UDC 531

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OPTICAL METHOD OF PHYSICAL SIMULATION OF LOCAL DEFORMATION DURING STRIP DRAWING USING MONOLITHIC TOOL

Introduction. At present in order to improve the technological processes of working materials by pressure the following methods for modeling of the deformation processes (Fig. 1) in the deformation zone are used [1, 2].

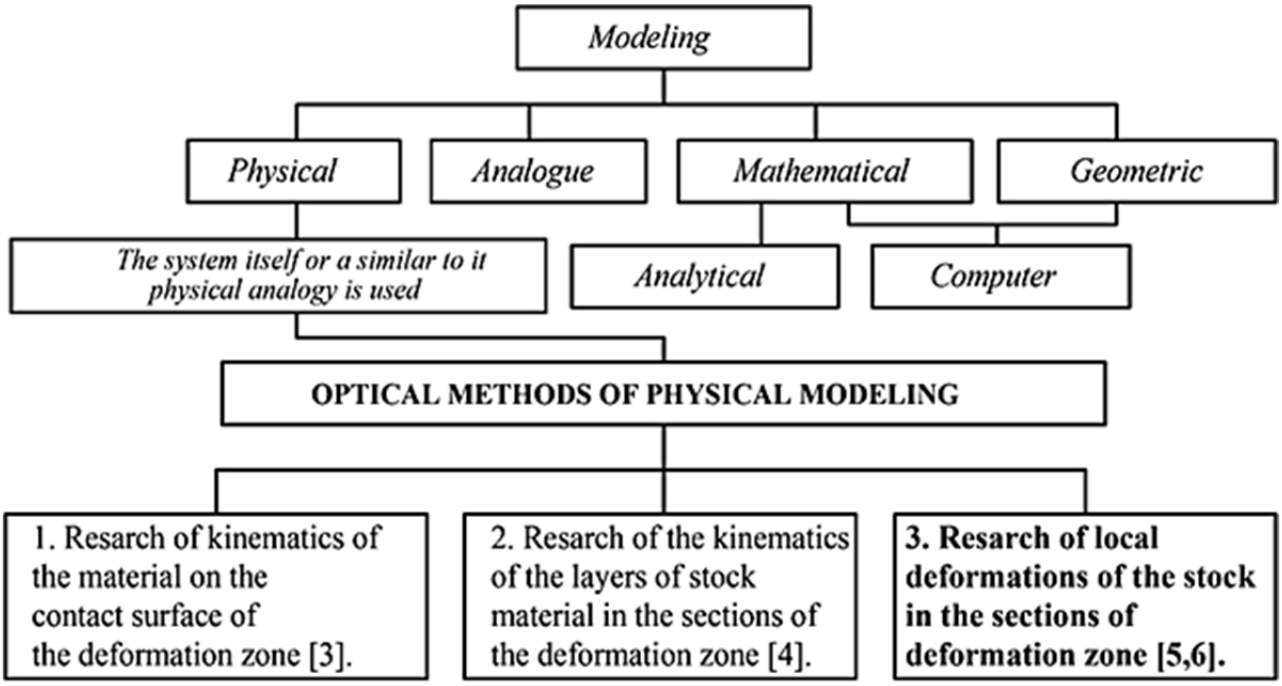

Fig. 1. Classification of methods for modeling of processes of working metals by pressure (words in italics) [1] and optical methods of physical modeling [3]

The aim of the work: Development of the optical method of physical modeling of local deformation during drawing a strip in monolithic tool to research the mechanics of the deformation process of the stock. Improvement of the mathematical model for determining the energy-force parameters of the drawing process, tool wear and the surface of the deformed strip.

Research. Let us consider (Fig. 2, *a*) the scheme of drawing of the stock 1 with velocity v_1 in the monolithic tool 2 with angle of cone α during change of the initial height of the stock from h_0 to h_1 [7, 8]. Let us consider at the entrance to the deformation zone (note I) elementary volume of material of unit thickness $c_0 d_0 e_0 f_0$ with dimensions Δx and Δy in the location of the center of mass m ($x_{0,m} < 0$, $y_{0,m} \le h_0$) with area $\Delta s = \Delta x \cdot \Delta y$.

Since at the entrance to the center of deformation axial speed of stock material $v_0 = v_x(x_{0,m}, y_{0,m}) = const$ does not depend on the coordinates $x_{0,m}$ and $y_{0,m}$, then when the center of mass m of the elementary area $c_0 d_0 e_0 f_0$ is moved with displacement $\Delta x_{0,m}$ the elementary area $c_0^/ d_0^/ e_0^/ f_0^/ = c_0 d_0 e_0 f_0$ does not change its position respectively to the new position of the center of mass m.

