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Development and Experimental Testing of a New Technology for Producing Screw Fittings from Bar Scrap of Ferrous Metals

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Abstract: One of the simplest and most frequently used methods of recycling ferrous scrap is its remelting and further reuse. But at the same time, in some countries of the world, another method of processing ferrous scrap has entered into practice, namely, recycling of some metal products that have served their service life by various methods of hot pressure treatment to obtain a finished commercial product. In our opinion, this method of processing ferrous scrap and alloys can be attributed to "green" technologies, as it allows you to make a small contribution to improving the environmental situation in the world. This work, carried out within the framework of grant № AP14869135, funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, is devoted to the development and research of a new technology for processing scrap in the form of pieces of reinforcement made of 25G2S steel to obtain high-quality finished metal products in the form of screw fittings. The developed technology included two stages. At the first stage, the reinforcement pieces are performed on a radial-shear rolling mill to obtain conventional rods of the desired diameter and create initial conditions for the formation of a gradient ultrafine-grained structure in the resulting screw profile. The second stage is the direct production of screw fittings with a gradient ultra-fine-grained structure on a combined installation. Metallographic studies have shown that after the implementation of the second stage of obtaining screw fittings, a gradient structure is observed in 25G2S steel in the longitudinal direction, with equiaxed grains (ranging in size from 11-14 μm) in the peripheral region and with elongated, directional-oriented grains in the central region of the resulting reinforcement.

Keywords: Radial-shear rolling, Combined installation, Bar scrap, Recycling, Screw reinforcement profile,

Introduction

At the beginning of this work, it is necessary to note two main points that determine its relevance. Firstly, everyone knows that in the modern world, industrial and civil engineering widely uses various building materials based on reinforced concrete structures. A key trend in this area is to increase the reliability and durability of reinforced concrete products while reducing the cost of reinforcement manufacturing as one of the main construction objects. Reinforcement, including screw reinforcement, has been used for decades in the construction industry, although it is quite durable, but in conditions of increased demand for the quality of reinforced concrete structures, the requirements for the quality of reinforcement, including an increase in its life cycle, are correspondingly increasing. Therefore, the development of new or improvement of previously known

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technologies for producing high-quality products in the form of reinforced reinforcement profiles for various purposes is, as noted above, currently an urgent task.

Secondly, currently in many countries of the world, a number of different technological processes have been developed for the processing of certain metal products that have served their service life using hot pressure treatment into a ready-to-sell product. The founder of this field of processing metal products that have served their service life by hot pressure treatment is the American scientist E.E. Slick, who at the beginning of the last century developed a technology for processing railway rails by hot rolling in calibers in order to obtain flange profiles (Slick, 2021). But then the technology he proposed was not widely used in practice. It was only at the end of the 20th century that the global scientific community and manufacturers of metal products became interested in this area. Here are just some works Badyuk and Leshchenko (2010) and Smirnov et al. (1995) and Bakhtinov (2000) and McGahhey (1991) devoted to the development and study of technologies for processing railway rails by hot rolling to produce various finished metal products. Another promising method of recycling some metal products that have served their service life is their rolling in radial-shear rolling mills (Galkin, 2007). However, most often this method is applicable only for recycling cylindrical metal products, for example, used railway axles (Grevtseva & Galkin, 2017) and pumping rods (Galkin & Romantsev, 2014), as well as bar scrap of ferrous metals and alloys (Lezhnev et al., 2021-1), including in the form of fittings (Lezhnev et al., 2021-2). In all cases, this method is based on the principle of hot radial shear rolling of a used so-called bar to a smaller diameter and then using the resulting bar with a smaller cross-section for its intended purpose. It should be noted that radial shear rolling makes it possible to obtain long-length products from various materials with a gradient ultrafine-grained structure, which has been proven, including in (Gamin et al., 2023; Ozhmegov et al., 2023; Dobatkin et al., 2019; Gamin et al., 2020; Karpov et al., 2018; Valeev et al., 2015), and in addition, this method is the most technologically advanced and easy to implement compared to many other methods of metal pressure treatment, which realize severe plastic deformation during the deformation process (Galkin et al., 2015).

As already mentioned above, radial-shear rolling makes it possible to obtain high-quality bars with a gradient fine-grained structure from ferrous scrap. These bars can be used as a final marketable product, or subjected to further pressure treatment to produce various metal products, for example, hardware products or a clamping screw for formwork. Continuing to develop the direction of processing ferrous bar scrap using radial-shear rolling, we proposed to use a previously developed new combined process (Lezhnev et al., 2023a) combining radial-shear rolling and pressing through a screw matrix for these purposes (processing of bar scrap) (Fig.1). The main difference in this case will be only that bar scrap of round cross-section of ferrous metals will be used as the initial blanks. The final product will still be a high-quality commercial product in the form of screw fittings with a gradient ultrafine-grained structure and with a given level of mechanical properties. That is, in this case, we are solving the two relevant tasks discussed above.

