

A New Mathematical Model for Helical Drill Back Face Geometry Study

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ABSTRACT

In this paper is showed a new analytical methodology for the study of the drill main back surface geometry. It's analyzed the back surface of the drill's main cutting edge as enveloping of a plane surface of the active zone of abrasive wheel, method equivalent with the conical sharpening proceeding. It is used the in-plane trajectories method for the enwrapping surfaces study. Is showed the form of the back face, the relieving lines on various points of the main cutting edge, the form of the crossing cutting edge and the variation law of the back angle along the drill radius. Also, we make mentions regarding the kinematics and constructive parameters influence on the back angle value along the drill's cutting edge.

Keywords: helical drill, back face, enwrapping surfaces

1. Introduction

For the helical drill with straight line cutting edges are used many main back face sharpening methods.

A helical drill sharpening method must assure the following conditions for the drill's cutting zone:

- growing back angle, from 6° - 10° at edge, to 20° - 30° to the drill centre;
- a convenient form of the crossing cutting edge, with small rake angle in absolute value (the rake angle is negative);
- the main cutting edge's symmetry;
- an effective relieving of the back face;
- a simple sharpening kinematics.

They are very used more sharpening methods, see figure 1.

The study of the helical drill geometry is making using the analytical geometry methods, assuming in a first approximation, that these surfaces are ruled surfaces or toroid surfaces.

More exactly, we can assume that the back surfaces are the result of the enveloping successive positions of the abrasive wheel, in the sharpening kinematical process, which will allow the generation errors of the cutting edge form, or the establishing of the actives surfaces modifications of the abrasive wheel, in order to accord the drill's geometry with the process requirements.

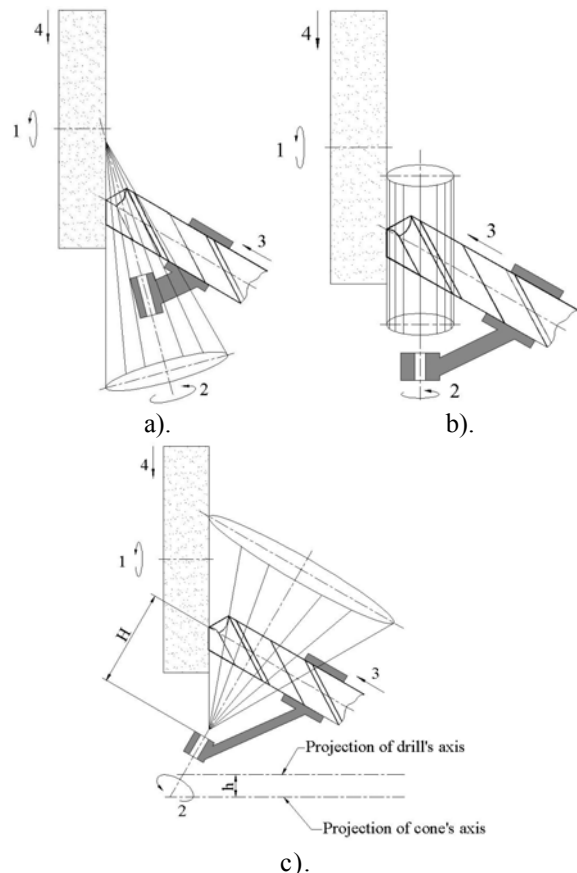


Fig. 1. Drill sharpening methods — Back face sharpening with: a) a conical surface; b) a cylindrical face; c) a conical surface with angle between cone axis and drill axis $\pi/2$

2. Back face sharpening with the plane face of the abrasive wheel

Following, is proposed a new method for the drill back face’s geometry study, based on the surfaces enveloping fundamentals theorems.

The main cutting edge back face is the result of the enrapping, in the relative sharpening motion, of the active face of abrasive wheel.

