Modeling and experimental evaluation of the possibility of using a radial-shear rolling mill for recycling bar scrap of ferrous metals

Lezhnev Sergey[1]; Naizabekov Abdrakhman[1]; Panin Evgeniy[2], Kuis Dmitry[3], Kasperovich Andrey[3]
[1] Rudny industrial institute, Rudny, Kazakhstan; [2] Karaganda industrial University, Temirtau, Kazakhstan
[3] Belarusian state technological university, Minsk, Belarus
e-mail: sergey_legnev@mail.ru

Abstract: *This work is devoted to the study of the use of radial-shear rolling mills for recycling bar scrap and some metal products from ferrous and non-ferrous metals that have served their service life to obtain a ready-made commercial product. In particular, the paper presents the results of computer modeling and experimental research of the process of scrap metal rolling in the form of rebar on a radial-shear rolling mill into a round cross-section bar, which prove that some metal products that have served their service life after recycling using the proposed technology into finished commercial products in the form of bars can find further use without remelting.*
Keywords: *RECYCLING, BAR SCRAP, RADIAL-SHEAR ROLLING, COMPUTER MODELING, EXPERIMENT.*

1. Introduction

One of the most important problems in the field of environmental protection is the problem of waste recycling from various industries and their further consumption. Therefore, for more than a decade, much attention has been paid around the world to the development of various methods not only for waste disposal (including scrap metal), but also for their processing, i.e. recycling.

"Iron garbage" is a special category of waste, which is called scrap metal. The ideal modern solution for recycling scrap metal is to recycle it for further use for human needs.

One of the easiest ways to process ferrous metal and alloy scrap is its remelting and further reuse. However, in some countries of the world, another method of processing it has also come into practice - recycling of some metal products that have served their service life by various methods of hot pressure treatment to obtain a ready-made marketable product [1-4]. Recently, a fairly new method of processing failed metal products by deforming them in the hot state on radial-shear rolling mills is also widely used [5-7].

The direction of radial-shear rolling began its development at NUST MISIS by S.P. Galkin and is a three-roll screw rolling scheme, similar to the scheme used for piercing pipes in the pipe rolling industry. The main difference between the scheme proposed by S.P. Galkin is the feed angle increased to $\alpha = 18°$-$20°$ at the usual rolling angle $\beta = 5°$ [8]. This is what contributes to the development of the strongest vortex deformation from the surface to the center when implementing radial-shear rolling, and the ability to avoid the appearance of tensile stresses in the axial part of the workpiece. Based on the proposed radial-shear rolling scheme, a number of rolling mills at NUST MISIS were developed and put into small-scale production.

It is proposed to use the technology of radial-shear rolling for processing ordinary ferrous metal scrap in order to obtain a high-quality commercial product in the form of bars of circular cross-section. Currently, Kazakhstan's metal bases that accept scrap metal have a large number of different black scrap, including bar scrap, which could also be processed at a radial-shear rolling mill to obtain high-quality bars with a fine-grained structure and an increased level of mechanical properties.

The purpose of this work is a theoretical (using computer modeling in the DEFORM software package) and experimental study of the possibility of using radial-shear rolling mills for recycling bar scrap in the form of rebar to obtain a ready-made commercial product.

2. Computer modelling

At the first stage, during computer modeling in the DEFORM software package, it was decided to use the parameters of the existing SVP-08 mill installed at the Rudny industrial institute to create a model of radial-shear rolling. The initial billet was a reinforcing bar with a diameter of 30 mm and a length of 250 mm (Figure 1).

As the workpiece material a stainless steel AISI-1015 was chosen, heating temperature was 1000°C; rolling speed was set to 50 rpm as the nominal value of the SVP-08 mill. The friction coefficient on contact of the workpiece and the rolls was adopted equal to 0.7, as recommended for hot-rolling rolls with roughened surface. As a result, the resulting model of the rolls of the SVP-08 mill had the form shown in Figure 2.

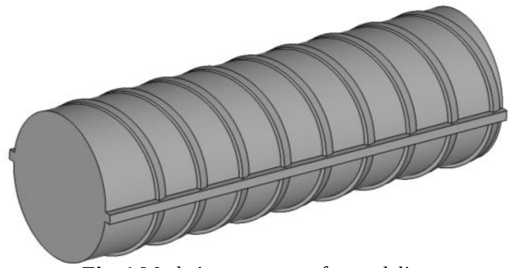


Fig. 1 *Workpiece geometry for modeling*

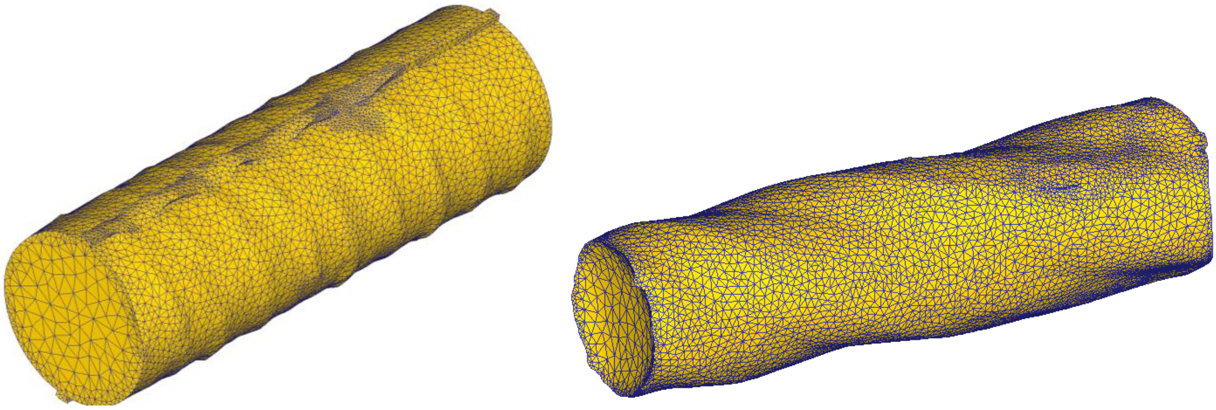
Fig. 2 *Model of rolls of radial-shear rolling mill*

