A New Approach of Helical Drill Sharpening Study

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ABSTRACT

In this paper, is presented, based on the general principles of surfaces enwrapping a modeling of the back surface of helical drills sharpened by helical proceed. Is analyzed, regarding the straight line generatrix model, some of the known methods: helical sharpening with the plane face of the grinding wheel; sharpening with a conical surface.

The specifically problems of this analysis were discussed: the variation law for the back angle along the main cutting edge; the back face relieving.

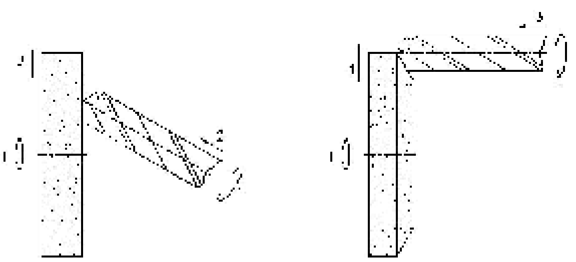
The constructive parameters and the influence of this on the helical drill geometry were showed.

The numerical examples present the problems point presented in this paper.

***Keywords**: helical drill, back face geometry, relieving lines, helical sharpening.*

1. Introduction

The classical method [1], [2], [3] for the helical drill back face study, start from the accepting an analytical known form of the main cutting edge. In this way, the main cutting edge back face and the front face of the helical drill flute are generated by the cutting edge movement regarding the sharpening process. [4].



a) b)

Fig. 1. *The generating straight line of the back face, helical sharpening:* ***a).*** *with plane grinding wheel;* ***b).*** *with conical grinding wheel*

Obviously, this approach, for various sharpening methods, despite the advantages of the analytical forms simplicity for the back face description, is, in some cases, relatively far from the physical reality.

The generating surfaces of the helical drill results from an enveloping process: the grinding wheel active surface, for which is accepted an analytical model, in its relative motion regarding the sharpened drill, generate a surfaces family of which enveloping is the enwrapping of the generated back face [5], [6], [7].

So, is normal to approach the problems of drill sharpening as an enveloping process, based on the known geometrical laws; using the geometrical models of the actives grinding wheels used in the sharpening processes.

In following, are analyzed the helical drill main back face generating processes at sharpening after a cylindrical helical surface with constant pitch, for three distinct sharpening methods, regarding the analytical method, simplified, to approach the back face geometry study.

2. The Simplified Analytical Model

The simplified analytical model presumes that the drill back face is generated by a Δ straight line, in its helical movement around the drill axis, figure 2.

Are defined the references systems:

XYZ is the relative reference system, joined with the *D* generatrix;

$X_1Y_1Z_1$ —the relative reference system, joined with the *XYZ* reference system, with *Z* axis over posed on the sharpened drill axis;

xyz — the global reference system, joined with the sharpened drill.

In the *XYZ* reference system, is defined the sharpening surface equations, in form:

$$S\left|\begin{array}{l} x=-u\sin c\,\cos j-\dfrac{d_0}{2}\sin j\,; \\ y=-u\sin c\,\sin j-\dfrac{d_0}{2}\cos j\,; \\ z=-u\cos c-pj\,, \end{array}\right. \qquad (1)$$

representing a cylindrical helical surface with constant pitch – the main back face analytical model.

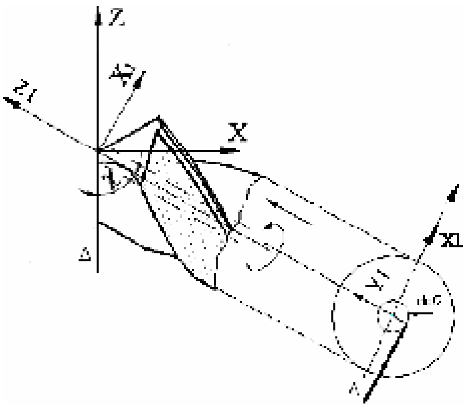


Fig. 2. *The back face generation – simplified model*

The back face may be described by the “relieving lines” – the intersection curves between the *S* helical surface and the cylinders with r_x radius,

$$r_x=\sqrt{x^2+y^2} \qquad (2)$$

result the generic form of the L_S relieving line:

$$L_S\left|\begin{array}{l} r_x=\sqrt{u^2\sin^2 c+\left(\dfrac{d_0}{2}\right)^2}\,; \\ Z=-u\cos c-p\cdot j\,. \end{array}\right. \qquad (3)$$

