ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 11 , November 2022

Optimization of Deep Hole Machining with Centrifugal Rolling

Fayzimatov Shukhrat Numanovich, Yakupov Artur Mansurovich, Khusanov Yunusali Yuldashaliyevich

P.G. Doctor of technical sciences, professor Department of "Mechanical engineering and automation", Fergana Polytechnic Institute, Fergana, Uzbekistan

Candidate of technical sciences, professor Department of "Mechanical engineering", Andijan Machine-Building Institute, Andijan, Uzbekistan

P.G. Doctor of technical sciences, professor Department of "Mechanical engineering and automation", Fergana Polytechnic Institute, Fergana, Uzbekistan

ABSTRACT: The processing of holes of large diameters with rotary tools presents certain difficulties, primarily due to the difficulty of ensuring stable deformation modes, and, consequently, the desired surface quality, as well as ensuring the size of the machined part within its tolerance. With an increase in the diameter of the hole with the same quality of accuracy, the tolerance increases.

Since the penetration depth of the deforming elements is commensurate, and even slightly less than the radial tolerance of the hole being machined, then when setting the tool to a given size, taking into account the measurement error, as well as the probabilistic nature of the actual dimensions of the holes coming for machining, the deformation force varies within certain limits. In addition, the use of traditional rotary tools involves the use of very expensive large support cones, which often fail under the influence of significant deformation forces and contact stresses.

KEY WORDS: rolling, tool, processing, deforming, plastic,

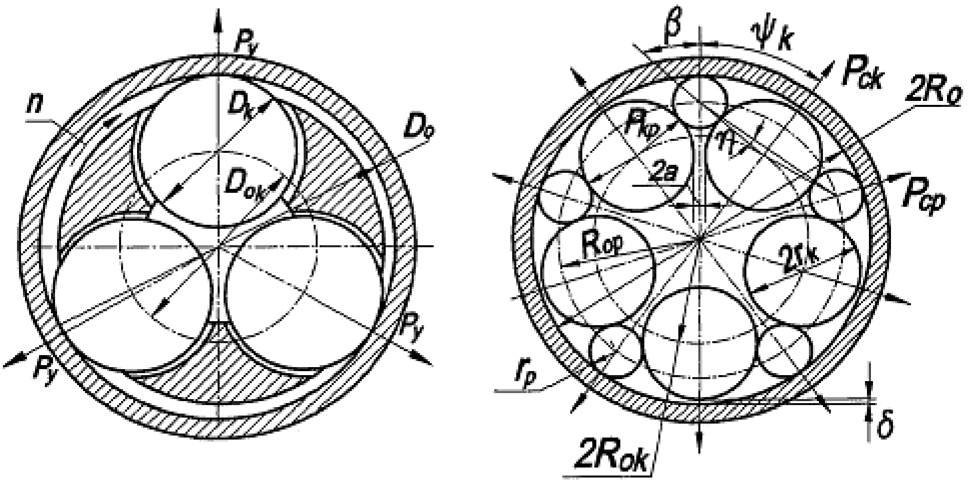
I. INTRODUCTION

Currently, centrifugal rolling has not found wide and widespread use, since there are no justifications for the expediency of its use and a method for calculating the optimal design parameters of the tool and technological processing modes.

The efficiency of a centrifugal rolling tool depends on the processing scheme and its design. At the same time, it is necessary to solve the issues of manufacturability in manufacturing, reliability in operation and maintenance, stability of the rolling process and the quality of the machined surface of the part. With centrifugal rolling, two layouts of the tool are possible. Let's conditionally call them direct rolling (Fig. 1, a) and rolling through intermediate track rollers (Fig. 1).

Processing in both cases is carried out by rotating the tool with a given frequency nu, during which the deforming elements move in the radial direction and, when interacting with the surface of the part, plastic deformation is carried out under the influence of the centrifugal force Ru Since the masses of the rollers and deforming elements are constant, and the rotation of the motor shaft almost does not change, this ensures a stable deformation force. For the convenience of calculations, in further calculations we will use the index "p" for the deforming roller and the index "k" for the track roller.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022



a b

Figure. 1. Schemes of layouts and actions of centrifugal rolling: a) - direct action; b) - through intermediate track rollers; r_p-radius of deforming elements;