To model the new recycling method, which includes successive stages of radial-shear rolling, it was decided to perform deformation according to the following scheme:

1) at the initial stage, radial-shear rolling is carried out at small compressions (0.5-1 mm per pass) in order to remove the longitudinal ribs of the reinforcement profile;

2) after removing the longitudinal ribs, the compression value increases to 3÷3.5 mm per pass for rolling out the transverse ribs and intensive processing of the surface layer of the workpiece.

The results of modeling these two stages are shown in Figure 3. Despite the fact that rolling with intensive compressions proceeded quite stably due to the absence of longitudinal ribs on the workpiece, the final shape of the workpiece can not be called "commodity" - it has a distinct spiral contour. This surface is created as a result of the intensification of compression. However, if when rolling an ordinary round billet, this contour will be barely noticeable (due to a more uniform distribution of deformation when rolling a billet of the correct shape), then in this case, rolling at increased compressions leads to a strong spiral surface relief.



a) *b)*

a) billet at the 1st stage of deformation (rolling out the longitudinal ribs);
b) billet at the 2nd stage of deformation (rolling out the transverse ribs and intensive radial-shear rolling)
Fig. 3 *Shape of the reinforcement profile during deformation at the radial-shear rolling mill*

Therefore, it was decided to conduct additional modeling of the second stage of deformation, where rolling will be carried out at the same small compressions as in the first stage of deformation. In this case, the number of deformation cycles will increase. Figure 4 shows the billet after a series of passes with small compressions.

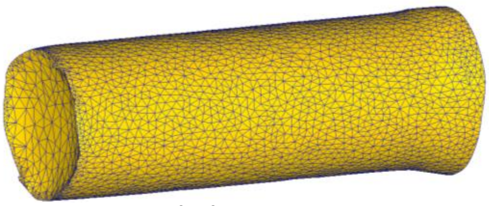


Fig. 4 *Billet at the 2nd stage of deformation when using small compressions*

It is clearly visible that after applying the small compression mode, the overall appearance of the workpiece has acquired the correct round profile. Therefore, it can be concluded that for recycling bar scrap in the form of reinforcement to obtain a finished product of the correct geometric shape using radial-shear rolling, it is necessary to carry out rolling at small compressions at all stages of deformation.

3. Experiment

At the second stage of research, a physical experiment was performed at the SVP-08 radial-shear rolling mill to confirm the possibility of implementing the proposed technology for recycling ferrous scrap in practice (Figure 5).

Fig. 5 *Rebar rolling process at the SVP-08 mill*

As the initial blanks, as in the simulation, pieces of rebar made of steel St5sp of A-II class (A300) GOST 5781-82 with a diameter of 30 mm and a length of 250 mm were used (Figure 6a). Before deformation, these pieces of rebar were heated in a Nabertherm R120/1000/13 tube furnace to a temperature of 1000°C with an exposure time of 30 minutes. Subsequent deformation of the heated samples was carried out on the SVP-08 radial shear rolling mill up to a diameter of 20 mm in five passes with an absolute compression step of 2 mm in diameter.

During the process of deformation of the reinforcement profile with a diameter of 30 mm on a radial-shear rolling mill, a rod with a diameter of 20 mm was obtained. Figure 6b shows that there is a slight curvature of this bar, so when the proposed technology is introduced into production, to give the bar the necessary straightness after reaching the required diameter, it will be edited on a special rolling mill [6].

4. Conclusion

The conducted simulation together with a physical experiment confirmed the possibility of processing various ferrous scrap bars, including rebar, to obtain a marketable product in the form of a metal bar.

5. Acknowledgments

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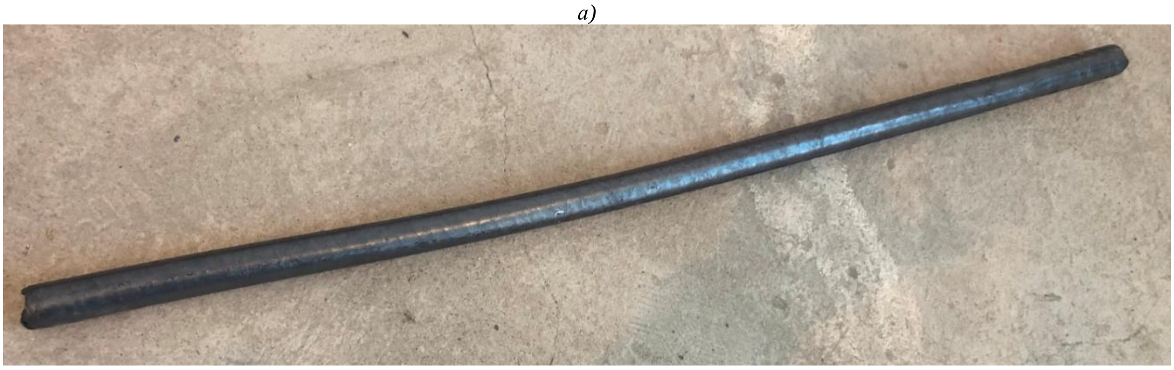
a)



b)

Fig. 6 *Bar scrap (reinforcement profile) before (a) and after (b) rolling*

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