

Determination of Radial Cutting Forces during Drilling

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ABSTRACT

The main purpose of this paper explore a method for determining the radial cutting forces during drilling and power spent on cutting, analytical way. Inspect and acquire the skills to work with reference books.which improved the tools efficiency .where not balanced radial components of the cutting forces δf_y , was found to specified the analytical dependences components of cutting forces. Calculations show that the vibrations of unbalanced force δf_y commensurate with magnitude f_y radial component of the cutting force, and sometimes exceed this force.

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Introduction

Currently, the scientific world has been a steady interest in the forces acting on the materials that provide high strength characteristics. This interest is widely distributed to the various branches of engineering. The main requirements for the cutting tools are precision size and shape of the part surface quality, durability, design and manufacturability, etc. The complete list of technical requirements for the tool include guidelines and recommendations on regulatory standards specifications manufacturing appropriate types of tools [1].

Importance of the problem

In determining the cutting force a number of difficulties: the complexity of the experimental determination of the components of the cutting force, the absence in the literature dependences for calculating the components of the cutting force for the specific processing conditions.

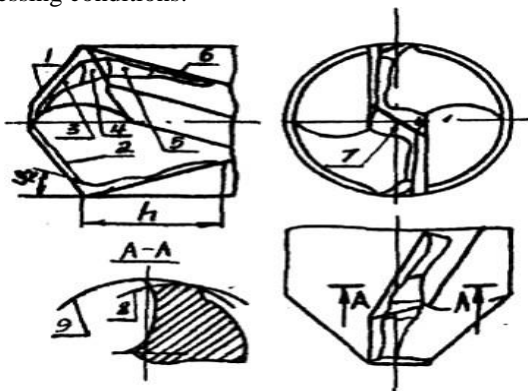


Fig 1. Wear drill standard design

1 - outline of the new drill 2-worn 3 - Surface wear on the main cutting edge 4 - by corner 5 - ribbon for 6 - along the edge of the ribbon;7 - top 8 - forming surface wear ribbons 9 - forming surface of the new ribbons; h - length worn cutting part. In actual practice, due to the asymmetric sharpening drill occurs unbalanced radial cutting force δF_y Causing bending tool and leads to additional errors in the longitudinal section of machined holes (Fig. 1).

The main part

The main sources on the relevance of the issue was the work of AA Vinogradov, II Sementchenko, GN Sakharov, NF Utkin, Y. Kizhnyaeva and other researchers devoted to the analysis of the geometry of the cutting spiral reground drills, and several works of SI Petrushin SV Rough - analysis of geometrical parameters of cutters depending on the orientation angles. Method of calculating the components of the cutting forces during drilling symmetrically sharpened drill proposed AA Vinogradov. It allows you to define the cutting force based on the geometric parameters of the shear layer and the physical and mechanical properties of the material.

The difficulty of using this technique to determine the components of the cutting force when drilling is necessary to know that the physic-mechanical properties of the material, shrinkage of the chip (or notional plane angle shift) and the geometrical parameters at each point of the cutting edge of the indexable insert. [2] The cutting force analysis was achieved using a three-axis dynamometer. The dynamometer was used to find the relevant tooling forces shown below (Fig. 2).

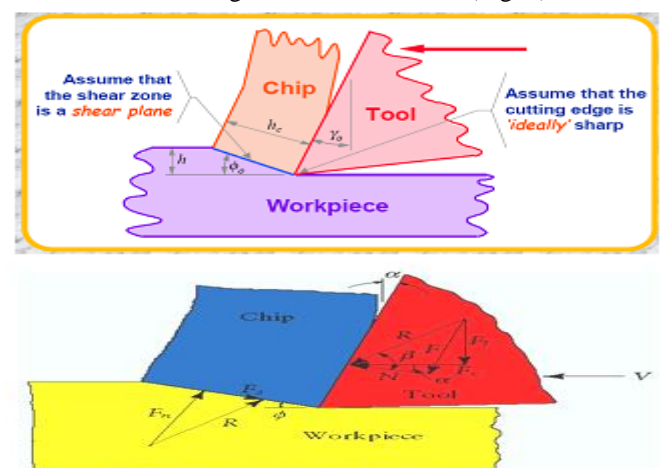


Fig 2. Orthogonal force and oblique force (F_x), radial thrust force (F_y) and tangential cutting force (F_z)

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A three-component dynamometer on which the workpiece is clamped gives the axial (feed) force directly. The other two outputs, instead, are projections on two fixed axes of a force that is the sum of the radial and tangential components, and that rotates at spindle speed.