R_{op}~ radius of the circle described by the centers of the deforming elements; R_{ok}- radius of the circle described by the centers of the intermediate rollers; R_o~ hole radius machined hole radius; P_y- deformation force (centrifugal force); $2\Psi_k$- angle between adjacent intermediate rollers or deforming members; η- the angle between the force acting on the deforming element from the track roller and the chord connecting the centers of the deforming elements; β- the angle between the direction of the deformation force and the chord connecting the centers of the deforming element and the track roller; δ-gap between the track roller and the hole to be machined; 2a- gap between adjacent road wheels; P_{ck}- centrifugal force acting on the deforming roller; P_{cp}- centrifugal force acting on a deforming element; P_{kp}- force acting on the deforming element from the side of the track roller.

II. MATERIAL AND METHODS

Thus, the formulas for calculating the centrifugal forces acting on the roller and roller will look like:

$$P_{cp} = \frac{m_p V_{op}^2}{R_{op}}; \; P_{ck} = \frac{m_k V_{ok}^2}{R_{ok}}; \qquad (1)$$

where P_{cp}, P_{ck}- centrifugal forces acting on rollers and rollers; , m_k- weights of rollers and rollers;V_{ok},V_{op}- speed of rotation of the axes of rollers and rollers around the axis of the part; R_{op}, R_{ok}- radii of circles described by the axes of rollers and rollers.

Since rollers and rollers are bodies of revolution, in sections perpendicular to the tool axis, they will be represented by circles. Assuming that the track rollers are straight cylinders, and the conical rollers have a small taper angle, they can also be represented as straight circular cylinders with a diameter equal to the average diameter of the rollers.

Masses of rollers and rollers are determined from dependencies

$$m_k = \pi \cdot r_k^2 \cdot L_k \cdot p_k; \; m_p = \pi \cdot r_{cp}^2 \cdot L_p \cdot p_p; \qquad (2)$$

where r_k, L_k- radii and lengths of rollers, respectively; ρ_k, ρ_p- material density of rollers and rollers.

The speeds of rotation of the axles of the rollers and rollers are calculated by the formulas

$$V_{ok} = \frac{\pi \cdot R_{ok} \cdot n_u}{30}; \; V_{op} = \frac{\pi \cdot R_{op} \cdot n_u}{30}; \qquad (3)$$

where n_u- tool speed, s^{-1}.

The dimensions of the track rollers and deforming rollers depend on their accepted number and the radius of the workpiece, therefore they are interconnected by a certain functional dependence. For example, for the values of the radii of circles described by the centers of rollers and rollers ; Rop, Rok in formulas (1) can be written

$$R_{op} = R_o - r_p; \; R_{ok} = R_o - r_k; \qquad (4)$$

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

where R_o- hole radius.

Подставив выражения (2), (3) и (4) в ф-лу (1) и, выполнив преобразования, получим

$$P_{ck} = C \cdot (r_k^2 \cdot R_o - r_k^3), \quad (5)$$

where the notation $C = \frac{\pi^3 \cdot L_k \cdot p_k \cdot n_u^2}{900} = const$

Having differentiated expression (6), taking as an independent variable the radius of the roller at a constant radius of the workpiece, and equating the derivative to zero, we obtain the equation

$$\frac{dP_{ck}}{dr_k} = 2 \cdot C \cdot R_0 \cdot r_k - 3 \cdot C \cdot r_k^2 = 0 \quad (6)$$

The solution of this equation gives the value of the roller radius, which provides the maximum deformation force during straight rolling

$$r_{kmax} = \frac{2}{3} R_0 = \frac{D_0}{3} \quad (7)$$

The resulting dependence shows that when machining holes according to the direct rolling scheme, the maximum force at a constant tool speed and roller length is achieved when the roller diameter exceeds half the radius of the part (Fig. 2).

