IMPROVEMENT AND RESEARCH OF A NEW COMBINED METHOD FOR PRODUCING SCREW FITTINGS USING COMPUTER MODELING

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ABSTRACT

This paper presents the results of modelling a combined process of radial-shear rolling and pressing in order to obtain a reinforcing profile at different rotation speeds of the screw matrix. The parameters of the stress-strain state in the zones of radial-shear rolling and the formation of a screw profile in the matrix on the surface and axial parts of the workpiece were analysed. It has been established that the forced rotation of the screw matrix not only helps to increase the process performance but also plays an important role in preventing the defects formation. The maximum value of the equivalent strain is achieved in a fixed matrix, the higher the rotation speed of the matrix, the lower the values of the equivalent strain. At the same time, in the case of a high rotation speed of the die, the minimum strain level is 10 approximately. Stress state analysis has shown that this deformation scheme creates a high level of compressive stresses, which are dominated by tensile stresses.

Keywords: combined process, FEM modelling, stress-strain state, damage criterion, screw profile.

INTRODUCTION

In modern market relations in any industry, including metallurgy and machine-building, great importance is given worldwide to improving the manufacturability of production, reducing material and energy costs, improving the quality of finished products and expanding the range. All this ultimately increases the competitiveness of any industrial enterprise. One of the ways to comprehensively solve these problems in the production of rolled products is to develop new and improve previously known combined pressure treatment methods. Currently, several combined metal forming methods have been developed to produce high-quality metal products for various purposes, including the combined processes described in [1 - 9].

Screw fittings are one of the promising types of long-range rolled products. Screw fittings belong to a special group of construction fittings. Its distinctive feature, which distinguishes it from conventional corrugated fittings, is that the edges of its profile form a so-called screw thread along the entire length of the rod. It is possible to screw various threaded fasteners onto such a thread, for example: nuts or couplings. This feature of screw fittings has opened up a wider field of use in the construction industry.

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 technologies for obtaining high-quality products in the form of reinforced reinforcement profiles for various purposes is currently an urgent task.

Previously, a new method for producing screw reinforcement was developed, which combines the deformation of the initial rods using radial shear rolling into a single technological process, as well as pushing and twisting the deformable rod in a screw matrix, which ensures the formation of a screw profile of the reinforcement [10, 11]. The possibility of implementing this method of producing screw fittings has been proven both theoretically using computer modeling and experimentally [12 - 14].

To increase the manufacturability of this method of producing screw fittings, a screw matrix was proposed to place in a specially designed device that rotates the screw matrix around its axis in the direction opposite to the workpiece rotation (Fig. 1).

The rotation of the screw matrix is ensured by the following features: the screw matrix is made up of two halves of a common circular cross-section assembly (Fig. 1a) and is enclosed in a housing, which is in a large radial bearing 3, which provides support for the structure from below and its free rotation (Fig. 1b). The housing rests in front the thrust bearing 1, which takes on the pressing force, is located between the die and the thrust plate and also provides free rotation of the structure. To ensure the rotation of the die, a large gear wheel 2 is mounted on the housing, which engages with an electric motor set to the desired number of revolutions. The gear wheel is fixed to the housing by a screw matrix by means of a cotter.

EXPERIMENTAL

To determine the possibility of implementing an improved combined method for producing screw fittings and studying the shape change and stress-strain state of the metal during its implementation, computer modelling in the DEFORM software package was performed. The rotation speed of the matrix in the opposite direction relative to the rotation of the workpiece was used as a variable parameter in the simulation: 0 (matrix was fixed), 25 and 50 rpm.

When creating a computer model of the combined process, the parameters of the RSR 10 - 30 radial-shear rolling mill were used as the main equipment.

