional power required when forming a helical surface by drawing with subsequent twisting; \( N_{w1} \) – power to obtain longitudinal grooves for subsequent twisting; \( N_{w2} \) – power for forming a helical surface by rolling; \( N_{tw} \) – power when twisting a screw profile; \( N_{rot} \) is the power for rotating the die in bearings.

After substitution and transformations, we obtain the calculated dependence for determining \( \Delta N \) in the form:

\[ \Delta N = \frac{6.28v}{h \cdot k} \left(0.12\sigma_s D^3 - P d_{bear} f'\right), \]

where \( v \) – the speed of drawing; \( h \) – the pitch of the screw profile; \( k \) – the number of runs of the helical surface; \( \sigma_s \) – the deformation resistance of the workpiece material; \( D \) – the diameter of the workpiece; \( P \) – the drag force; \( d_{bear} \) – diameter of the thrust bearing; \( f' \) – the coefficient of friction in the bearing.

The absolute value of \( \Delta N \) shows how much more power is required to obtain screw sections by drawing with twisting. According to formula (2), technological factors and the design of the deforming device influence \( \Delta N \). Usage of the absolute value \( \Delta N \) gives an idea of the energy efficiency of the proposed method, however, it does not allow the benefit in rubles to be evaluated. To determine the material benefits of the proposed solutions, energy consumption must be presented in specific values kWh/t. Using dependence (2), we obtain a formula for estimating the specific energy consumption (\( \Delta e \)) in the form:

\[ \Delta e = \frac{v \cdot f'}{593.2 G \cdot h \cdot k} \left(0.12\sigma_s D^3 - P d_{bear} f'\right), \]
where $t$ – the drawing time of one workpiece; $G$ – the mass of the workpiece.

A more obvious possible change in energy consumption depending on the geometrical parameters of the screw section is shown in figure 1.

![Figure 1](image)

**Figure 1.** The diagram of the dependence of the additional specific energy costs required for drawing with subsequent twisting on the number of passes of the helical surface and the diameter of the workpiece.

The economic effect ($\Delta E$) from the use of the developed method and tool when receiving helical cold worked sections can be calculated by the formula:

$$
\Delta E = \Delta e \cdot P_E,
$$

where $P_E$ is the price of kW·h of electricity for enterprises.

An analysis of the effectiveness of using the proposed method for producing multi-helical screw sections in relation to the conditions of JSC EVRAZ ZSMK was made using the above formulas to determine energy consumption. According to the data obtained, an increase in the diameter of the drawn wire from 6 to 14 mm during the formation of a three-way surface allows production costs to 9-10 rub/t to be reduced.

To verify the operability of technological equipment, it is necessary to carry out strength calculations based on knowledge of the force required during deformation. The drawing force that occurs when obtaining long multi-pass screw sections can be found by the formula;

$$
r = 1,6k\sigma_e\sqrt{\Delta h^2 R_p (1 + f \cdot \text{ctg}\varphi)},
$$

where $\Delta h$ – the amount of compression during the formation of the helical groove; $\varphi$ – the angle depending on the pitch of the helical surface; $f$ – the coefficient of friction in the deformation zone; $R_r$ is the radius of the deforming roller.

$$
\varphi = \arccos \left( \frac{3hS_1 \ln \frac{S_h}{S_1}}{4\pi\Delta h \sqrt{R_r(D - \Delta h)^3}} \right),
$$

where $S_0, S_1$ are the cross-sectional areas of the workpiece and the screw section.
The permissible resulting stress at the end located in the grips during drawing can be determined using the fourth strength theorem:

\[
[\sigma] \geq \sqrt{\frac{1.6k\sigma_s}{S_i} \left(1 + f \cdot \text{ctg} \phi\right) + 3 \left(\frac{P(D - \Delta h)\sin 2\phi}{0.8D_g^4}\right)^2},
\]

where \(D_g\) is the diameter of the end of the profile located in the grips.

The given dependences for determining the drawing force of long-length screw sections, the condition for the strength of the cross-section to which the load is applied, are necessary for strength calculations of equipment, choosing the drive of the drawing mill, and determining the probability of breaks in the drawing process. Successful experience in obtaining long screw sections in the current production environment is given in works [5 - 9].

3. Conclusions

1. The possibility of obtaining innovative products – cold-rolled screw sections in the conditions of drawing production of EVRAZ ZSMK JSC was shown.
2. The energy efficiency of the proposed solution for the production of cold-rolled screw sections in comparison with known methods is proved.
3. Formulas have been obtained, the use of which allows energy-efficient modes for producing cold-rolled screw sections to be determined, check the equipment for strength, and assess the probability of breaks during drawing.

References

[1] Parshin S V 2007 Production of Rolled Products 12 27–30
[2] Kargin V R 1994 Processes for Producing Screw Profiles and Pipes (M: Metallurgiya) p 96
[3] Fastikovskii A R et al 2015 Patent of the Russian Federation No 2553728 publ. 06.20.2015
[4] Fastikovskii A R, Chinokalov E V et al 2014 Utility Model Patent of the Russian Federation No 143099 publ. 07.10.2014
[5] Fastikovskii A R, Chinikalov E V et al 2014 Metallurg 6 128–131
[6] Fastikovskii A R, Chinikalov E V et al 2014 Steel 10 48–50
[7] Fastikovskii A R, Chinikalov E V et al 2013 Production of Rolled Metal 10 40–42
[8] Fastikovskii A R and Chinikalov E V 2019 Steel 7 50–51
[9] Fastikovskii A R and Chinikalov E V 2019 Ferrous Metals 6 35–37