INVESTIGATION OF THE PARAMETERS OF THE QUALITY AT AN AXISYMETRIC DRAWING

ИССЛЕДОВАНИЕ ПАРАМЕТРОВ КАЧЕСТВА ПРИ ОСЕСИММЕТРИЧНОЙ ВЫТЯЖКЕ

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Abstract : *Based on the analysis of the initial equations of the plastic state,established the distribution of strains in the initial and final stages of axisymmetric drawing. The dependencies to assess the accuracy of linear and diametrical sizes taking into account volumetric of strain state.*

Keywords**:** stress, strain, deep drawing, hardening, sheet blank.

1. Introduction.

One poorly developed theoretical problems of the drawing process is to assess the impact of amount and distribution of stress and strain on parameters and strength of precision manufactured parts. The scientific-technical handbooks no calculated based, allowing to determine the maximum possible deviations of linear and diametrical dimensions and strength values at different degrees of deformation and technological characteristics of the materials used [1, 2].

This state is due to the fact that the existing theoretical approaches to the creation of science-based methods for the analysis of the stress-strain state built, as a rule, based on simplifying assumptions, the most important of which are the adoption of the plane scheme strain state, the analysis methods of deformation theory with the approximate conditions of plasticity adoption perfectly rigid-plastic model deformable material.

The decisions derived from such approaches are very approximate and provide a idea of the stress-strain state of the blank. Besides this, the theoretical analysis methods developed in many respects depend also on the interests of authors of scientific studies and carry to some extent subjective.

An essential feature of the drawing process is that initially the same material elements sheet blank, plastically deformed acquire certain identity, characterized by changing the thickness of the accumulated value of deformation due to hardening effects, the change indicator of resistance to deformation.

Obviously, the performance precision linear and diametrical sizes of cylindrical parts of an isotropic material, manufactured by drawing, without the influence of the he elastic aftereffect must be due to the value and distribution of finite deformation and strength parameters under the same conditions - the total and the distribution of the index of deformation resistance.

In the present paper the process of drawing cylindrical parts sets the following tasks:

- *Establishment of settlement dependences allowing to define the dimensions of workpieces with volume strain state;*
- *Determination of the distribution of finite quantities and component deformation and deformation resistance index.*

2.An analysis of the initial stage of the drawing process.

Numerous studies have established that the drawing process starts with plastic deformation of the uncompressed part annular portion of the blank located between the contact zones deforming tools[3,4].At this stage, as you move the deforming tool is increasing stress deformation and plastic deformation of the flange cover the entire piece. Set a balance between effort and drawing resistance to plastic deformation of the flange and the second stage of the process - the retraction flange blank into a die.

At the initial stage of the outer boundary of the plastic material and the field elements are moved radially in opposite directions, and the second stage - in the same direction. In both phases of the size of the plastic zone are continuously changing, so that the process of forming the blank is transient in nature. Therefore, scientifically based methods of analysis of drawing should be based on the theory of plastic flow with the hardening material and of volumestrain state.

Given the complexity of the analysis of the processes occurring in the initial stage of drawing, first consider an axially symmetric tension thin plate with a low-cut, limited radius circular contour r_0 along which the specified uniformly distributed normal stresses σ_ρ .Existing solutions such tasks usually carried out either for a plate of constant thickness, or for perfectly rigid-plastic model deformable material with plasticity condition for the hypothesis of constant maximum shear stress, thus cannot be used for the task [5].

In [6,7] that the stress-strain state in the process of forming an axially symmetric parts from sheet metal appropriate and convenient to represent the deviatory plane Mises plasticity cylinder in oblique two-dimensional coordinate system. The possibility of such a representation should be the condition on which the incompressible materials for three linear strain are interdependent and have only two degrees of freedom, as well as the assumption that the deformation of the blank with the flange stretching occurs under conditions close to the plane stress[3].

In these studies found that the module current vector magnitude equivalent strain is numerically equal to the value of accumulated deformation (strains rate), the current value of the linear strains are the projections of the vector equivalent strain in the oblique coordinate axes, and the pattern of accumulation of strains in this material element describes the nature of the change in the vector equivalent strain in time.

Consequently, the problem of assessing the performance precision linear and diametrical sizes, as well as the final value of the index of deformation resistance is reduced to the analysis of time-dependent vector fields equivalent deformations.