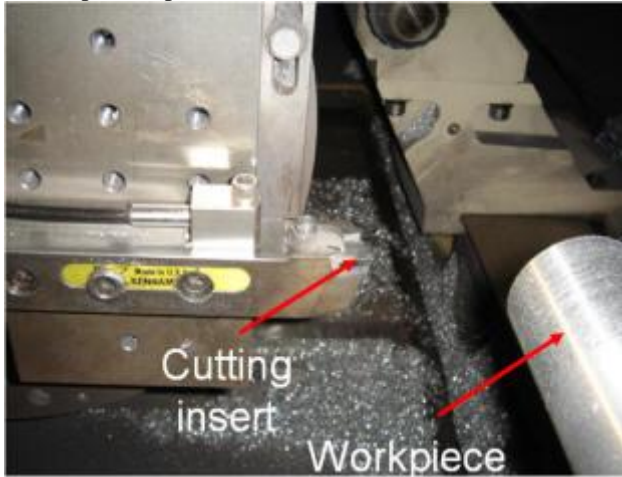


Fig 3. Metal Cutting

Cutting forces can be resolved into three components: feed force (Fx), radial thrust force (Fy) and tangential cutting force (Fz). Usually the tangential cutting force is the largest of the three components, though in finishing the radial thrust force is often larger, while the feed force is minimal. This arrangement in finishing can be explained by studying the particular cutting regime and tool geometry used in the tests. The curved part of the cutting edge, performs the whole cutting job, thus the acting cutting edge angle varies along the tool-work contact arc of the tool nose. The largest value of the angle appears at the position where the cutting edge meets the original work part surface (Fig. 2).

Radial cutting force acting on the rear surface perpendicular to the direction of traffic pulling, expressed significantly lower values than the force acting along the axis of the broach. Change radial cutting force and radial movement of the tool involves a change in the geometry of the tool and change the chip section. Due to the radial oscillations on the surface of the tool describes the product wavy line, with this angle changes. By radial cutting force and tangential force calculated deflection of the workpiece, conditioning precision machining parts and machine parts and cutting edge strength.

Analysis of the forces encountered during the machining process, indicates that the radial cutting force Fy can be determined from the relationship (1) [3]:

$$F_y = F_N \cos(\Phi \pm \beta) \tag{1}$$

where FN - cutting force component directed along the normal to the tool tip;

ϕ - Entering angle,

β - The angle of deflection of chips. Accept: "plus" sign with a negative angle ϕ and "minus" sign with a positive angle ϕ .

Equation (1) to determine the radial force does not consider changes in the geometric parameters of the tool along the cutting edge, which is characteristic of the drill. Power FN represents a component of force Fz, and can be calculated as [4] of the expression:

$$F_N = F_Z \tan(45-\theta) \tag{2}$$

where Fz - the force acting in the direction of the main motion; θ - Corner chipping. When processing of plastic materials can be taken in the calculations,

$$\theta = 250 + \gamma N \tag{3}$$

where γN - Rake angle normal cutting plane.

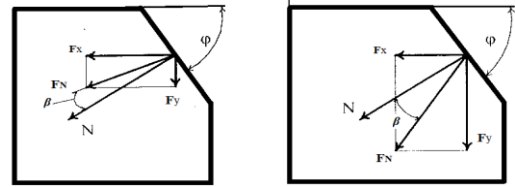


Figure 4. the definition of force Fy
a - positive angle β ; B - negative angle β .

Force Fz can be determined from the expression:

$$F_z = 0,89 \sigma_v S_z t (1 + \cot \theta) \tag{4}$$

where σ_v - Tensile strength of the material being processed;
Sz - feed per tooth drill; t - depth of cut.

Cutting depth for drilling [3] shall be equal to the radius of the machined surface: $t = 0,5 D$, where D - diameter drilling.

Consider the definition of the deflection angle of the chip ϕ . One of the parameters in determining the radial component of the cutting force Fy. If non-free cutting angle and inclination of the main cutting edge deflection angle chips should be calculated according to the formula:

where β^* - Auxiliary design angle, the value of which is determined by the relationship:

$$\beta^* = \arctan \frac{S_z \sin^2 \phi}{1 + S_z \sin^2 \phi \cdot \cot(\phi + \phi^*)} \tag{5}$$

where β - Auxiliary angle in the plan for drilling: $\beta = 0$.