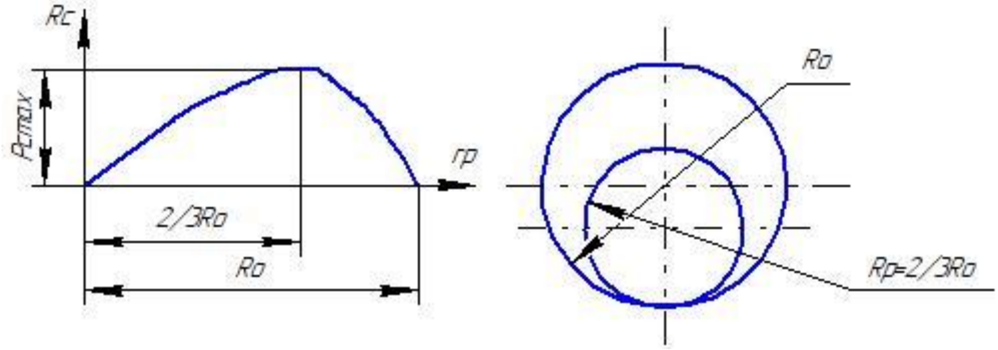


Figure.. 2. Change in the centrifugal force acting on the roller from its radius for a given hole diameter

Under this condition, only one roller can be installed in the instrument. To ensure the balance of the tool, it is necessary to install at least two rollers in it. Thus, in a balanced tool containing at least two rollers, with an increase in their size, the deformation force will increase. In thhais case, the contact area increases proportionally, and the average pressure and maximum stress in the center of the contact almost do not change, or change very slowly.

The main task when choosing the design parameters of the tool is to ensure a given stable quality and productivity, which are determined by the design parameters of the deforming rollers and the choice of the required deformation force.

Since the quality indicators of the surface layer are functions of the average and maximum stresses in the contact, an increase in the size of the rollers to increase the centrifugal force at a given tool speed does not lead to the required results. It follows from this that the design of the tool must be provided with such geometric parameters of the deforming rollers that, at a given tool rotation frequency, create the required geometric parameters of the contact and the specified stress state in the contact zone.

In production practice, two types of rollers are used: profiled, the working surface of which is the surface of a torus with a profile radius Rpr, and conical, forming a drop-shaped contact during processing (Fig. 3.). From the point of view of providing high performance with the required surface quality, a drop-shaped contact is more preferable than an elliptical contact. At the same time, the design of the tool for centrifugal rolling should be universal, allowing the installation of deforming elements of any configuration, including toroidal and tapered rollers..

Consider the layout of a centrifugal tool with a different number of deforming rollers and track rollers (Fig. 4). One of the design parameters of the centrifugal forming tool that affects the deformation force is the angle η. This is the angle between the segment connecting the centers of two adjacent rollers, and the direction of the force P_{cr} acting between the deforming rollers and the track rollers.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