The [6,7] initial equations of plastic flow under plane stress deformation and axial symmetry, namely the equilibrium equation for the changes in thickness of the material condition of plasticity Mises condition of constant volume equation relating voltage and increment (speed) of strains are shown in single structure and displayed in the deviatoric plane plasticity cylinder as the differential between the radial dependence of tensile stress and strain accumulate $d\sigma_\rho = \sigma_s d\varepsilon_i$.

Acceptance of the power law strain hardening $\sigma_s = A\varepsilon_i^n$ allowed to integrate said differential dependence and dependence to obtain and a component of accumulated strains on a parameter φ ωin the form of:

$$\left.\begin{aligned} |\vec{\varepsilon}|_1 &= \varepsilon_i = (\ln K + n)\frac{2}{\sqrt{3}}\cos(\varphi + \pi/6); \\ \varepsilon_\rho &= \frac{\ln K + n}{2}\left(1 + \cos 2\varphi - \frac{\sqrt{3}}{3}\sin 2\varphi\right); \\ \varepsilon_\theta &= -\frac{\ln K + n}{2}\left(\cos 2\varphi + \frac{\sqrt{3}}{3}\sin 2\varphi\right); \\ \varepsilon_z &= -\frac{\ln K + n}{2}\left(1 - \frac{2\sqrt{3}}{3}\sin 2\varphi\right). \end{aligned}\right\} \quad (1)$$

where $|\vec{\varepsilon}|_1$ - the magnitude of equivalent strain in the initial stage of the drawing process, $n = \ln(1+\delta)$ - in the received exponent law strain hardening , δ - relative uniform deformation of the material when tested in uniaxial tension, φ - the angle between the polar axis and the radial strain vector equivalent strain varying within $0 \le \varphi \le \pi/3$ (Fig. 1), $\varepsilon_\rho, \varepsilon_\theta, \varepsilon_z$ - linear deformations, respectively, in the radial and circumferential directions, as well as perpendicular to the workpiece surface, the coefficient of drawing $K = R_0/r_0$ (R_0 and r_0 - respectively outer radius of the workpiece and the radius of the point of the die).

Dependence $\varepsilon_i(\varphi)$ on deviatoric plane is a circle of radius $(\ln K + n)/\sqrt{3}$ $(\ln K + n)/\sqrt{3}$, centered on the line $\varepsilon_\theta = 0$ and passes through the origin [6].

The possibility of integrating the differential above depending based on the assumptions made about the same for the considered material element of the vector direction of the increment equivalent strain in the deviatoric plane, which is equivalent to the assumption of proportional relationships change over time component strains $(\varepsilon_\rho/\varepsilon_\theta = const)$.

Upon receipt of (1) the following dependence for the radial and circumferential stress

$$\sigma_\rho = \sigma_s \frac{2}{\sqrt{3}}\cos(\varphi + \pi/6); \quad \sigma_\theta = -\sigma_s \frac{2}{\sqrt{3}}\sin\varphi \ , \qquad (2)$$

satisfying Mises plasticity plane stress condition and set of joint solution of the equations of stress and communication increments (speeds) strains with the condition that the volume [7] .

From the analysis of (1) that the resulting solution can be represented as the sum of two deformed states. The first term describes the initial plastic state for ideal rigid-plastic model deformable material ($n = 0$) is the largest size of the plastic zone $(K = e)$ and characterizes the distribution of strains in the parameter φ. The second term linearly superimposed on the first, describes the increment of strains at a given index in the received power-law strain hardening.

Such an interpretation of the results based on the fact that the oblique axes in the deviatoric plane are logarithmic dimension, whereby it becomes possible additive sum strains.

Dependencies (1) and (2), describing the stress-strain state are closed parametric solution of axially symmetric stretching thin plate with a low-cut, limited circular contour, taking into account the interdependent changes in the thickness of the material and work hardening.

From (1) it also follows that as the indicator, the relative magnitude of the plastic region increases in the direction of the inner contour (reduced radius of the inner contour). This result follows from the condition, according to which the external contour of the workpiece is realized the stress state of the linear compression, regardless of the relative magnitude of the field of plastic and technological characteristics of the deformable material.

In between these kinds of deformed states is a smooth transition from one type to another strain state. The schedule of dependence (1) and (2) as well as the main characteristics of the distribution of stresses and strains in detail in [7,8].