The *u* parameter variation limits are defined by:

$$u_{\min}=0; \qquad u_{\max}=\frac{D}{2\sin c}, \qquad (4)$$

where: *D* is the sharpened drill diameter and *c* is the main angle of attack.

Also, is defined the back angle, see figure 3, along the main cutting edge, for a point belongs of the cutting edge, at r_x radius, in form

$$tga_{r_x}=\frac{2p\cdot p}{2p\cdot r_x}=\frac{p}{r_x}. \qquad (5)$$

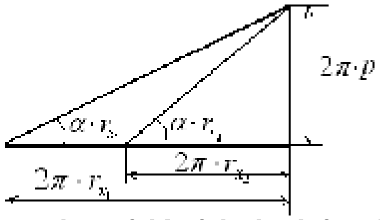


Fig. 3. *The unfold of the back face helix*

Obviously, when the r_x radius decrease, the back angle will increase, which is according with the requirements for a helical drill sharpening process (see figure 7).

3. Helical Sharpening Using the Plane Face of Grinding Wheel

A concrete modality for drill back face helical sharpening is that when is used the plane face of the grinding wheel [1], [2], [3].

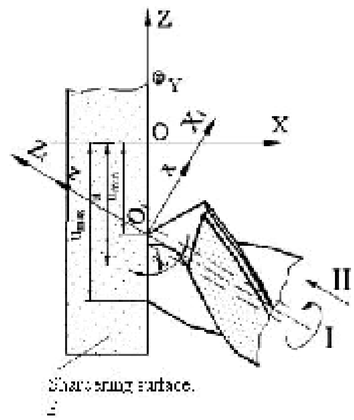


Fig. 4. *The back face generation kinematics. Reference systems*

They are defined the reference systems:

XYZ is the reference system joined with the grinding wheel;

$X_1Y_1Z_1$ — reference system joined with the helical drill;

xyz — global reference system, initially over posed with the $X_1Y_1Z_1$ reference system and having the *z* axis over posed with the helical drill axis.

Is defined the sharpening surface model — the plane surface of the grinding wheel — in form:

$$P\left|\begin{array}{l} X=0; \\ Y=t; \\ Z=-u, \end{array}\right. \qquad (6)$$

where: *u* and *t* are variable parameters (*t* isn’t show on the picture).

The sharpening surface model, in the reference system joined with the sharpened drill, have the form:

$$P_{X_1Y_1Z_1}\begin{vmatrix} X_1 = -u\sin c; \\ Y_1 = t; \\ Z_1 = -u\cos c. \end{vmatrix} \quad (7)$$

Is modeled the sharpening process by moving the generating plane on a helical movement around z axis and with helical parameter p:

$$x = w_3^T(j)\cdot\left[a\cdot(X-A)\right] - p\cdot j\cdot\vec{k}, \quad (8)$$

where: j is the angular parameter of the helical movement around z axis, parameter which determines the surfaces family.

After developments, result the in-plane surfaces family of the grinding wheel in the sharpened drill reference system:

$$(P)_j\begin{vmatrix} x = t\sin j - u\cos j\sin c; \\ y = t\cos j + u\sin j\sin c; \\ z = -u\cos c - pj. \end{vmatrix} \quad (9)$$

The back surface result from (9) equations and from the enwrapping condition, which, according to Gohman theorem, have form

$$\vec{N}_P\cdot\vec{v} = 0, \quad (10)$$

where: $\vec{N}_P = \vec{i}$ is the normal to the in-plane peripheral surface of the grinding wheel;
$\vec{v}$ — speed in the global movement of the peripheral surface of grinding wheel regarding the sharpened drill.