At the exit from the deformation zone (note II) during motion of the center of mass m ($x_m^/ > L$, $y_m^/ \le h_1$) of the elementary area Δs of the material of the stock $c_1 d_1 e_1 f_1$ with a constant velocity $v_1 = v_x(x_m^/, y_m^/) = const$ with displacement $\Delta x_m^/$ the form of the elementary area $c_1 d_1 e_1 f_1$ respectively to the new center of mass m is not changed $c_1^/ d_1^/ e_1^/ f_1^/ = c_1 d_1 e_1 f_1$.

In its turn in the deformation zone with length L due to the uneven speed of the motion of the material of the stock $v_x(x, y) \ne const$ and $v_y(x, y) \ne const$ the form of the area Δs of the elementary volume of the material of the stock $cdef$ (note III) in the location of the center of mass m ($0 \le x_m \le L$, $y_m \le h_x$) is changed.

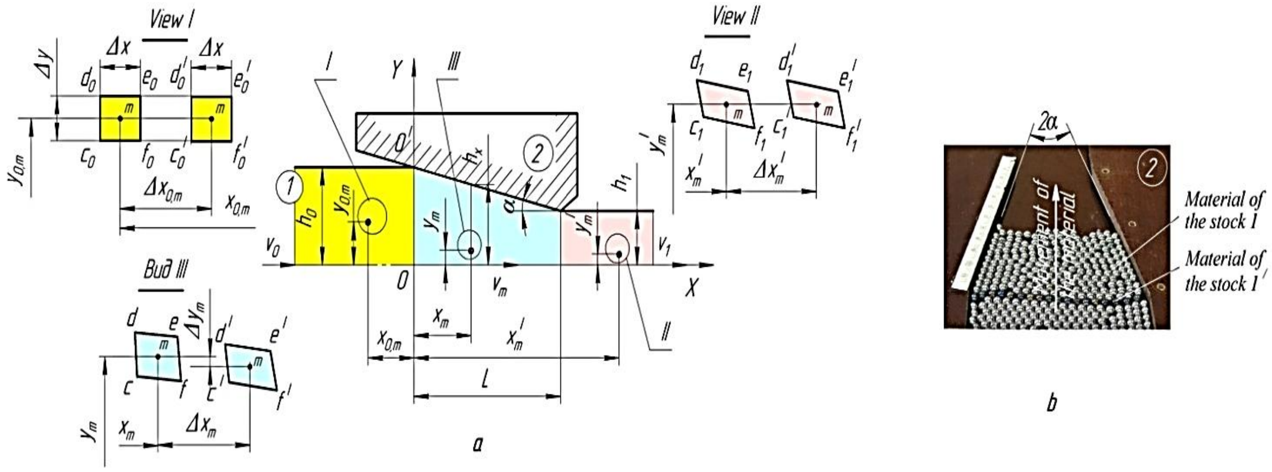

Fig. 2. Scheme of deformation of stock material in the form of elementary volumes:
a – made of plastically deformable material; b – during modeling

During movement of the center of mass m with displacements Δx_m and Δy_m the dimensions and the position of the side surfaces of the elementary volume $c^/ d^/ e^/ f^/$ without change of the area Δs during flat strain [2]

$$\begin{cases} \dfrac{\partial U}{\partial x} + \dfrac{\partial V}{\partial y} = 0; \\ \dfrac{\partial U}{\partial y} + \dfrac{\partial V}{\partial x} = 0, \end{cases} \tag{1}$$

where $U = U(x, y)$ and $V = V(x, y)$ – respectively the displacement functions of the stock material in the deformation zone along the coordinate axes OX and OY. In this case the displacement functions can be represented in the form:

$$\begin{cases} U(x, y) = s_{m,x} + U_\Delta(x, y); \\ V(x, y) = s_{m,y} + V_\Delta(x, y), \end{cases} \tag{2}$$

where $s_{m,x} = \Delta x_m$ and $s_{m,y} = \Delta y_m$ – respectively, the displacement of the center of mass of the elementary volume $cdef$ in deformation zone in the directions the coordinate axes OX и OY; $U_\Delta(x,y)$ and $V_\Delta(x,y)$ – respectively, the displacement functions along the coordinate axes OX and OY in the location of the center of mass of the elementary volume.

That is the change in the position of a non-deformable point taken as the center of mass of the elementary volume of the stock material can, in a first approximation, characterize the local deformation of this elementary volume [8, 9].