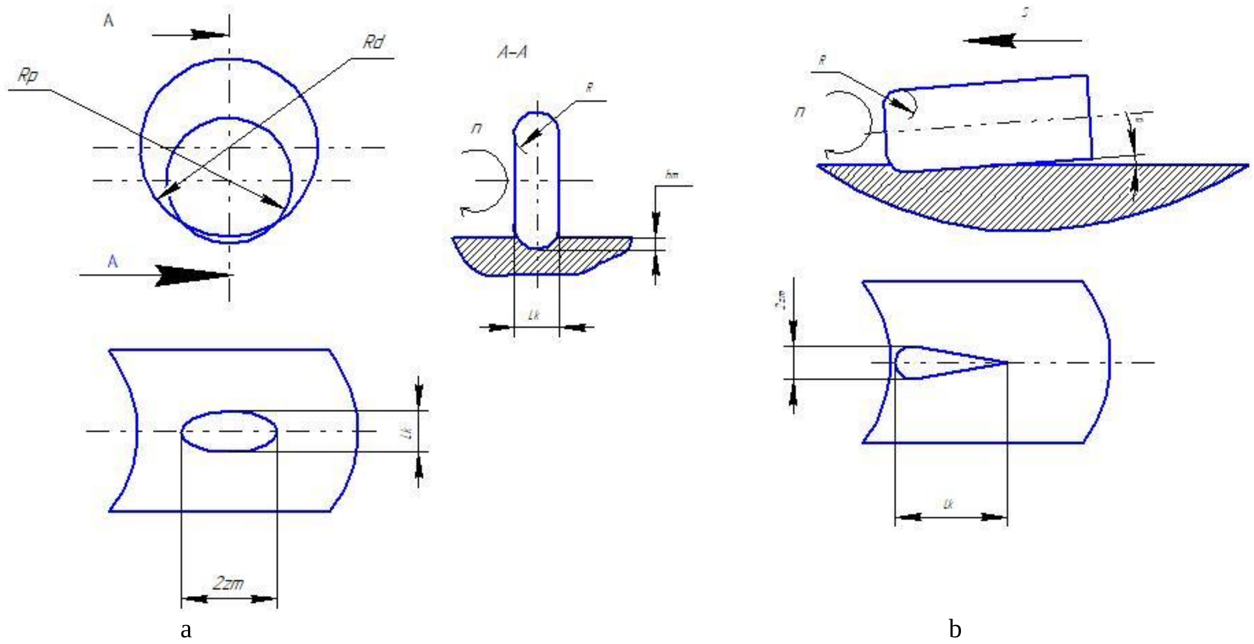


Figure. 3. The main types of rollers and the forms of contacts formed during the processing of these rollers: a- processing with a profile roller (ellipse contact shape), b- processing with an elongated conical roller (tear-shaped contact form)

However, for schemes with two and three road wheels, as can be seen in Fig. 3, a and Fig. 4, the angle is negative, and with four rollers, the angle η=0. This means that the rollers and track rollers under the action of centrifugal forces do not interact with each other during processing, but diverge in radial directions each separately (Fig. 4, c).

Therefore, in the case when the tool uses less than five rollers, the implementation of the processing scheme through the intermediate rollers is impossible and is converted into a direct action scheme.

Thus, processing through intermediate track rollers is possible when at least five rollers are installed in the tool. Taking into account that the centrifugal force Psu grows in proportion to the increase in the size of the rollers, the five-roller tool provides the maximum deformation force according to the processing scheme with intermediate support rollers. With a larger number of rollers and rollers, their dimensions decrease, therefore, the centrifugal force also decreases at the same tool speed. When assembling the tool according to the scheme of rolling through the intermediate track rollers. With a larger number of rollers and rollers, their dimensions decrease, therefore, the centrifugal force also decreases at the same tool speed..

When assembling the tool according to the scheme of rolling through the intermediate rollers, the deforming rollers have dimensions significantly smaller than the track rollers. This allows processing with less deformation force, and, consequently, with a lower tool rotation frequency compared to processing according to the direct rolling scheme..

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

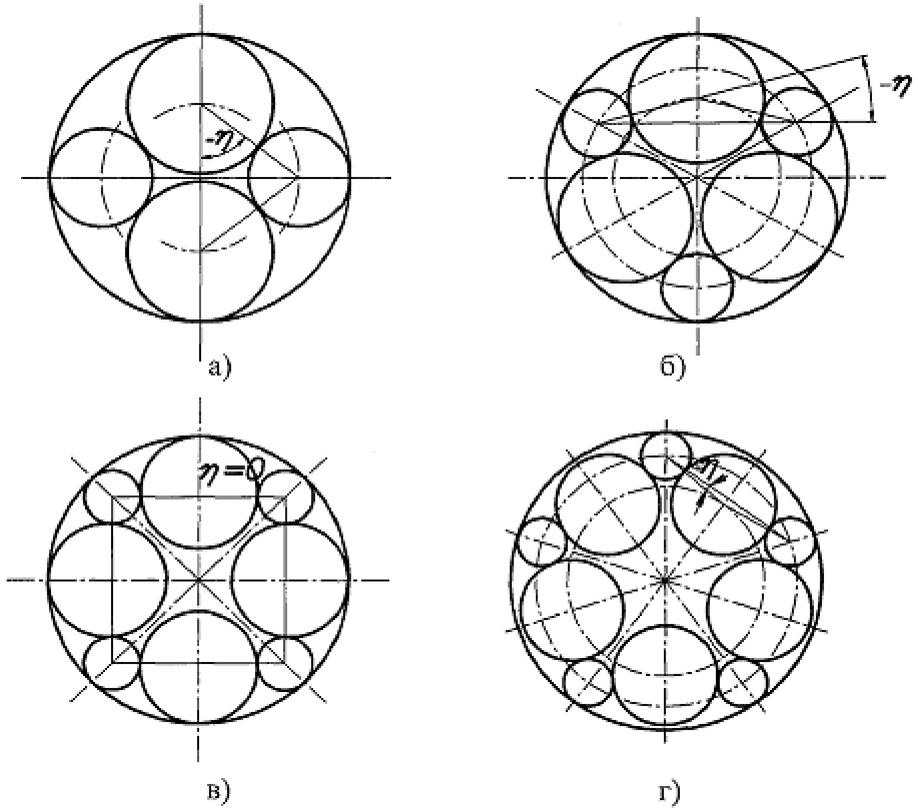


Figure. 4. Possible configurations of the centrifugal tool design: a) 2 rollers; b) -3 rollers; c) -4 rollers; c) -5 rollers