(1) is determined by the highest relative value of the plastic region $R_0/r = \exp(1+n)$ (R_0, r - respectively the radii of the outer and inner contours of the plate in a deformed state). Obviously, when $n = 0, r = r_0$, the relative value $K = R_0/r_0 = e(\approx 2,718)$ and coincides with the results of the prior art for a plate of constant thickness at an ideal rigid-plastic model deformable material [3,5].

3. An analysis of the second stage of the drawing process.

The main problem of analysis of the second step drawing process is obtained for mapping the initial stage parametric solutions (1) and (2) into the material of the deformable medium of the preform. To do this, first consider the process of being drawn into the die blank flange, excluding the effect of hardening $(n = 0)$ and bending effects on the stress-strain state.

With the reduction of the outer radius of the blank flange material elements moving radially coordinates $R_0 \le \rho \le r_0$, accumulate a certain deformation and radius reaching further move vertically without deforming. At the end of this process for forming cylindrical parts set a specific variable distribution of accumulated strain, the values of which can be determined by the well-known relationship between the parameter φ in the deviatoric plane and relative coordinates ρ/r_0 in a material medium deformable billet.

The previous section established that for a perfectly rigid-plastic model deformable material nature of the distribution of the accumulated deformation in (1) and radial stresses in relative units (2) are similar in the deviatoric plane and described the same functional dependence $F(\varphi) = (2/\sqrt{3})\cos(\varphi + \pi/6)$. From (1) and (2) it also follows that the initial stage of drawing $(\sigma_s = \sigma_{0,2}; \varepsilon_i = 0,2\%; n = 0)$ blank thickness remains constant,

the distribution of radial stresses in relative units of well-known solution has the form $\sigma_\rho/\sigma_s = \ln R/\rho$ [3] on the basis of which (2)

$$\frac{\rho}{r_0} = K^{\left[1 - \frac{2}{\sqrt{3}}\cos\left(\varphi + \frac{\pi}{6}\right)\right]}. \qquad (3)$$

For (1) and (3) it is possible to find the distribution of the accumulated strain in the deviatoric plane and forming the cylindrical member. Different range φ of fixed K and (3) defines the relationship ρ/r_0 $0 \le \varphi \le \pi/3$ and the value calculated by the formula $\varepsilon_\theta = \ln(r_0/\rho)$ district deformations. Among the relevant points of the negative direction of the axis ε_θ drop a perpendicular to the intersection with radial rays φ. Connect the start of oblique coordinate the points of intersection is set equivalent to the vector field strains for all material elements.Based on the generality of the methodical approach and to simplify the numerical calculations, the outer radius of the plastic zone R_0 is adopted when changing K is the fixed and variable radius of the die is considered r_0.

From trigonometric representation strains in the deviatoric plane (Figure 1) shows $\varepsilon_\rho/|\varepsilon_\theta| = \cos\varphi/cos(\pi/3-\varphi)$ where the absolute value of the components of the district, according to (3) shall be determined from the equation $\varepsilon_\theta = \ln(\rho/r_0)$. On the basis of the established relationship between φ the parameter and the relative coordinate ρ/r_0 in a material medium deformable billet it becomes possible to install the distribution component of finite deformations and appropriate equivalent deformations of the vector field

$$\left.\begin{aligned} |\vec{\varepsilon}|_2 &= \frac{|\varepsilon_\theta|}{\cos(\pi/3-\varphi)}; \\ \varepsilon_\rho &= [1-F(\varphi)]\frac{\cos\varphi}{\cos(\pi/3-\varphi)}\ln K; \\ \varepsilon_\theta &= -[1-F(\varphi)]\ln K; \\ \varepsilon_z &= [1-F(\varphi)]\left[1-\frac{\cos\varphi}{\cos(\pi/3-\varphi)}\right]\ln K \end{aligned}\right\}, \qquad (4)$$

where $|\vec{\varepsilon}|_2$ - the magnitude of equivalent strain (cumulative strain) in the second stage of the drawing process.

Figure 1 shows a plot of the component deformation and deformation resistance index at the end of the second stage drawing at K = 2 assigned in accordance with (3), to the original plastic state. From the analysis of (4) and provided graphs implies that the radial component of the outer contour near the blank (at a certain distance from the end of the extended parts (ρ/r_0 = 1.76) reached the highest value (0.36), and the strain in the thickness achieves the lowest (-0.047) values near the points of the matrix (at some distance from the bottom of the elongated parts ρ/r_0 = 1.13). On the basis of (3) and (4) it is possible to define the size of blanks on the set sizes detail and thickness distribution of the generator with volume strain state.