From the in-plane surface equations, see (6), result the normal at the plane, $\vec{N}_P$, in the XYZ reference system, which, transferred at the xyz reference system joined with the sharpened drill have the directrix parameters,

$$(\vec{n}_P)_{xyz}:\begin{vmatrix} n_x = \cos c; \\ n_y = 0; \\ n_z = -\sin c. \end{vmatrix} \quad (11)$$

The speed in the global movement, resulted from the transformation (8), is expressed in form:

$$\vec{v} = \vec{R}_j. \quad (12)$$

From equation (8), result

$$R_j = \frac{dx}{dj} = \dot{w}_3^T(j)\cdot\left[a\cdot(X-A)\right] - \begin{Vmatrix} 0 \\ 0 \\ p \end{Vmatrix} \quad (13)$$

From (13), result, after replacements, the directrix parameters of the $\vec{R}_j$ vector:

$$\begin{vmatrix} R_{jx} = t\cos j + u\sin j\sin c; \\ R_{jy} = -t\sin j + u\cos j\sin c; \\ R_{jz} = -p. \end{vmatrix} \quad (14)$$

The (14) equations represent the directrix parameter of the “speed” vector, $\vec{R}_j$, in the global movement of the generating plane (3) regarding the drill axis (the helical movement with z axis and p parameter).

In this way, the enveloping condition may be bringing at form:

$$u\sin c\sin j + t\cos j + p\tan c = 0. \quad (15)$$

The (9) and (15) equations assembly represent the back surface of the helical drill (sharpened drill).

The P surface characteristically curve, in its movement regarding the drill to be sharpened is determinate, as is known from the equations assembly:

- the in-plane surfaces family in the helical movement with z axis and p helical parameter,

$$(P)_j\begin{vmatrix} x = t\sin j - u\cos j\sin c; \\ y = t\cos j + u\sin c; \\ z = -u\cos c - pj; \end{vmatrix} \quad (16)$$

- the enwrapping condition;

$$u\sin c\sin j + t\cos j + p\cdot tg\,c = 0, \quad (17)$$

where: $j = const.$, $(j = 0)$.

In this way, the characteristically curve, after replacement, have equations:

$$C_p\begin{vmatrix} x = -u\sin c; \\ y = -p\cdot tg\,c; \\ z = -u\cos c. \end{vmatrix} \quad (18)$$

Note: Obviously, the characteristically curve, in this case (p=const.) is a straight line, in a plane parallel with y axis.

Now, we can imagine, a new express of the back face (the sharpened face), if we give to the characteristically curve, the common curve of the two enveloping surfaces (the P plane and the sharpened surface), a helical movement for which the axis and helical parameter are identical with those of the generating movement

$$x = w_3^T(-\Phi)\cdot X_1 - p\cdot\Phi\cdot\vec{k} \quad (19)$$

or, developed

$$\begin{Vmatrix} x \\ y \\ z \end{Vmatrix} = \begin{Vmatrix} \cos\Phi & \sin\Phi & 0 \\ -\sin\Phi & \cos\Phi & 0 \\ 0 & 0 & 1 \end{Vmatrix}\cdot\begin{Vmatrix} -u\sin c \\ -p\cdot tg\,c \\ -u\cos c \end{Vmatrix} + \begin{Vmatrix} 0 \\ 0 \\ -p\cdot\Phi \end{Vmatrix} \quad (20)$$

with Φ variable parameter in the revolving movement around z axis.

We arrived at the back face equations:

$$S\begin{vmatrix} -u\sin c\cos\Phi - p\cdot tg\,c\sin\Phi; \\ y = u\sin c\sin\Phi - p\cdot tg\,c\cos\Phi; \\ z = -u\cos c - p\cdot\Phi. \end{vmatrix} \quad (21)$$

The analytical model of the drill's back face (21) allows the determination, on this surface, as so as along the main cutting edge of:

- the shape of relieving lines of the drill's back face;
- the back angle variation law, along the drill's main cutting edge.

The relieving line is defined as the intersection of the *S* back face with a cylinder with r_x radius (r_x variable) coaxial with the drill. The relieving line form should to indicate that the point belongs to this curve on the tool's cutting edge is the most advanced point of the tool's cutting edge in the working drill sense, see figure 2.