When creating the model, the following assumptions were made:

- the material of the workpiece is isotropic;
- type of tools - rigid; type of workpiece - plastic;

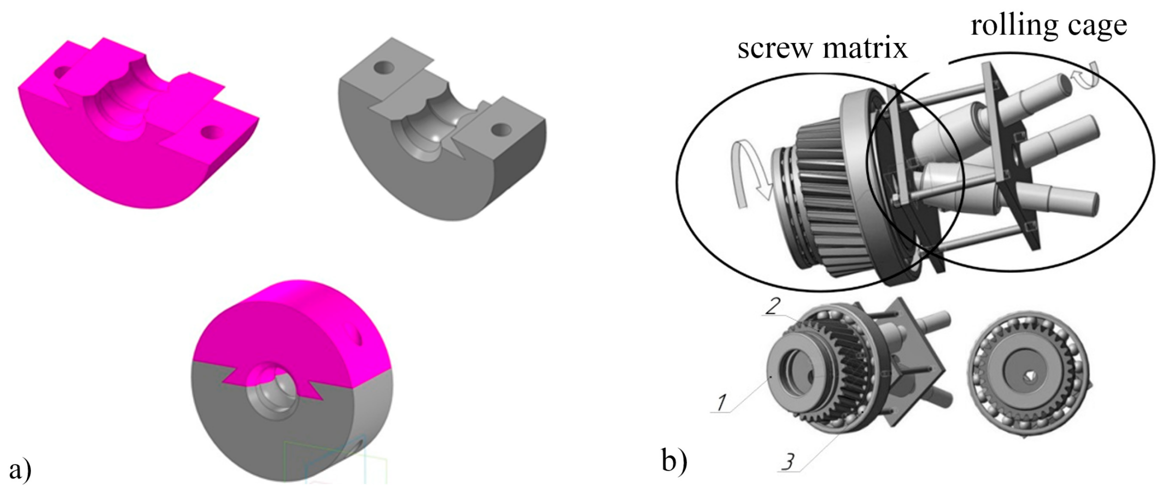

Fig. 1. Diagram of the implementation of a new combined process for producing screw fittings: 1 - thrust bearing, 2 - gear wheel, 3 - radial bearing.

- a grid of 85000 finite elements with an average edge length of 1.3 mm is applied to the workpiece.;
- the diameter of the initial blank is 22 mm;
- the material of the workpiece is AISI 1015 steel;
- the initial heating temperature of the initial workpiece is 1100°C;
- the temperature of the working tool (rolling rolls), the screw matrix and the environment is 20°C;
- the heat transfer coefficient between the deformable steel billet and the rolling rolls was assumed to be 5 kW (m^{-2} $°C^{-1}$). The heat transfer between the deformable workpiece and the surrounding environment has been activated;
- the length of the screw matrix is 33 mm [13];
- the friction coefficient on the rolls is 0.7, and in the channel of the screw matrix is 0.1 [13];
- the type of friction at the contact of the workpiece and with the channel of the screw matrix was set by Siebel;
- the rotation speed of the rolls was assumed to be 50 rpm;
- 1100 calculation steps were set with a time increment of 0.01 sec per step.

RESULTS AND DISCUSSION

It can be clearly seen from Fig. 2 that under the same boundary conditions, an increase in the rotation speed of the die contributes to the rate of deformation of the workpiece through it, thereby reducing the process time, and this is undoubtedly a positive factor. Thus, a fixed die slows down the process due to the occurrence of high backpressure, and with the same simulation duration, the workpiece was deformed by about 60 % along its length. At rotational speeds of 25 and 50 rpm, the workpiece was deformed in length by 70 % and 80 %, respectively.

Next, the damage criterion was considered, which is determined by default according to the Cockcroft-Lapham law using the Eq. (1):

$$D = \int_{0}^{\varepsilon} \frac{\sigma_1}{\sigma_{eqv}} d\varepsilon \,, \qquad (1)$$

where ε - accumulated strain intensity at the moment of fracture; σ_1- the principal tensile stress; σ_{eqv} - stress intensity (equivalent stress).

For the effectiveness of the assessment, a scale from 0 to 1 was used in all cases. The coefficient value can take values of more than 1, however, exceeding this value leads to the formation of defects at the micro level, which then, with an increase in this coefficient, pass to the macro level (become visible to the naked eye). When comparing this criterion (Fig. 3), which shows potential areas of defects during workpiece deformation, it was found that in all three cases the highest value of the damage criterion is achieved when the workpiece passes through the screw channel of the matrix, however, with increasing rotation speed of the matrix, the potential for defects decreases, the length of the critical zones becomes smaller, as well as the maximum values in them. So, the maximum value of the coefficient is 1.58 in a fixed matrix; in a matrix with a rotation speed of 25 rpm, this coefficient has a value of 0.92, and 0.81 in a matrix with a rotation speed of 50 rpm. Thus, it can be concluded that the forced rotation of the screw matrix not only helps to increase the productivity of the process but also plays a crucial role in preventing the formation of defects.