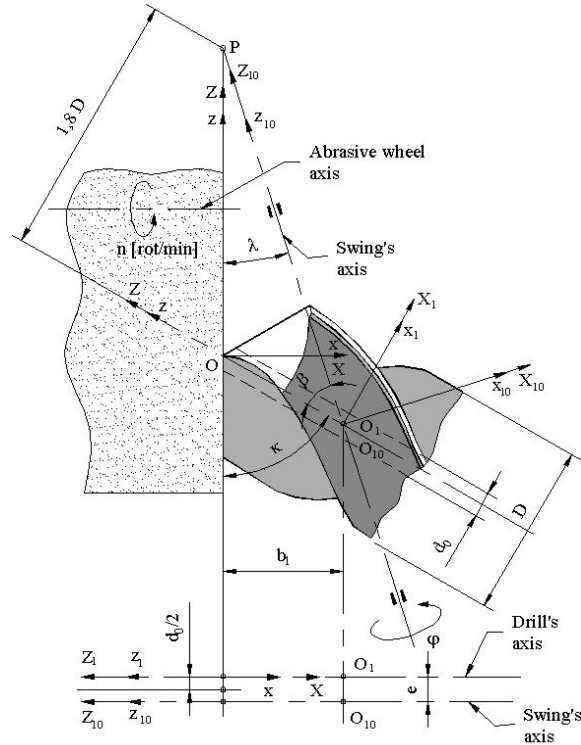


Fig. 2. Back face generation kinematics — references systems

The back surface’s form may be rigorous determined without the assumptions, not every time real, regarding the geometrical form of the theoretically sharpening surfaces: conical, cylindrical, helical or hyperboloid surface (on constant or variable pitch).

Is proposed, as example, a new calculus method, for a generating surface, initial assumed as plane, of the back surface geometry of a drill with twin straight line cutting edge, see figure 2.

They are defined the references systems:

xyz is the fixed reference system;

XYZ —mobile reference system, joined with the generating surface of the abrasive wheel, initial with axis over posed on the xyz reference system;

X1Y1Z1 —mobile reference system, joined with the drill’s axis;

x1y1z1 —fixed reference system, over posed with the drill’s axis;

X10Y10Z10 —mobile reference system joined with the swing axis of the sharpening device;

x10y10z10 —fixed reference system, with z10 axis over posed with the swing axis.

If we mark with φ the angular parameter of the swing movement, then, the space associated with the $X_{10}Y_{10}Z_{10}$ system, execute, regarding the $x_{10}y_{10}z_{10}$ reference system, the moving:

$$x_{10} = \omega_3^T(\varphi) \cdot X_{10}. \quad (1)$$

Between the fixed references systems they are defined the relative positions,

$$x_l = \beta(x_{10} - A), \quad (2)$$

where β is the position transformation matrix, see figure 2,

$$\beta = \begin{pmatrix} \cos \beta & 0 & \sin \beta \\ 0 & 1 & 0 \\ -\sin \beta & 0 & \cos \beta \end{pmatrix} \quad (3)$$

and $A^T = \begin{pmatrix} 0 & e & 0 \end{pmatrix} \quad (4)$

We define “e” is the position, along y_{10} axis, of the $x_1y_1z_1$ reference system origin.

Is defined the relationship between the fixed references systems,

$$x_{10} = \lambda(x - B) \text{ and } x = X, \quad (5)$$

where:

λ is the orthogonal transformation matrix between the $x_{10}y_{10}z_{10}$ and xyz references systems unitary vectors,

$$\lambda = \begin{pmatrix} \cos \lambda & 0 & \sin \lambda \\ 0 & 1 & 0 \\ -\sin \lambda & 0 & \cos \lambda \end{pmatrix}; \quad (6)$$

B —matrix formed with the $x_{10}y_{10}z_{10}$ reference system’s origin coordinates in the xyz reference system,

$$B^T = \begin{pmatrix} b_1 \\ -e \\ -b_1 \\ \text{tg} \kappa \end{pmatrix}, \quad b_1 = \frac{1,8 \cdot D}{\sin(\kappa - \lambda)} \cdot \sin \lambda. \quad (7)$$

In this way, is possible to define the relative motion of the abrasive wheel regarding the reference system joined with the drill:

$$X_l = \beta[\omega_3(\varphi)\lambda(X - B) - A]. \quad (8)$$

2.1. Generating surfaces family

Is defined the active surface of the abrasive wheel, in his own reference system, by the vector:

$$X^T = \begin{pmatrix} 0 & t & H \end{pmatrix}, \quad (9)$$

with “t” and “H” variables parameters.

From (8) and(9), after replacement of the abrasive wheel surface, result

$$\begin{pmatrix} X_I \\ Y_I \\ Z_I \end{pmatrix} = \begin{pmatrix} \cos \beta & 0 & \sin \beta \\ 0 & 1 & 0 \\ -\sin \beta & 0 & \cos \beta \end{pmatrix} \cdot \begin{pmatrix} \cos \varphi & \sin \varphi & 0 \\ -\sin \varphi & \cos \varphi & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} \cos \lambda & 0 & \sin \lambda \\ 0 & 1 & 0 \\ -\sin \lambda & 0 & \cos \lambda \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} - \begin{pmatrix} b_l \\ -e \\ -b_l/tg\kappa \end{pmatrix} = \begin{pmatrix} 0 \\ e \\ 0 \end{pmatrix} \quad (10)$$

Is possible to determine the surfaces family generated in the relative motion regarding the sharp drill's references system.