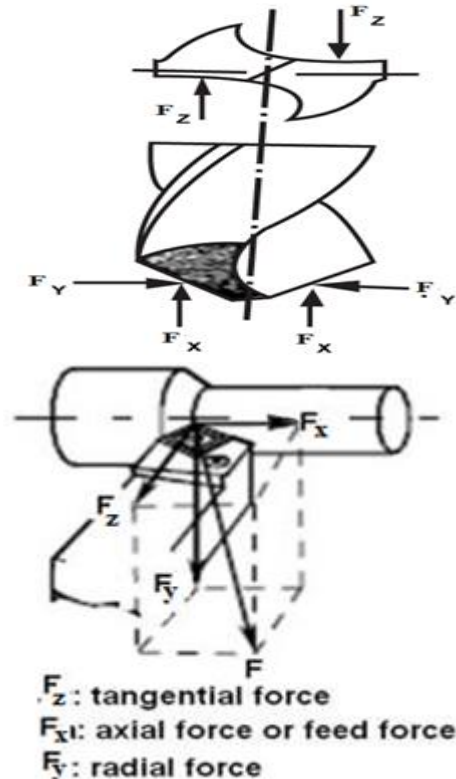


Fig 5. Twist drill showing cutting forces

It is known that some of the parameters characterizing the process of cutting, are variable depending on the position of a point of the cutting edge of the drill, in which they are measured. The angle ϕ defined by the relationship:

$$\sin \phi = r_c / r_x \tag{6}$$

where r_c and r_x - the radius of the core drill and the current radius of an arbitrary point of the cutting edge.

Figure 6 also designated: r - The nominal radius of the drill; ω - Angle of the flute.

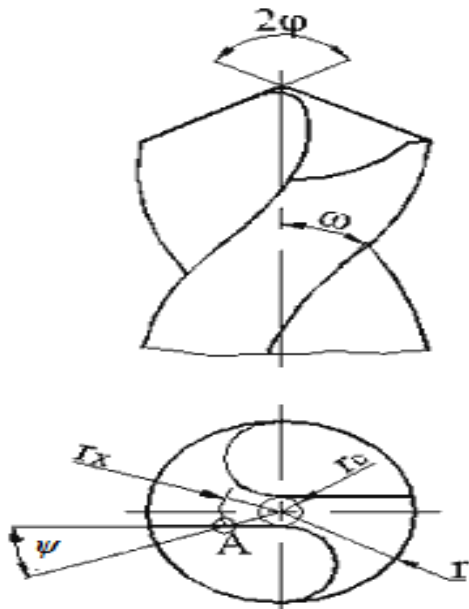


Figure 6 . the definition of the angle ψ

Necessary for subsequent analysis calculated dependences of geometrical parameters ψ , ϕ and γ_N determined based on the data of [4, 5]. The angle of inclination of the cutting edge:

$$\sin \psi = [(Rc / r) \sin \phi'] : (Rx / r), \quad (7)$$

where ϕ' - The apex angle of the drill.

Angles ϕ and ϕ' 'Are related by:

$$\tan \phi = \tan \phi' \sqrt{1 - \left(\frac{r_c / r}{r_x / r}\right)^2} ;$$

or

$$\tan \phi = \tan \phi' \sqrt{1 - \left(\frac{r_c}{r_x}\right)^2} \quad (8)$$

The thickness of the layer being removed during drilling is also variable and depends on the position of the analyzed point of the cutting edge of the drill bit [4, 7]

$$a = 0,5 \frac{1}{\sqrt{1 + \left(\frac{\cot \phi}{\cos \phi}\right)^2}}$$

where s - submission tool.

Rake angle normal cutting plane (Fig. 3) is determined from the expression:

$$\gamma_N = \gamma_2 - \gamma_3 \quad (9)$$

where the angles γ_2 and γ_3 determined on the basis of some other design parameters of the drill. Expression for determining the angle γ_2 depends on the type of the front surface of the drill. For example, in a flat front surface:

$$\tan \gamma_N = \tan \gamma_1 / \sin \phi$$

To the front surface formed in a spiral groove:

$$\tan \gamma_2 = \frac{(r_x / r) \cdot \tan \omega \cdot \cos \gamma}{\sin \phi - (r_x / r) \cdot \tan \omega \cdot \sin \gamma \cdot \cos \phi'}$$

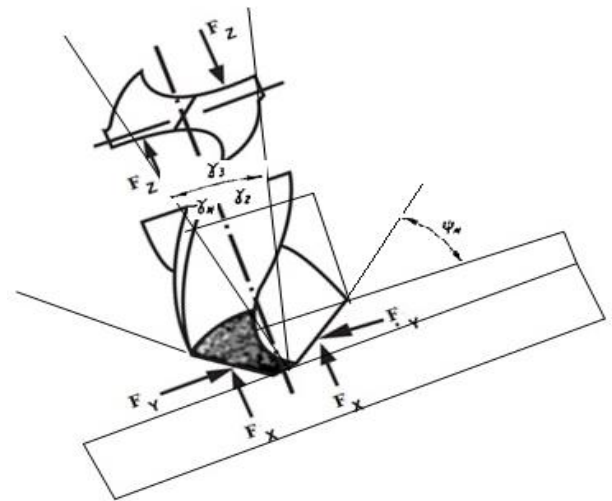


Fig 7. cutting elements in normal cutting plane.