On the basis of the foregoing, it can be concluded that the use of deforming rollers of rational diameters in the tool, which ensure the achievement of the required quality of the machined surface with a minimum deformation force, is possible only according to the layout scheme of the centrifugal forming machine through intermediate support rollers in five roller centrifugal forming machine.

The implementation of centrifugal rolling in the form of a specific tool design can be carried out after identifying the relationship between the power and design characteristics of the centrifugal forming machine and the technical indicators of the PPD process.

The deformation force during centrifugal rolling directly depends on the design parameters of the tool and the frequency of its rotation. The calculation scheme for determining the mathematical model of the relationship between the structural elements and the force factors of the forming tool is shown in fig. one.

The angle between two adjacent deforming rollers, as well as track rollers, is equal to:

$$\Psi_k = \frac{\pi}{z_p}, \qquad (8)$$

where z_p- the number of deforming rollers and, accordingly, the rollers in the forming machine. On the other hand

$$sin(\Psi_k) = \frac{r_k + a}{(R_0 - \delta) - r_k}, \qquad (9)$$

where $r_к$-the radius of the track roller, Ro is the radius of the hole being machined, a is the gap between adjacent track rollers, δ is the gap between the track roller and the hole being machined.

Transforming expression (8), we find the value of the radius of the track roller:

$$r_k = \frac{(R_0 - \delta)\sin(\Psi_k) - a}{1 + \sin(\Psi_k)}, \qquad (10)$$

and roller diameter

where R_{ok}-the radius of the circle described by the centers of the road wheels.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 11 , November 2022

The volumes of the deforming rollers and track rollers are calculated depending on their shape, length and diametrical dimensions.

For a cylindrical roller, the volume is determined from the expression:

$$V_k = \pi \cdot r_k^2 \cdot L_k, \qquad (11)$$

For a tapered roller, the volume is defined as

$$V_k = \frac{\pi \cdot (r_6^2 \cdot r_m^2 + r_6 \cdot r_m) L_p}{3} \qquad (12)$$

where $r_б$, $r_м$-radii of small and large section of the tapered roller, Lp-length of the roller.

For ring (toroidal) roller

$$V_k = \pi \int_0^{2R_{pr}} \left[r_0 + \sqrt{R_{pr}^2 - (R_{pr}^2 - R_{pr})^2}\right]^2, \qquad (13)$$

For the ball

$$V_b = \frac{4\pi \cdot r_b}{3}, \qquad (14)$$

where $r_ш$- radii of small and large section of the tapered roller.

where barrel roller

$$V = 0.262 \cdot (8 \cdot r_6^2 + 4 \cdot r_m^2) L_p, \qquad (15)$$

From the scheme presented in fig. 1 it follows that the deformation force is the sum of the centrifugal force created by the road wheels and deforming rollers, as well as the centrifugal force of the bearing housings in which the rollers are located

$$P_y = 2P_{kp} cos\beta + P_{cp}, \qquad (16)$$

where P_{cp}- centrifugal force acting on the roller; Pkp-force of interaction between rollers and rollers, calculated by the formula

$$P_{kp} = \frac{0.5(P_{ck} + P_{cp})}{sin\eta}, \qquad (17)$$

The values of the angles η and β are

$$\eta = 90 - \frac{\Psi}{2} - \beta; \qquad (18)$$

$$\beta = arcsin\left(\frac{r_k + a}{r_p + r_k}\right), \qquad (19)$$

Centrifugal forces acting on rollers and rollers

$$P_{ck} = 0.034 \cdot L_p \cdot p_k \cdot n^2 \cdot r_k^2 \cdot (R_0 - r_k - \delta); \qquad (20)$$

$$P_{cp} = 0.034 \cdot L_p \cdot p_p \cdot n^2 \cdot r_p^2 \cdot (R_0 - r_p); \qquad (21)$$