Using the notations:

$$\begin{aligned} A &= -b_l \cos \lambda \cos \varphi + (t+e) \sin \varphi + \\ &+ \left(H + \frac{b_l}{tg\kappa} \right) \sin \lambda \cos \varphi; \\ B &= b_l \cos \lambda \sin \varphi + (t+e) \cos \varphi - \\ &- \left(H + \frac{b_l}{tg\kappa} \right) \sin \lambda \sin \varphi - e; \\ C &= b_l \sin \lambda + \left(H + \frac{b_l}{tg\kappa} \right) \cos \lambda, \end{aligned} \quad (11)$$

after development, the surfaces family equations are:

$$\begin{cases} X_I = A \cdot \cos \beta + C \cdot \sin \beta; \\ Y_I = B; \\ Z_I = -A \cdot \sin \beta + C \cdot \cos \beta. \end{cases} \quad (12)$$

The enveloping of the (12) surfaces family is the back face of the main cutting edge of the helical drill.

2.2. Generating surfaces family

For the study of the surfaces family enveloping is proposed “the in-plane trajectories method” [6], [10].

Is studied the intersection curve between perpendiculars planes on Z_{10} axis and $(\Sigma)_\varphi$ surfaces family.

The $(\Sigma)_\varphi$ family is defined, in $X_{10}Y_{10}Z_{10}$ reference system, by transformation:

$$\begin{cases} X_{10} = X_I(t, H, \varphi) \cdot \cos \beta - \\ \quad - Z_I(t, H, \varphi) \cdot \sin \beta; \\ Y_{10} = Y_I(t, H, \varphi) + e; \\ Z_{10} = X_I(t, H, \varphi) \cdot \sin \beta + \\ \quad + Z_I(t, H, \varphi) \cdot \cos \beta. \end{cases} \quad (13)$$

A plane, variable as position along Z_{10} axis and perpendicular on this, has the equation

$$Z_{10} = H_I, \quad (H_I \text{ variable}), \text{ see figure 2. (14)}$$

$$H = \left(H_I - b_l \sin \lambda - \frac{b_l \cos \lambda}{tg\kappa} \right) \cdot \frac{1}{\cos \lambda}. \quad (15)$$

The (13) and (14) equation assembly give the condition

$$X_I(t, H, \varphi) \sin \beta + Z_I(t, H, \varphi) \cos \beta = H_I. \quad (16)$$

which, with the (13) equations, transformed by the (11) definitions, may be rewrite in form

$$\begin{cases} X_{10} = A; \\ Y_{10} = B + e. \end{cases} \quad (17)$$

Also, the (16) condition will have the form

$$b_l \sin \lambda + H \cos \lambda - \frac{b_l \cos \lambda}{tg\kappa} = H_I. \quad (18)$$

The (17) and (18) equations assembly represent, in plane $X_{10}Y_{10}$, the intersection curve of the abrasive wheel active surface, so, by the in-plane trajectories method, the enveloping condition may written as [5], [6], [10]

$$\frac{X'_{10\varphi}}{X'_{10}} = \frac{Y'_{10\varphi}}{Y'_{10}}, \quad (19)$$

or, after development, drive at the form

$$\frac{A'_\varphi}{A'_I} = \frac{B'_\varphi}{B'_I}. \quad (20)$$

After replacement, the enveloping condition is reduced at

$$t = -e. \quad (21)$$

2.3. H_1 parameter variation limits

They are defined the H_1 parameter variation limits thus the section planes to move along all the length of the drill's main cutting edge, see figure 1.

$$\begin{aligned} H_{1min} &= 2 \cdot 1.8 \cdot D \cos \beta - \frac{\left(1.8D + \frac{D}{2} \right)}{\sin \kappa} \cos \lambda; \\ H_{1max} &= 2 \cdot 1.8 \cdot D \cos \beta - \frac{1.8D}{\sin \kappa} \cos \lambda. \end{aligned} \quad (22)$$

For various values of H_1 parameter is defined the (18) condition and, based on the intersection with the (14) and (21) surfaces family, is determined a curves family representing the main back face of the helical drill.

3. Fitting parameters

They are defined the fitting parameters of the surface which is the back face, figure 2:

- λ is the inclination angle of the swing axis regarding the vertical plane;
- κ —the setting angle of the drill's main cutting edge;
- β —the angle between the swing axis and drill's axis;
- $d = (1.8...1.9) \cdot D$ —the distance from the

intersection point between the swing axis and disk surface to drill's axis;

- D —the drill's diameter [mm];

- $e = (0.05 \dots 0.07) \cdot D$ —the eccentricity of swing axis regarding the drill's axis;

- $d_0 = (0.12 \dots 0.14) \cdot D$ —the drill's core diameter.

