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METHOD FOR MULTI-EDGE DRILLS WITH CURVED CUTTING EDGE SHARPENING

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Abstract: *Multi-edge drills are constructions of tools for drilling in bulk pieces, characterized by a better tool alignment during the drilling process, as consequence of both pyramidal cutting edge shape and higher circularity precision of hole, last one due to the greater number of guiding flats. The construction of multi-edge drills, having a variable setting angle along the major cutting edge can also bring to these tools a higher durability, relative to the drills with straight cutting edges. This new constructive shape of the drill requires specific sharpening methods to be used. In this paper, there are suggested a specific kinematics and the analysis of the main aspects concerning the new sharpening method – the clearance along the major cutting edge and the relieving of the major flank.*

Key words: *multi-edge drill, curved cutting edge, sharpening method, clearance, relieving.*

1. INTRODUCTION

Helical drills, considered as tools used to do bulk materials machining, have specific geometry, due to their difficult conditions of cutting and throwing out the chips. A multitude of solutions were imagined to improve the properties of these tools, when drilling in different types of materials. Specific geometrical profiles of the transversal cutting edge, to enable the reduction of axial cutting force [5], materials with high wearing resistance used to make drill active part [6], new cooling – lubrication systems, adapted to this kind of process particularities [6], coatings to reduce wearing and friction coefficients [6, 8], the use of CNC machine tools to generate complex geometries of active lips – all of them are ways to increase the efficiency during exploitation of this kind of tool. New analytical models were also developed in order to study the helical drills complex geometry [4, 5, 8].

A thoroughly made analysis of chip formation enabled the elaboration of new models concerning the cutting edge profile, aiming to realize a uniform unitary energetic loading of its constitutive points [1, 2, 3, 7]. The new type of drills existence required the synthesis of both tools to generate their surfaces and specific sharpening methods [2, 3].

The progresses of the analysis focused on improving the profile of the major cutting edge imposed a new cutting edge model, elliptic and more than that, a 3-D cutting edge model [1]. Same time, the extension of major cutting edge new geometry was suggested in the case of multi-edge drilling tools (with 3 or 4 lips), which ensure, by increasing the number of guiding surfaces, a better alignment to the machined hole and starting from here, an increased precision.

These new geometries imposed the appearance of new methods to do major flank sharpening, by ensuring a variation law for the clearance magnitude growing from periphery to tool axis, same time with a continuous decreasing of the setting angle from tool front point to its periphery. The new methods must also allow a good relieving of the major flank, by using a single positioning of the drill into the sharpening device.

In this paper, we suggest a new sharpening scheme, characterized by a simple kinematics (a minimal number of required motions), which is further allowing a rigorous reproducibility of the sharpening process.

2. PROCESS KINEMATICS AND REFERENCE SYSTEMS

2.1. Process kinematics

The kinematics of new sharpening method is presented, in principle in Fig. 1. It consists from the following motions:

- I is the drill oscillation motion, around x_1 axis (overlaid to X_1 axis);
- II – the longitudinal feed motion;
- III – the grinding wheel rotation motion (the cutting motion).

The position of sharpened drill axis is referred to the grinding wheel through a_x and a_y coordinates, arbitrarily chosen. The eccentricity of drill axis, relative to the oscillation axis $A – A$, is denominated by e.

2.2. Reference systems

To find the equations of the new sharpening method motions, the following reference systems should be considered:

- xyz is a fix system, having the z axis coincident with grinding wheel axis;
- XYZ – a mobile system, attached to the grinding wheel, with Z axis overlaid to z axis;
- $x_1y_1z_1$ – a fix system, having its x axis the same with the oscillation axis;
- $X_1Y_1Z_1$ – a mobile system, attached to the drill, Z_1 being coincident to drill axis and parallel to Z axis;
- $X_TY_TZ_T$ – a mobile system, attached to the oscillation axis and, same time, to XYZ system, having parallel and identical oriented axis with it.