Based on the foregoing is proposed it is the method [10] for modeling the kinematics of local plastic deformation (Fig. 2, *b*) according to which the stock material is represented in the form of a single row of magnetized colored balls contacting each other 1 and $1'$, which move in the axial section of a geometrically similar model of tool *2*. Simultaneously with the relative movement of the balls at the exit of the tool (due to the displacement of the model of the tool in the opposite direction) digital filming is carried out, which allows us to analyze the model of plastic deformation in the dynamics of the process and its photographs at any time during modeling of plastic deformation.

On Fig. 3, *a* the initial position of the vertical layer of balls is given $1'$ at the entrance to the deformation zone is shown. On the Fig. 3, *b* is shown intermediate position of the initial layer of darkened balls $1'$ in the deformation zone. On the Fig. 3, *d – e* $1'$ is shown at the exit from the deformation zone.

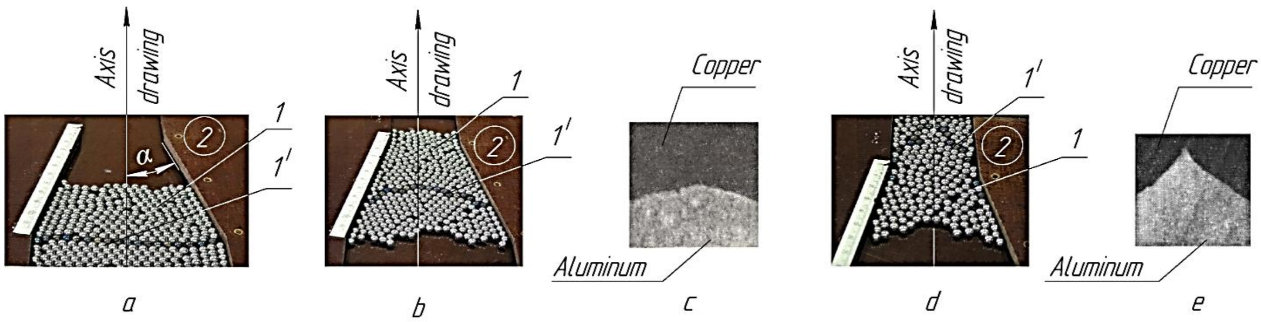

Fig. 3. Modeling the displacement of a vertical layer ($1'$ – darkened balls) of the material (1 – white balls) of the stock in the deformation zone:

a – at the entrance to the deformation zone; *b* – inside the tool; d – at the exit from the monolithic tool; *c* and *e* – polished sections of welded stock deformed in monolithic tool [7]

To compare the results of the simulation with the results experimental research the polished sections of the places of preliminary welding of the round wire made of aluminum and copper after drawing with drawing ratio μ: *в* – $\mu = 2{,}2$; *д* – $\mu = 3$ [7] are shown on the Fig. 3, *c* and *e*.

Analysis of the results of the study presented on Fig. 3 shows that the mechanical "ball-shaped model of local deformation" shows the nature of the change in the shape of the transverse layer of a plastically deformed stock and can be used to investigate the local deformation of any (by location) layer of stock material at the entrance to a monolithic tool.

Fig. 4 shows fragments of changes in the positions of points (balls) of the axial source layer of material of the stock (balls $1'$) before the entrance to the deformation zone (Fig. 4 *a*), in the deformation zone (Fig. 4 *b*) and outside the deformation zone (Fig. 4 *c*). Analysis of photos on Fig. 4 *a*, *b*, *c* shows that the points of the stock material in the axial layer before entrance to the deformation zone (darkened balls $1'$ on Fig. 4, *a*) practically remain on the axis of symmetry of the stock as in the deformation zone (Fig. 4, *b*) and outside the tool (Fig. 4, *c*).