When entering the screw matrix channel, the workpiece is subjected to intense deformation due to twisting. As a result, there is a significant increase in strain over the entire workpiece section. As the rotation speed of the matrix increases, the intensity of accumulation of equivalent strain decreases - in the surface layers of the workpiece, which acquire a volumetric helical shape, the amount of strain in the stationary die reaches 14.1, and when the matrix rotates at 25 and 50 rpm, strain decreases to 11.1 and 9.84, respectively (Fig. 4). In all cases, after passing through the screw channel, a significant decrease in the variation of strain values along the length of the workpiece can be noted. And although the intensity of the equivalent strain decreases with increasing speed, its values are in all cases quite high and it can be said that an increase in the rotation speed of the matrix is not negative.

For further analysis of the stress state, the following parameters were considered: equivalent stress (or stress intensity) and average hydrostatic pressure.

The radial-shear rolling process implies that the maximum equivalent stress values occur in the contact zones of the metal with the rolls, reaching a value of 200 MPa (Fig. 5). In all three cases, the distribution pattern of this stress-strain state indicator is approximately the same. In contact-free zones, the equivalent stress ranges from 80 - 100 MPa. When entering the matrix,

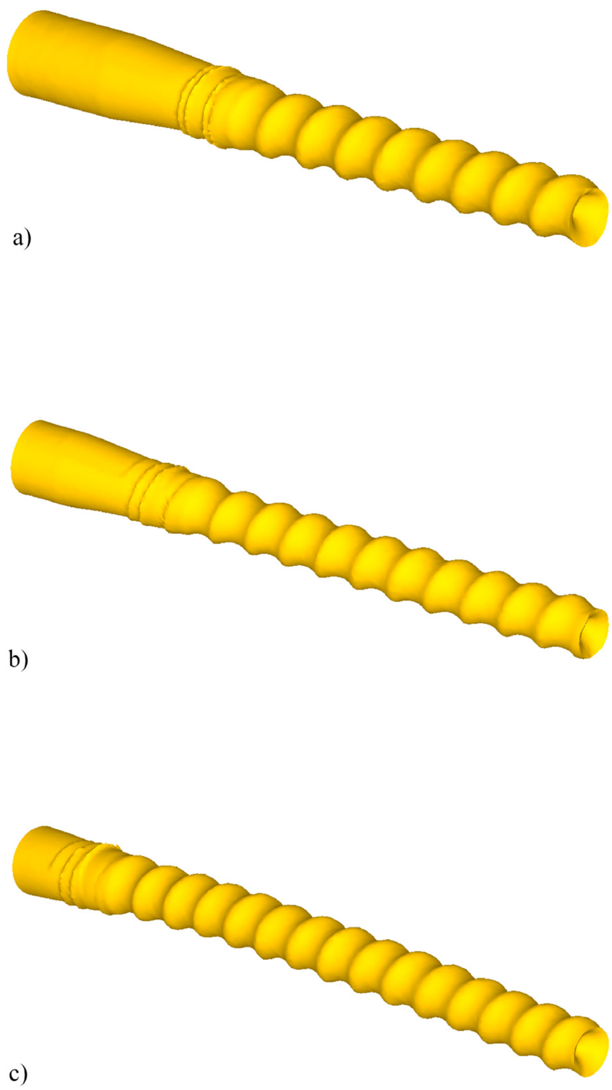

Fig. 2. Workpiece shape: (a) - fixed matrix, (b) - rotation speed 25 rpm, (c) - rotation speed 50 rpm.