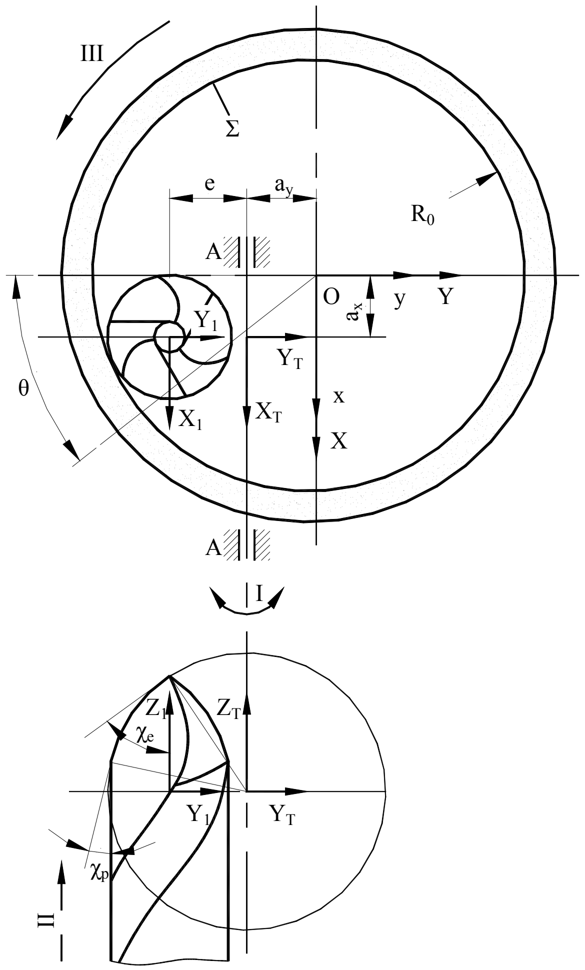

Fig. 1. Sharpening process kinematics and reference systems.

Coordinates transformation between systems $X_TY_TZ_T$ and XYZ is given by

$$X_T = \alpha[X - A], \tag{1}$$

where

$$\alpha = I^* \text{ and } A = \begin{Vmatrix} a_x \\ -a_y \\ 0 \end{Vmatrix}. \tag{2}$$

The motion of XYZ system, together to the grinding wheel, referred to $X_TY_TZ_T$ system is

$$\begin{Vmatrix} X_T \\ Y_T \\ Z_T \end{Vmatrix} = \omega_1^{\,T}(\varphi)\left(\begin{Vmatrix} X \\ Y \\ Z \end{Vmatrix} - \begin{Vmatrix} -a_x \\ -a_y \\ 0 \end{Vmatrix}\right). \tag{3}$$

During (3) motion, the family of surfaces whose envelop is the drill flank is generated.

3. THE FLANK OF THE DRILL MAJOR CUTTING EDGE

The analytical model of the grinding wheel peripheral surface Σ can be defined referred to XYZ system, depending on R_0 (grinding wheel interior radius) and θ, t – parameters, as it follows:

$$\Sigma\left|\begin{aligned} &X = R_0 \sin\theta; \\ &Y = -R_0 \cos\theta; \\ &Z = t. \end{aligned}\right. \tag{4}$$

If we accept the approximation that the flank generating line is the circle from the grinding wheel frontal plane, having the radius R_0, ($t = 0$), by taking (3) motion, the surface Σ is generating the family of surfaces

$$\begin{Vmatrix} X_T \\ Y_T \\ Z_T \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi \\ 0 & \sin\varphi & \cos\varphi \end{Vmatrix} \cdot \begin{Vmatrix} R_0 \sin\theta - a_x \\ -R_0\cos\theta + a_y \\ 0 \end{Vmatrix}, \tag{5}$$

or, after developing,

$$\left|\begin{aligned} &X_T = R_0 \sin\theta - a_x; \\ &Y_T = \left(-R_0\cos\theta + a_y\right)\cos\varphi; \\ &Z_T = \left(-R_0\cos\theta + a_y\right)\sin\varphi. \end{aligned}\right. \tag{6}$$

If now, the transfer to the drill reference system, $X_1Y_1Z_1$, is made, conform to relation

$$\begin{Vmatrix} X_1 \\ Y_1 \\ Z_1 \end{Vmatrix} = \begin{Vmatrix} X_T \\ Y_T \\ Z_T \end{Vmatrix} - \begin{Vmatrix} 0 \\ -e \\ 0 \end{Vmatrix}, \tag{7}$$

it finally results the system of equations:

$$\left|\begin{aligned} &X_1 = R_0 \sin\theta - a_x; \\ &Y_1 = \left(-R_0\cos\theta + a_y\right)\cos\varphi + e; \\ &Z_1 = \left(-R_0\cos\theta + a_y\right)\sin\varphi, \end{aligned}\right. \tag{8}$$

which is representing the surface generated by the generator circle, into the drill reference system – the drill major flank; there are 2 parameters in these equations: θ and φ.