Angle γ_3 the type independent front surface:

$$\tan \gamma_3 = \tan \phi \cdot \sin \phi$$

Thus, using the above relationships, we can determine the radial component of the cutting force F_y . For a strictly symmetrical drill sharpening these components of the cutting force acting on each tooth tool equal. However, in practical production may be drills certain value runout of the cutting edges of the tool [6,8], which leads to unbalanced radial cutting force component δF_y .

One of the parameters that affect the amount of force F_z (See Equation 4), and hence the strength of F_y is the feed per tooth drill s_z , Defined as:

$$s_z = a / \sin \phi \quad (10)$$

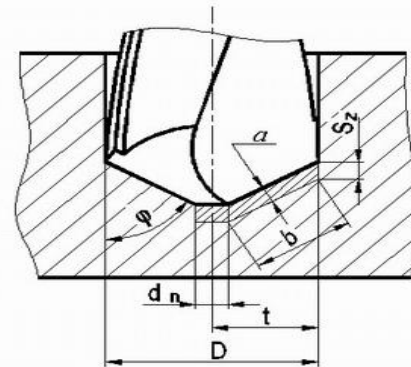


Fig 8. The thickness of the shear layer

Unbalanced sharpening drill leads to a change δa the thickness of the shear layer, and consequently change δs_z feed per tooth of the bit. As a result, oscillations δF_z tangential component of the cutting force, which ultimately leads to unbalanced radial component of the cutting force δF_y . An analytical expression for estimating this component of cutting force. For this we use some of the above dependencies, namely expressions to determine the parameters of the cutting process, which vary in the presence of asymmetric sharpening drills. Taking the limit oscillation slice thickness chips δa allowable amount equal runout drill cutting edges B_o :

$$\delta a = B_o \quad (11)$$

we obtain an expression for the fluctuations of feed per tooth drill:

$$\delta s_z = \delta a / \sin \phi \quad (12)$$

Changes in the tangential and normal components of the cutting forces will make (see expression 4 and 2):

$$\delta Fz = 0,89 \sigma v S z t (1 + \cot \theta)$$

$$\delta FN = FZ \tan(45-\theta)$$

Denote: $\beta(\beta)$ And $\beta(\beta^*)$ - Oscillation angles respectively β and β^* Caused by asymmetric sharpening drills. Angle value β^* Can be found from the expression (6), taking into account the fact that the feed per tooth drill ranges δs_z :

$$\tan \beta(\beta^*) = \frac{\delta s_z \cdot \sin^2 \varphi}{t + \delta s_z \sin^2 \varphi \cdot \cot(\varphi + \varphi_1)}$$

Angle fluctuations β (See equation 5) because of the asymmetry of sharpening drill defined by the relationship:

$$\beta(\beta) = \pm \lambda - \beta(\beta'), \quad (13)$$

Now possible to determine the unbalanced radial component of the cutting force (see equation 1):

$$\delta Fy = \delta FN \cos [\varphi \pm \beta(\beta)]$$

Calculations show that the vibrations of unbalanced force δFy commensurate with magnitude Fy radial component of the cutting force, and sometimes may exceed this force. This greatly affects the position of the tool axis, and hence on the error of the processed hole. Unbalanced sharpening drill leads to a change δa the thickness of the shear layer, and consequently change Sz : Feed per tooth of the bit. As a result, oscillations δFz - Tangential component of the cutting force, which ultimately leads to unbalanced radial component of the cutting force δFy . An analytical expression for estimating this component of cutting force. For this we use some of the above dependencies, namely expressions to determine the parameters of the cutting process, which vary in the presence of asymmetric sharpening drills.

Conclusions

The article studied the method of determining the radial cutting forces during drilling spent on cutting. Not balanced radial component of the cutting force δFy , Was found to

determine the analytical dependence component of cutting force. For this have been used by some of the above dependencies, namely expressions to determine the parameters of the cutting process, which vary in the presence of asymmetric sharpening drills. Calculations show that the vibrations of unbalanced force δFy commensurate with magnitude Fy radial component of the cutting force, and sometimes may exceed this force. This greatly affects the position of the tool axis, and hence on the error of the processed hole.

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