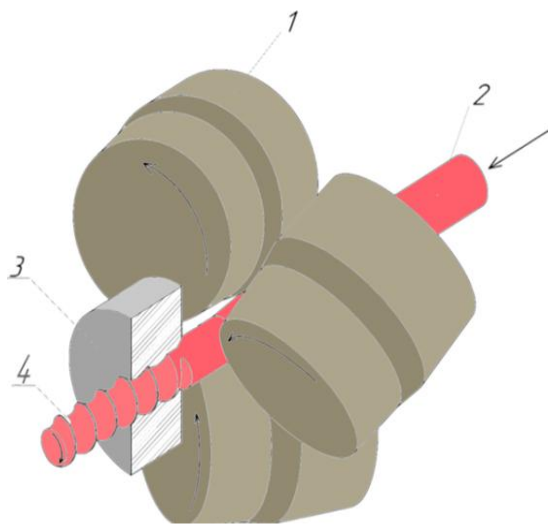
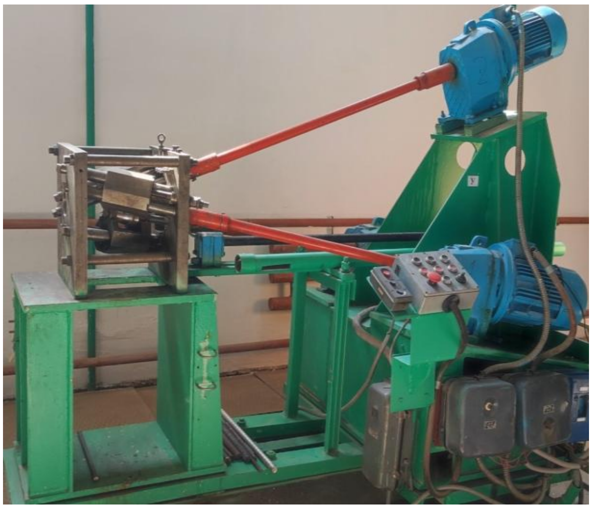


Figure 1. Combined method for producing screw fittings: 1 – rolling rolls, 2 – initial blank, 3 – die, 4 – screw profile

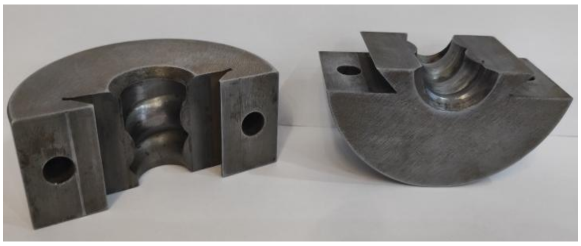
In the works Lezhnev et al. (2024) and Lezhnev et al. (2023b) devoted to computer modeling in the DEFORM software package of a new combined process for producing screw fittings, the possibility of its implementation has already proved. The purpose of this work is to experimentally confirm the possibility of obtaining commercial products from bar scrap in the form of screw fittings with a gradient ultrafine-grained structure during the implementation of a new combined method, the scheme of which is shown in Figure 1.

Method

To achieve this goal, physical experiments were conducted using two radial-shear rolling mills: SVP 14-40 and RSR 10-30. At the same time, a laboratory combined installation for producing screw fittings was assembled on the basis of the RSR 10-30 mill (Fig. 2a), by installing on it a specially made die with a screw profile with maximum diameter of the working screw channel 20 mm (Fig. 2b-c).



a)



b)

c)

Figure 2. Combined installation for producing screw fittings assembled on the basis of the RSR 10-30 mill: a – radial-shear rolling mill RSR 10-30; b – die with a screw profile; c - working cage of the RSR 10-30 mill with an installed die

Ferrous scrap in the form of rebar pieces with a diameter of 32 mm and a length of 150 to 200 mm (steel grade 25G2S), which were subjected to homogenizing annealing, were used as the initial blanks for the physical experiment. The technology of rolling scrap in the form of pieces of reinforcement (GOST 5781-82) into a ready-to-sell product in the form of screw reinforcement included two stages: the 1st stage was the production of a conventional cylindrical billet from the reinforcement, i.e. rolling out the reinforcing profile of the initial billet (reinforcement) at the radial-shear rolling mill SVP 14-40. At this stage, in addition to rolling out the reinforcement profile, initial conditions are created for the formation of a gradient ultrafine-grained structure in the future of the resulting screw reinforcement. The 2nd stage is the direct production of screw fittings with a gradient ultrafine-grained structure by deforming a cylindrical billet previously obtained at the first stage on a combined installation assembled on the basis of the RSR 10-30 mill.

During the implementation of the 1st stage, pieces of reinforcement with a diameter of 32 mm, preheated and kept at a temperature of 1000°C, were deformed on a radial-shear rolling mill SVP 14-40 to a diameter of 22 mm in 4 passes according to a reversible scheme (Galkin & Kharitonov, 2003) with an absolute compression step in diameter per pass equal to 2.5 mm. After that, the received rods were sent back to the furnace for heating (the temperature in the furnace is 1000°C). At the 2nd stage, the rods with a diameter of 22 mm obtained at the 1st stage were deformed using a combined installation assembled on the basis of the RSR 10-30 mill. In this case, the rod was first rolled in the working cage of the RSR 10-30 mill with an absolute compression of 2 mm in diameter, at the outlet of which it entered the matrix with a working screw channel (Fig. 2b) and, due to the pushing force created by the rolls, was pushed through the screw channel.