4. NUMERICAL APPLICATION

A numerical application was developed based on the upper equation, to find the curves of intersection between the drill flank and planes normal to drill axis. The following input data were used:

- grinding wheel radius: $R_0 = 45$ mm;
- drill diameter: $D = 20$ mm;
- drill core diameter: $d_0 = 5.4$ mm;
- setting angle at drill end $\chi_e = 5^\circ$;
- setting angle at drill periphery $\chi_e = 60^\circ$.

Starting from the upper parameters values, other required parameters were determined by using geometric relations (see also Fig. 1):

$$a_x = 0.2 \cdot R_0\,; \tag{9}$$

$$R_T = \frac{\sqrt{\dfrac{D^2}{4} - \dfrac{d_0^{\,2}}{4}}}{\cos\chi_p - \cos\chi_e}\,; \tag{10}$$

$$e = R_T \cos\chi_e\,; \tag{11}$$

$$a_y = -R_T + \sqrt{R_0^2 - \left(a_x - \frac{d_0}{2}\right)^2} ; \qquad (12)$$

$$\theta_{min} = \arcsin\left(\frac{a_x - \frac{d_0}{2}}{R_0}\right) ; \qquad (13)$$

$$\theta_{max} = \arcsin\left(\frac{a_x + \frac{D}{2}}{R_0}\right) . \qquad (14)$$

By using a special dedicated soft, we first calculated the geometric parameters from (9) … (14): a_x = 9 mm; R_T = 19.405 mm; e = 9.702 mm; a_y = 25.152 mm; θ_{min} = 0.1405 rad; θ_{max} = 0.4359 rad.

Then the coordinates of the points owning to intersection curves in 6 planes (corresponding to 6 equidistant values of φ, between χ_p and χ_e) were calculated. For example, in Table 1 there are the coordinates of points from plain corresponding to $\varphi = \chi_p$.

Finally, the curves were drawn by using AutoCAD (Fig.2).

Table 1

Coordinates of points from intersection curves

Crt. no.	X_1 [mm]	Y_1 [mm]
1	-2.7000	-9.6286
2	-2.5684	-9.6099
3	-2.4368	-9.5907
4	-2.3053	-9.5712
5	-2.1739	-9.5513
6	-2.0425	-9.5311
7	-1.9112	-9.5104
8	-1.7800	-9.4893
9	-1.6488	-9.4679
10	-1.5176	-9.4461
11	-1.3866	-9.4238
12	-1.2556	-9.4012
13	-1.1247	-9.3783
14	-0.9938	-9.3549
15	-0.8630	-9.3311
16	-0.7323	-9.3070
17	-0.6016	-9.2825
18	-0.4711	-9.2576
19	-0.3406	-9.2323
20	-0.2102	-9.2066
…	…	…
97	9.5166	-6.0991
98	9.6377	-6.0444
99	9.7586	-5.9894
100	9.8794	-5.9340
101	10.0000	-5.8783

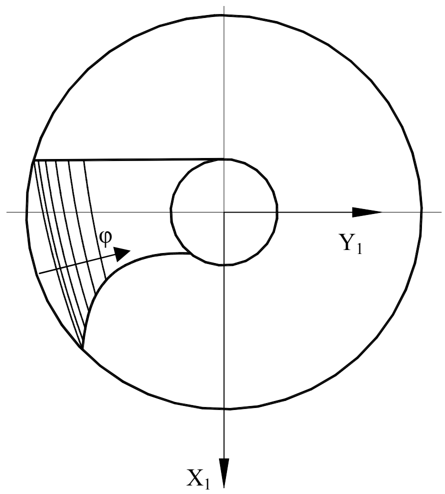

Fig. 2. Drill flank profile.

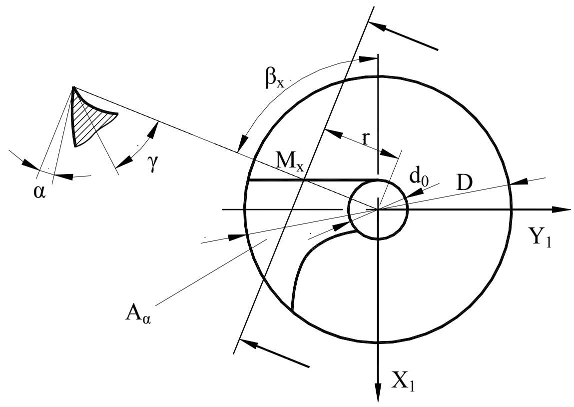

Fig. 3. The clearance in the measuring plane.