4. Numerical results

In figure 3, is showed the forms of the back face of main cutting edge, generated as enveloping of the successive positions of the abrasive wheel active face.

The values of fitting parameters are: $\kappa=60^\circ$; $\beta=45^\circ$; $\lambda=15^\circ$; $D=20$ mm; $d_0=0.12 D$ mm; $e=0.07 D$ mm; $d=1.8 D$ mm.

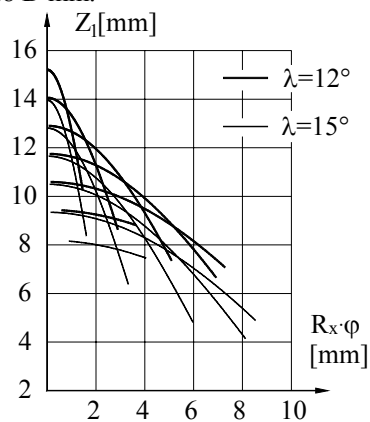


Fig. 3. Back face of main cutting edge

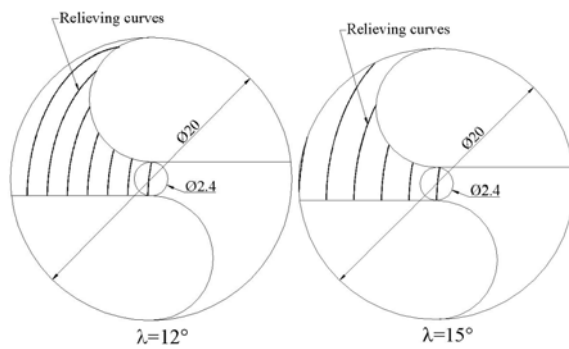


Fig. 4. Relieving curves in X_1Y_1 plane

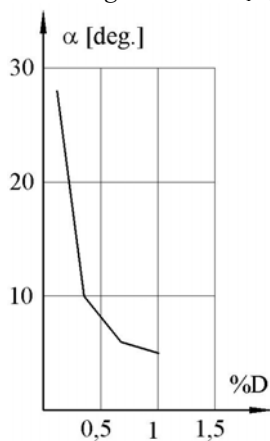


Fig. 5. Back angle ($\lambda=15^\circ$; $e=0,07D$)

5. Conclusions

The drill's main cutting edge back face study, based on the specifically theorems of the surfaces enveloping, has the advantage that allow a geometry of back face more closed to the real form of these.

More is possible to define more rigorous the relieving lines, along the back face, and, in this way, to establishing more exactly the drill's geometry.

The presented methodology has the advantage that is possible to consider the modifications of the abrasive wheel active surface and is possible to evaluate the effective modifications of the drill's back face.

This method may be applied for various shapes of the abrasive wheel, cylindrical, conical or hyperboloid forms.

The methodology allows covering all the problems of the drills sharpening, by all known proceedings.

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Un nou model matematic pentru studiul geometriei fețelor de așezare ale burghiilor elicoidale

Rezumat

În prezenta lucrare este prezentată o nouă metodologie pentru studiul geometriei feței de așezare a burghiilor elicoidale. Este analizată suprafața de așezare a muchiiilor așchietoare a burghiilor, ca înfășurătoare a suprafeței plane a discului abraziv, metodă echivalentă cu procedeul de ascuțire conică. A fost utilizată metoda traiectoriilor plane pentru studiul suprafețelor în înfășurare. Sunt prezentate forma feței de așezare prin curbele de detalonare în diferite puncte ale tăișului principal și legea de variație a unghiului de așezare în lungul razei burghiului. De asemenea, sunt prezentate considerații referitoare la influența cinematicii și a parametrilor constructivi asupra valorii unghiului de așezare în lungul tăișurilor burghiului.

Un nouveau modèle mathématique pour le foret hélicoïdal en arrière font face à l'étude de la géométrie

Résumé

En cet article est montré une nouvelle méthodologie analytique pour l'étude de la géométrie de surface de dos de force de foret. Il a analysé la surface arrière du tranchant principal du foret comme enveloppant d'une surface plate de la zone active de la roue abrasive, méthode équivalente avec la marche à suivre de affilage conique. Il est utilisé dans la méthode de trajectoire pour l'étude d'enveloppe de surfaces. Est montré la forme du visage arrière, le soulagement raye sur de divers points du tranchant principal, la forme du tranchant passant et de la loi de variation de l'arrière angle le long du rayon de foreuse. Aussi, nous faisons des mentions quant au cinématique et l'influence de paramètres constructive sur l'arrière valeur de montage le long du tranchant de la foreuse.