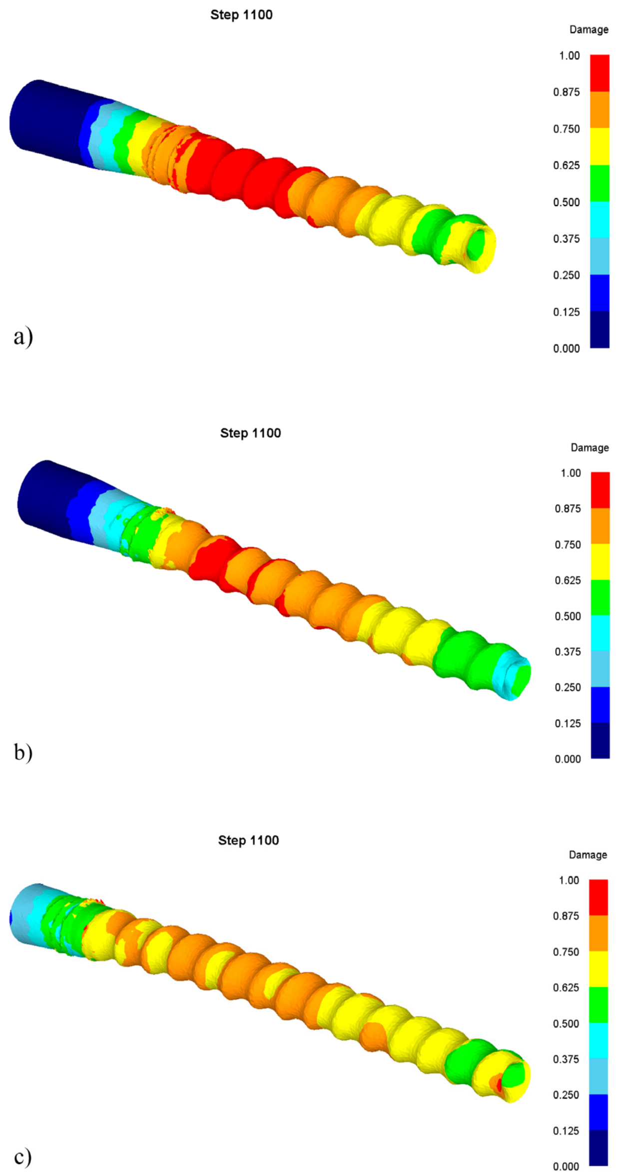

Fig. 3. Damage criterion: (a) - fixed matrix, (b) - rotation speed of the matrix 25 rpm, (c) - rotation speed of the matrix 50 rpm.

the maximum stress level develops only at the first turn, where a helical profile is formed. Here, the value of the equivalent stress is in the range of 140 - 150 MPa in the surface layers undergoing molding, and 90 - 100 MPa in the central part of the workpiece. In subsequent turns, the stress value is relatively small (30 MPa), since the metal moves in them with a ready-made helical shape.

When considering the equivalent stress, it is necessary to understand that being a root expression, its value is always positive. To estimate the magnitude of the stress, considering the sign, it is advisable to consider the average hydrostatic pressure or the average stress (Fig. 6).

For the most effective evaluation of this parameter in Deform, it is recommended to set the scale range so