5. THE CLEARANCE VARIATION LAW, ALONG THE MAJOR CUTTING EDGE

The clearance is defined into the orthogonal plane (perpendicular to the tool reference plane), corresponding to a given point on the cutting edge, M_x, between the tangent to the intersection curve with the flank, A_α and the plane

$$Z_1 = const. \qquad (15)$$

Let consider (see Fig. 3) the normal to the orthogonal plane, in M_x point

$$\vec{N} = -\cos\beta_x \cdot \vec{i} - \sin\beta_x \cdot \vec{j} , \qquad (16)$$

where

$$\cos\beta_x = \frac{d_0}{2r} . \qquad (17)$$

The equation of the orthogonal plane corresponding to M_x point can be written as

$$\left(X_1 - X_{1M_x}\right)\cos\beta_x + \left(Y_1 - Y_{1M_x}\right)\sin\beta_x = 0 , \qquad (18)$$

where the coordinates of M_x point are, referred to X_1Y_1 system,

$$M_x \begin{vmatrix} X_{1M_x} = -\dfrac{d_0}{2}; \\ Y_{1M_x} = -r_x, \end{vmatrix} \quad (19)$$

when

$$0 \le r_x \le \sqrt{\frac{D^2}{4} - \frac{d_0{}^2}{4}} . \quad (20)$$

From the condition of intersection between the orthogonal plane and the drill major flank, (16) and (8), the following relation result:

$$\cos\varphi = \frac{\left(R_0 \cos\theta - a_x + \dfrac{d_0}{2}\right)\dfrac{\cos\beta_x}{\sin\beta_x} + e + r_x}{R_0 \sin\theta - a_y} . \quad (21)$$

As consequence, the equations of the intersection curve between the orthogonal plane and the drill flank can now be written,

$$C_{A\alpha} \begin{vmatrix} X_1 = R_0 \cos\theta - a_x; \\ Y_1 = \left(-R_0 \sin\theta + a_y\right)\cos\varphi + e; \\ Z_1 = \left(-R_0 \sin\theta + a_y\right)\sin\varphi, \end{vmatrix} \quad (22)$$

with φ calculated through (21).

The tangent to $C_{A\alpha}$ curve, owning to the drill flank and resulted from its intersection with the orthogonal plane has the following direction coefficients:

$$\begin{vmatrix} \dfrac{dX_1}{d\theta} = -R_0 \sin\theta; \\ \dfrac{dY_1}{d\theta} = -R_0 \cos\theta\cos\varphi - \left(a_y - R_0 \sin\theta\right)\sin\varphi \cdot \dfrac{d\varphi}{dd\theta}; \\ \dfrac{dZ_1}{d\theta} = -R_0 \cos\theta\sin\varphi - \left(a_y - R_0 \sin\theta\right)\cos\varphi \cdot \dfrac{d\varphi}{d\theta}. \end{vmatrix} \quad (23)$$

Thus, the clearance in the orthogonal plane can be calculated with

$$\sin\alpha_{M_x} = \frac{\dfrac{dZ_1}{d\theta}}{\sqrt{\left(\dfrac{dX_1}{d\theta}\right)^2 + \left(\dfrac{dY_1}{d\theta}\right)^2 + \left(\dfrac{dZ_1}{d\theta}\right)^2}} . \quad (24)$$

The values for R_0, a_x, a_y, e are process constructive parameters and must be defined from technological considerations (R_0) or from functional considerations (a_x, a_y and e).

6. CONCLUSIONS

The method for multi-edge drills with curved cutting edge sharpening, presented in this paper, represents a new method to make multi-edge tools with plane cutting edge sharpening. The cutting edge constructive profile is circular, the arc of circle segment which constitutes the cutting edge ensuring a variation of the setting angle between 60º at the end and 5º at the drill periphery.

There were realized analytical models of the clearance magnitude in the points from the major cutting edge, proving that the suggested sharpening scheme fulfill the basic requirement for such a kind of tools – the increasing variation of the clearance from the periphery to the end. The relieving of the flank was also studied, proving by numerical models that the back of the tool tooth relieving can be done by using a single positioning of the cutting edge relative to the sharpening surface.

The sharpening method presented has a simple kinematics, with a minimal number of required motions, compared to the other known sharpening methods. The upper exposed problematic can be developed by adopting new models of sharpening surfaces or new types of sharpening surfaces. A patent request, concerning the equipment for multi-edge drills sharpening, by using the new method, is on course of examination at OSIM.

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