Are studies the back intersection between the back face and the revolution cylinders, coaxial with helical drill's axis, cylinders having r_x radius:

$$x^2 + y^2 - r_x^2 \le 0 . \quad (22)$$

Regarding the (21) back face form, the relieving line (its general form) is:

$$\begin{vmatrix} r_x = \sqrt{u^2 \sin^2 c + p^2 tg^2 c}\,; \\ k = \left| u \cos c + p \cdot \Phi \right|, \end{vmatrix} \quad (23)$$

where *k* is the "relieving" value on the cylinder with r_x axis.

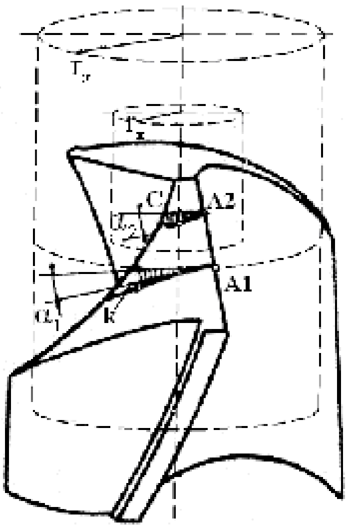


Fig. 5. *The intersection between back face and cylinders coaxial with drill's axis, having r_x radius*

Note

The simplified analytical method considers that the generating line of back face is over-posed to the main cutting edge (regarding as straight line).

The study of the back face as enveloping of the successive positions of the grinding wheel's in-plane surface accentuate that although the characteristically curve of the grinding wheel is a straight line, this depend as position, on the two surfaces, to the sharpening surface's pitch value, which may lead to the modification of the cutting edge shape, form which result from the intersection between the two helical surfaces, the drill flute and the back face.

Only for:

$$p \cdot tg\, c = \frac{d_0}{2}, \quad (24)$$

see equations (3) and (23), the two methods for the drill's back face geometry study are concurrent.

4. Helical sharpening with the conical surface of grinding wheel

They are defined the references systems:

XYZ is the mobile reference system, joined with the grinding wheel;

$X_1Y_1Z_1$ - mobile reference system, joined with the grinding wheel, with Z_1 axis over-posed to the helical drill axis;

xyz - global reference system, joined with the helical drill.

The conical surface in its own reference system is

$$\Delta : \begin{vmatrix} X = -u \sin b\,; \\ Y = 0; \\ Z = u \cos b\,, \end{vmatrix} \quad (25)$$

where: $b = c$.

In the XYZ reference system, is defined the conical surface of the grinding wheel by revolving the Δ generatrix around Z axis:

$$X = w_3^T(q) \cdot \begin{Vmatrix} -u \sin b \\ 0 \\ u \cos b \end{Vmatrix} \quad (26)$$

or, in developed form,

$$\begin{Vmatrix} X \\ Y \\ Z \end{Vmatrix} = \begin{Vmatrix} \cos q & -\sin q & 0 \\ \sin q & \cos q & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} -u \sin b \\ 0 \\ u \cos b \end{Vmatrix} \quad (27)$$

generate the conical surface of the grinding wheel,

$$P : \begin{vmatrix} X = -u \sin b \cos q; \\ Y = -u \sin b \sin q; \\ Z = u \cos b\,, \end{vmatrix} \quad (28)$$

with *u* and q independent variable parameters,

$$\begin{vmatrix} u_{\min} = \dfrac{r_{\min}}{\sin b}; \\ u_{\max} = \dfrac{r_{\max}}{\sin b}. \end{vmatrix} \quad (29)$$

4.1. The grinding wheel movement regarding the helical drill

The (28) equations are transposed at $X_1Y_1Z_1$ reference system by transformation:

$$X_1 = a\left(X - A\right) \qquad (30)$$

where: a is the transformation matrix for the unitary vectors direction of the $X_1Y_1Z_1$ and XYZ reference systems;

$a = I^*$ - unit matrix;