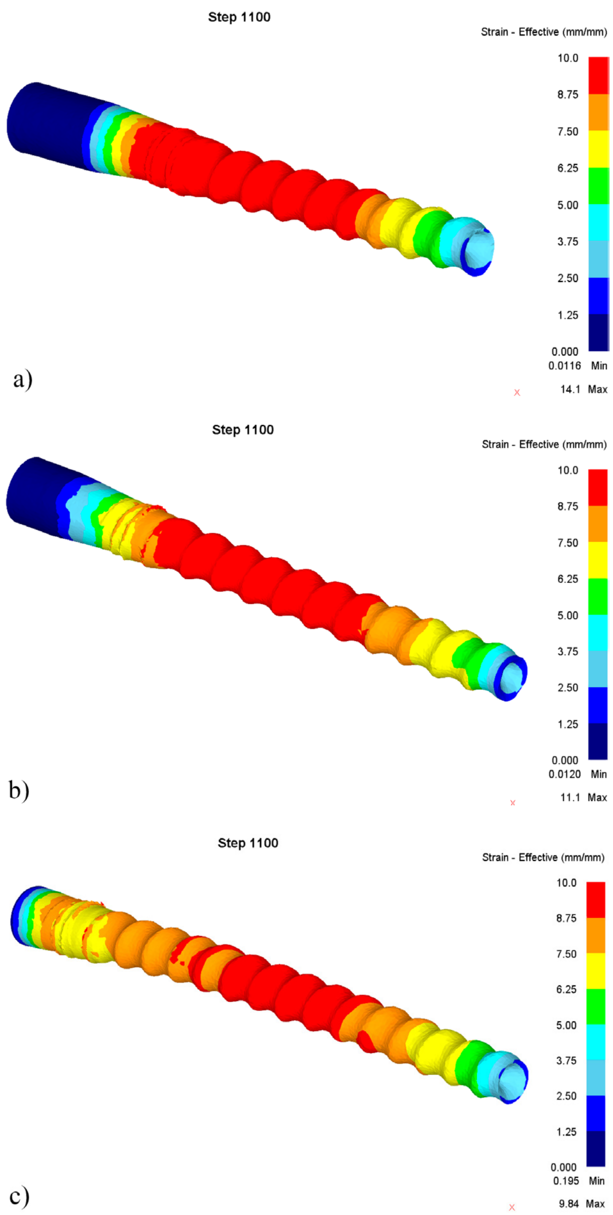

Fig. 4. Equivalent strain: (a) - fixed matrix, (b) - rotation speed of the matrix 25 rpm, (c) - rotation speed of the matrix 50 rpm.

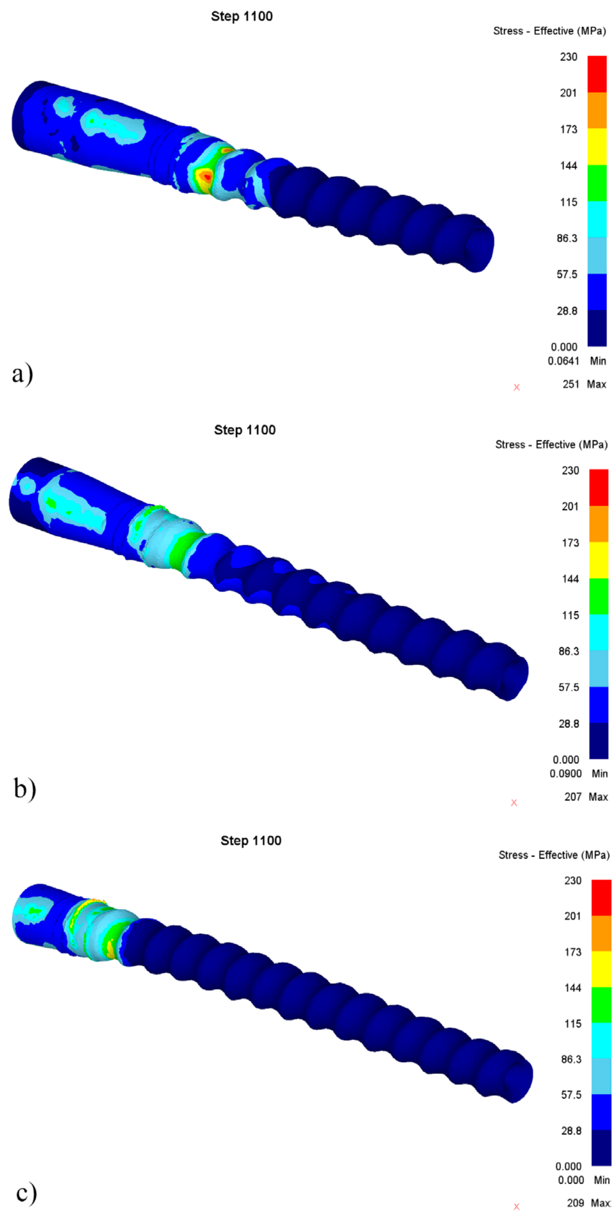

Fig. 5. Equivalent stress: (a) - fixed matrix, (b) - rotation speed of the matrix 25 rpm, (c) - rotation speed of the matrix 50 rpm.

that the zero mark approximately falls on any boundary of the colour scale. This will make it easy to identify areas of tensile and compressive stresses.