The current value for a given height K and $h(\varphi)$ can be determined by comparing the width $d\rho$ of the ring members on the initial preparation and the increment dh in the cylindrical part, according to the expression $\varepsilon_\rho = \ln(dh/d\rho)$, which, after transformation, taking into account (3) and (4) leads to the following differential equation

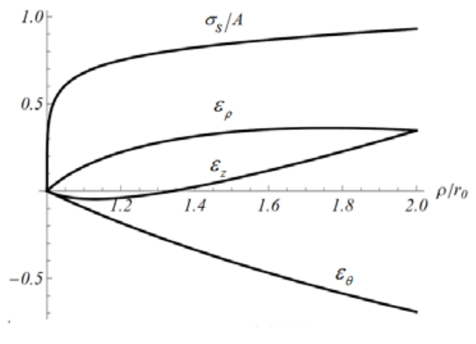

Figure 1. *The distribution of the components of deformation and deformation resistance index at the end of the second stage drawing*

$$d\left(\frac{h}{r_0}\right) = K^{[1-F(\varphi)]\left[\frac{\cos\varphi}{\cos(\pi/3-\varphi)}+1\right]}\frac{2}{\sqrt{3}}\sin(\varphi+\pi/6)\ln K d\varphi. \qquad (5)$$

Integrals $\int_0^\varphi \Phi(\varphi;K)\ln K d\varphi$ allow us to determine the current value of the relative height of the cylindrical part $h/r_0(\varphi)$ of the annular portion of the blank $\rho - r_0$, as well as the distribution of thickness in a volume strain state.

The main difference between the stated and the actual drawing process is that when drawing deforming tool in a region close to the inner contour of the blank has the effect of limiting the radial movement of certain material elements. Material element initially located at a radius r_0 moves vertically in the absence of circumferential strain $(\varepsilon_\theta = 0)$ and, according to the equation $\varepsilon_\rho = |\varepsilon_z|$, it is deformed in a shear plane $(\rho;z)$.

The vector equivalent strain characterizing the deformation of the element, the deviatoric plane is shifted to the left and becomes perpendicular to the axis ε_θ, and the parameter φ has values in the range $-\pi/6 \le \varphi \le \pi/3$. Absence of circumferential deformation at constant unit vector equivalent strain offset by increased strain thinning.

4. Results and discussion. Let us compare the results of studies with similar results obtained by making assumptions about the constancy of the thickness of the material in the process of drawing cylindrical parts with a diameter $2r_0$ and height h, excluding the radius of curvature [2]:

$$\frac{h}{r_0} = \frac{1}{2}(K^2-1) \ . \qquad (6)$$

For the same K values h/r_0, taking into account the volume of strain state, is smaller than the corresponding values calculated by (6) $(2,72 \to h/r_0 = 2,66;\ 2 \to h/r_0 = 1,34;\ 1,5 \to h/r_0 = 0,59)$. In expressing this difference as a quadratic trinomial, after determining the relevant standing, we obtain the expression $\Delta(h/r_0) = 1/3[(2/3)K^2 - (5/3)K + 1]$, from which it follows that the relative height of the cylindrical part, with the of volume strain state $1,5 \le K \le e$ it can be written as:

$$\frac{h}{r_0} = \frac{1}{2}(K^2-1) - \frac{1}{3}\left(\frac{2}{3}K^2 - \frac{5}{3}K + 1\right) \ . \qquad (7)$$

From a comparison of (6) and (7) it follows that the relative error of the height of the cylindrical part, without changing the thickness reaches 20%.

Despite some arbitrariness of the analysis obtained calculated dependences allow to determine the relative error of linear and diametrical sizes, as well as indicators of resistance to deformation and to evaluate the quality of cylindrical parts.

5. Conclusion

1. Is given the theoretical accuracyestimateof linear and diametrical sizes and index of resistance to deformation of cylindrical parts in drawing.
2. Set vector fields equivalent deformations for the initial and final stages of the drawing process.
3. Based on the display of finite strains in deformed blank material environment identified characteristic features of the distribution of the radial deformation and deformation in thickness.

6. References

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