Centrifugal force acting on the bearing housing

$$P_{cp} = k \cdot P_{ck}, \qquad (22)$$

On fig. 5, a shows the dependence of the deformation force on the radius of the hole being machined for a straight pattern of rolling and two rollers in the tool, the diameters of which are equal to half the diameters of the hole being machined, and in fig. 5b shows the dependence of the radial deformation force according to the scheme of processing through intermediate rollers for a five-roller forming machine at different tool speeds. From a comparison of the graphical dependencies, it can be seen that at the same tool speeds, the deformation force according to the scheme through the intermediate rollers is greater than when processing according to the direct rolling scheme. If we take into account that the diameters of the rollers during processing through the intermediate rollers are smaller, then we can conclude that rolling according to the scheme through the intermediate support rollers has an undoubted advantage compared to the former operating in a straight line, since a lower frequency is achieved in this case. rotation of the part, and, therefore, it is possible to machine parts from diameters of 90 mm and above.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 11 , November 2022

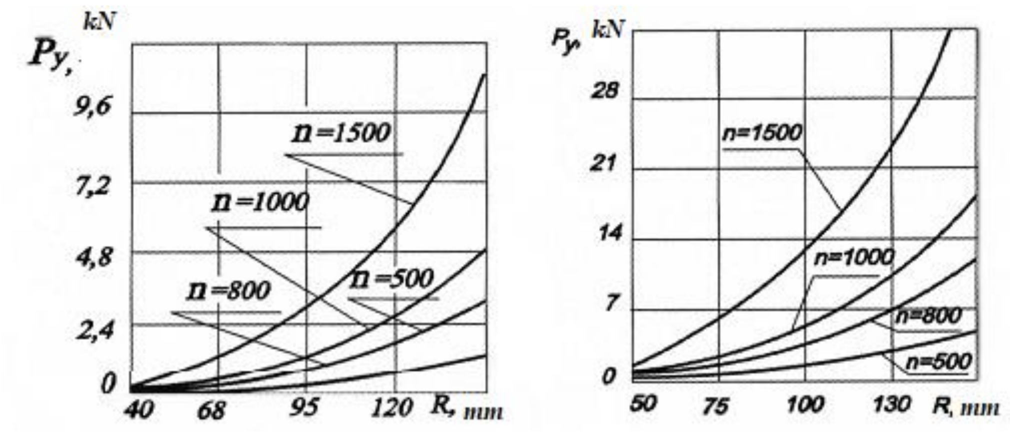


Figure.. 5. Dependence of the deformation force on the radius of the hole to be machined and the speed of the tool: a) - according to the scheme of direct rolling, the number of rollers zp = 2, the diameters of the rollers are equal to half the diameters of the holes to be machined, minus the gaps; b) - according to the scheme of rolling through intermediate rollers, the number of rollers zp=5

III. CONCLUSION

1. The design features of the existing deforming tool for SPD processing are considered. The reasons for unstable machining by this tool are established, ways to improve the reliability of the tool are outlined by choosing the optimal design of the support cones and methods of fastening deforming tools in the grooves of the separators.

2. A method of centrifugal opening of holes, which is not used in practice, is proposed, which provides a stable specified quality of the surface layer with high processing productivity. Mathematical models for calculating the design parameters of forming machines are obtained.

3. The main provisions and methods for automated calculation of rational design parameters of deforming tools and technological modes of processing during PPD have been developed.

REFERENCES

1. В.Г. Ковалёв, С.В. Ковалёв ТЕХНОЛОГИЯ ЛИСТОВОЙ ШТАМПОВКИ Технологическое обеспечение точности и стойкости

2. Burr, 1. R. (1976). Statistical Quality Control Methods Marcel Dekker, New York, New York. ;

3. Ford Motor Company (1984). Continuing Process Control and Process Capability lpmrovement. Ford Motor Company, Dearborn, MI. часть 3.2

4. Hahn, G. J. (1970). "Statistical Intervals for a Normal Population Part 1. Tables. Examples and Applications." Journal of Quality Technology 2, pp. 115-125. часть 3.2

5. Hotter, P. (1985). "Moving to Prevention: An Industry in Transition." Quality Progress 18, pp. 24-26. часть 3.2

6. Jessup, P. T. (1983). "Process Capability, The Value of Improved Performance," paper presented at the ASQC Automotive Division Workshop Seminar, November 2-4, Southfield, Michigan. часть 3.2