As in the case of the equivalent stress, the distribution pattern of the average hydrostatic pressure is approximately the same in all three models compared. During radial-shear rolling (Fig. 6), compressive stresses develop mainly in the areas of metal contact with the rolls, reaching a value of -200 MPa. In contact-free zones, the value of this parameter reaches -50 MPa. During molding in the matrix (Fig. 6), compressive stresses of about -80 MPa develop in the first turn in the surface layers undergoing molding and -50 MPa in the central part of the workpiece.

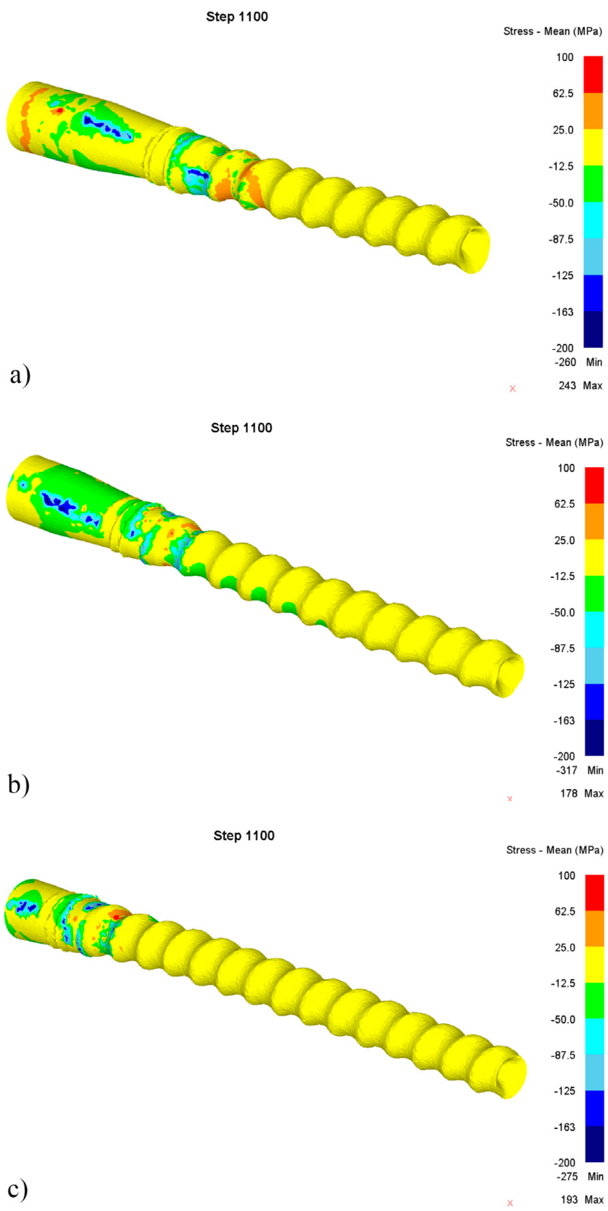

Fig. 6. Average hydrostatic pressure: (a) - fixed matrix, (b) - rotation speed of the matrix 25 rpm, (c) - rotation speed of the matrix 50 rpm.

CONCLUSIONS

In this work, the following task was set and solved: modeling a combined radial-shear rolling and pressing process to obtain a reinforcing profile at different speeds of rotation of the matrix: fixed, 25 and 50 rpm in the opposite direction of workpiece rotation. Based on the results of computer modelling, the parameters of the stress-strain state in the zones of radial shear rolling and the formation of a screw profile in the matrix on the surface and axial parts of the workpiece were analysed. Equivalent deformation, equivalent stress, and average hydrostatic pressure were selected as stress-strain state parameters. The maximum value of equivalent strain is achieved when forming a screw profile on a workpiece in a fixed matrix, which indicates intensive processing of the initial structure, the higher the rotation speed of the matrix, the lower the values of the equivalent deformation index. Nevertheless, although the processing of the workpiece with a rotating matrix is worse, rather large values of this parameter still develop in the workpiece. As for the stress comparison, the distribution pattern is approximately the same in all three cases. The advantage of implementing this process with a rotating die is that the process of deforming the workpiece itself is faster, thereby increasing productivity.

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