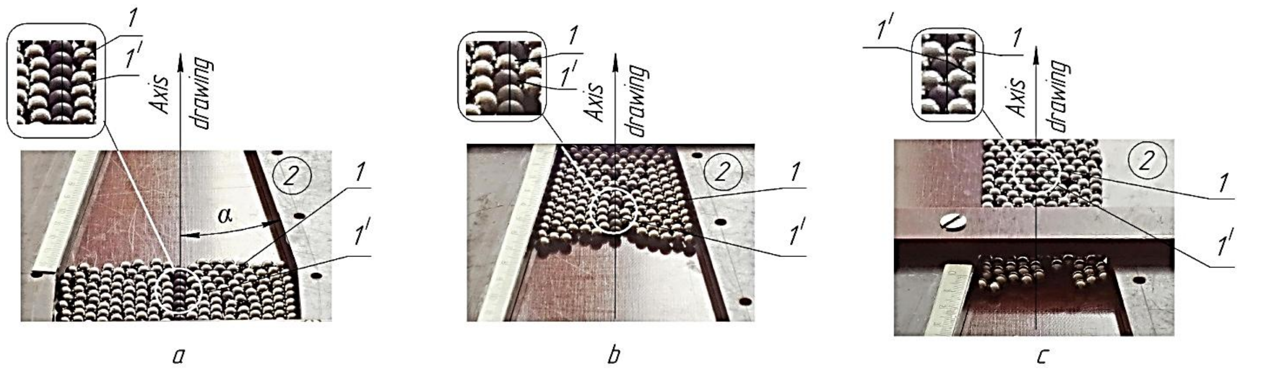

Fig. 4. Modeling the movement of the axial layer ($1'$ – darkened balls) of the material of the stock (1 – white balls) in the deformation zone during drawing:

a – at the entrance to the deformation zone; *b* – inside the tool; *c* – at the exit from the tool

At the same time, between them on the axis of symmetry inside the deformation zone white balls (Fig. 4, *b*) move from layers located above and below in the direction of the darkened balls. These white balls stay on the axis of symmetry of the deformed strip outside the tool (Fig. 4, *c*). This kind of local deformation of the stock material in the location of the axis of symmetry of the deformation zone indicates that for a part of the stock material (darkened balls on the fig. 4, *b*) on the axis of symmetry the velocity is equal to $v_y(x, y=0)=0$ and for the other part of the material (white balls on the Fig. 4, *b*) the velocity is equal to $v_y(x, y=0) \to 0$.

On the Fig. 5 is shown fragments of changes in the positions of the points (balls) of the outer source (darkened $1'$) layer of the stock material (balls $1'$) before entering the deformation zone (Fig. 5 *a*) in the deformation zone (Fig. 5 *b*) and outside the deformation zone (Fig. 5 *c*).

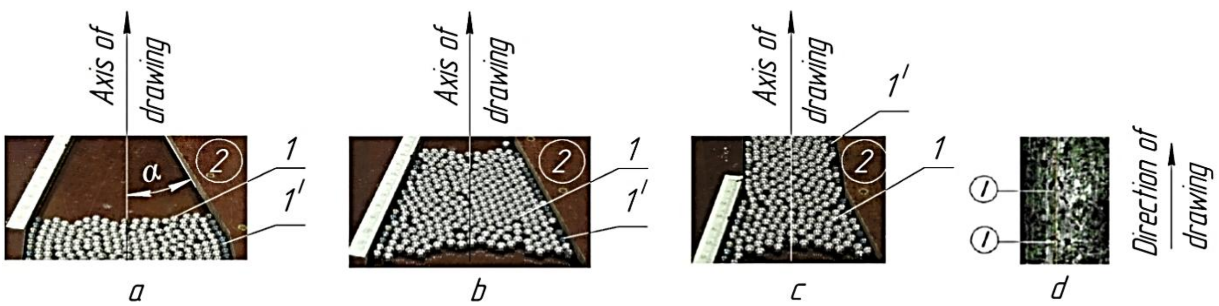

Fig. 5. Modeling the movement of the surface layer ($1'$) of the material (1) of the stock during drawing:

a – at the entrance to the deformation zone; *b* – inside the tool; *c* – at the exit from the deformation zone; *d* – wear of the surface of the drawn wire

Analysis of photographs on the fig. 5 *a*, *b*, *c* shows that the points of the stock material on the surface before entering the deformation zone (darkened balls $1'$ on the Fig. 5, *a*) stay on the surface in the deformation zone (Fig. 5, *b*) and outside the tool (Fig. 5, *c*). Between them inside the deformation zone fresh points of the material of the stock appear from the internal (deep) layers of the stock (white balls on the Fig. 5, *b*), which stay on the contact surface of the stock, providing conditions for monotonous deformation of the stock during the laminar flow of the stock material [8]. This type of relative movement of the stock material causes uneven wear of the surface of the deformed stock. On the fig. 5, *d* a photograph of a fragment of the surface of deformed wire (x100) with locations of increased wear I is shown.

CONCLUSION

The optical method for research of local deformations of a mechanical model of the stock made of magnetized colored balls moving in a geometrically similar model to visualize the characteristic features of the deformation process depending on the technological parameters of drawing is developed.

These features of the kinematics of the deformation in monolithic tool determine the boundary conditions of the deformation process of the strip, which must be taken into account when developing a mathematical model for calculation of energy-force parameters of the drawing process, wear of contact surface of the tool and the finished product.

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