Results and Discussion

The analysis of the microstructure evolution of the resulting screw reinforcement was carried out using a metallographic complex, including a MI-1 light microscope, a Nikon Colorpix-4300 digital camera with a photo adapter. The microstructure was studied in the center and surface area of the resulting screw reinforcement. The results of metallographic studies are shown in Figure 3.

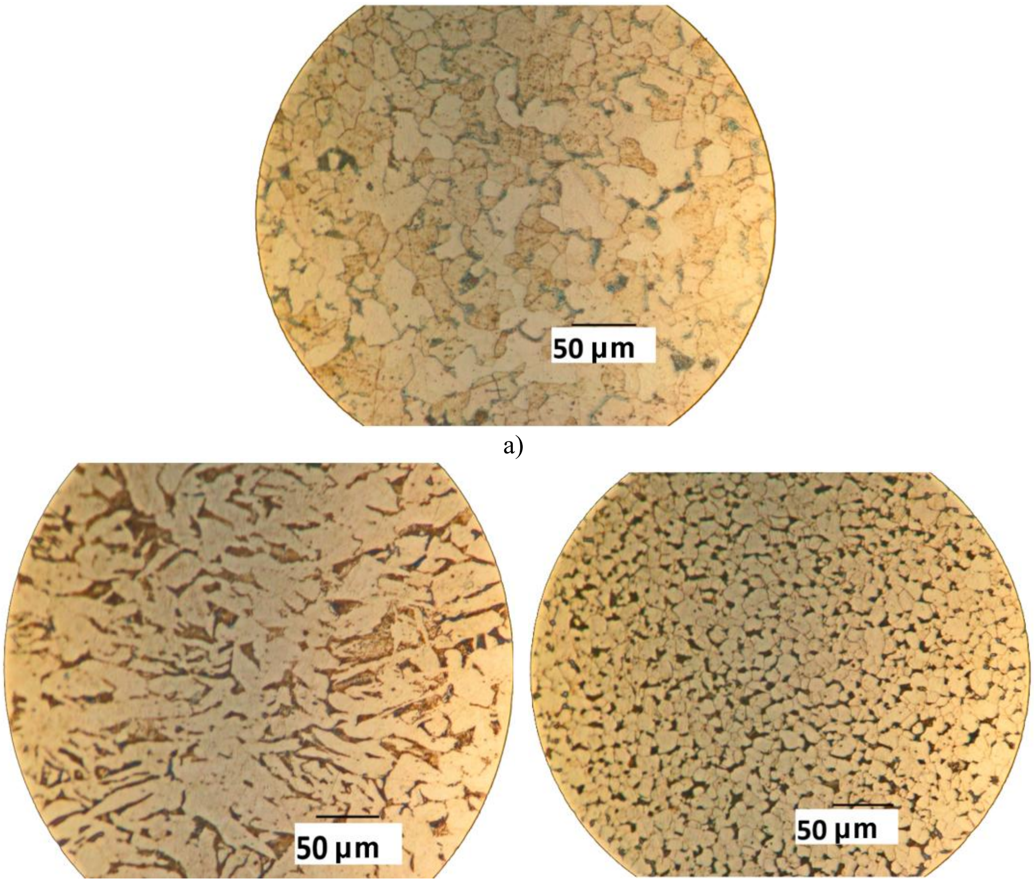


Figure 3. Microstructure of the resulting screw reinforcement of 25G2S steel (longitudinal direction): a – initial; b – central zone; c – surface zone

An analysis of the microstructure evolution of 25G2S steel after the implementation of the 2nd stage of deformation showed that during the implementation of the proposed technological process, the initial microstructure significantly decreased throughout the volume of the deformable metal. Thus, in the surface zone, the grain size decreased to 11-14 μm (Figure 3a). In this case, the microstructure in this zone of the resulting screw profile has a predominantly equiaxed ultrafine-grained character. In the central zone of the resulting screw reinforcement, grains elongated in the direction of rolling are observed to a greater extent, ranging in size from 6-10,5 x 1,1-1,7 μm (Fig. 3b), which is due to the preliminary deformation of the initial pieces of reinforcement according to the standard radial-shear rolling scheme . But at the same time, elongated grains, misoriented in directions, are also observed in the central zone, lying also in the range of 6-10,5 x 1,1-1,7 μm (Fig. 3c), which is justified by the back pressure arising from the side of the screw die and the additional twisting of the bar in this die when pushing the bar through it.

Conclusion

The research carried out in this work has proved that the proposed combined technological process for producing screw fittings from ferrous scrap is feasible in practice. Metallographic studies have shown that during the implementation of the new combined process, the goal was achieved to produce screw fittings with a gradient structure. Thus, the resulting reinforcement has an ultrafine-grained recrystallized grain structure with a grain size of 11-14 μm in the surface zone, and a structure with elongated, directional grains in the central zone of this reinforcement.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Conflict of Interest

The authors declare that they have no conflicts of interest

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