A – matrix formed with the $X_1Y_1Z_1$ reference system origin coordinates regarding the XYZ reference system,

$$A = \begin{Vmatrix} -u_{max}\sin b \\ -e \\ u_{max}\cos b \end{Vmatrix}. \qquad (31)$$

The grinding wheel movement regarding the helical drill is give by the transformation

$$x = w_3^T\left(-\Phi\right)X_1 - p\cdot\Phi\vec{k} \qquad (32)$$

or, after replacement,

$$x = w_3^T\left(-\Phi\right)\left[a\cdot\left(X - A\right)\right] - p\cdot\Phi\vec{k} \qquad (33)$$

where:

Φ is the angular parameter of the helical movement around the *z* axis;

e – the position of the $X_1Y_1Z_1$ reference system origin along to the z_1 axis;

p – the helical movement parameter.

In the developed form, the (33) equation becomes:

$$\begin{vmatrix} x = \left[-u\sin b\,\cos q + u_{max}\sin b\,\right]\cos\Phi + \\ +\left[-u\sin b\,\sin q + e\right]\sin\Phi; \\ y = -\left[-u\sin b\,\cos q + u_{max}\sin b\,\right]\sin\Phi + \\ +\left[-u\sin b\,\sin q + e\right]\cos\Phi; \\ z = u\cos b - u_{max}\cos b - p\Phi, \end{vmatrix} \qquad (34)$$

with variable parameters: *u*, *q*, *Φ* (*Φ* is the parameter which determine the family).

The (34) equations represent the conical surface family of grinding wheel, in the helical movement regarding the sharpened helical drill.

4.2. The enwrapping condition

The back face result associating with the (34) equations family the enwrapping condition, which, in conformity with Gohman theorem, has form:

$$\vec{N}_P\cdot\vec{v} = 0, \qquad (35)$$

where: $\vec{N}_P$ is the normal at the grinding wheel’s peripheral surface;

$\vec{v}$ - the velocity, in the global motion, of the grinding wheel’s peripheral surface regarding the sharpened helical drill.

The velocity in the global motion, result from (33) equation, in form:

$$\vec{v} = \vec{R}_\Phi \qquad (36)$$

$$R_\Phi = \frac{dx}{d\Phi}$$

$$\frac{dx}{d\Phi} = w_3^T\left(\Phi\right)\cdot\left(X - A\right) + \begin{Vmatrix} 0 \\ 0 \\ -p \end{Vmatrix}. \qquad (37)$$

From (37) result after development the forms:

$$\begin{vmatrix} R_{jx} = -\left[-u\sin b\,\cos q + u_{max}\sin b\,\right]\sin\Phi + \\ +\left[-u\sin b\,\sin q + e\right]\cos\Phi; \\ R_{jy} = -\left[-u\sin b\,\cos q + u_{max}\sin b\,\right]\cos\Phi - \\ -\left[-u\sin b\,\sin q + e\right]\sin\Phi; \\ R_{jz} = -p. \end{vmatrix} \qquad (38)$$

The (38) equation represents the directrix parameters of the “velocity” vector in the global motion of the generating cone (28) around drill’s axis.

The normal at *P* surface (28) has the directrix parameters:

$$\vec{N}_P = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ -\sin b\,\cos q & -\sin b\,\sin q & \cos b \\ u\sin b\,\sin q & -u\sin b\,\cos q & 0 \end{vmatrix}. \qquad (39)$$

In the (39) form, the normal $\vec{N}_P$ is defined in the reference system joined with the grinding wheel. The writing of the enwrapping condition presumes that the two vectors to be defined in the same reference system, the *xyz* reference system and therefore, this leads to:

$$\begin{vmatrix} N_x = \cos q; \\ N_y = \sin q; \\ N_z = tg\,b. \end{vmatrix} \qquad (40)$$

Result the condition for the characteristically curve determination $\vec{N}_P\cdot\vec{R}_\Phi = 0$, for $\Phi = 0$,

$$e\cos q + a\sin q - p\cdot tg\,b = 0. \qquad (41)$$

We use the notation $a = u_{max}\sin b$, with a and e technological constants.

Note:

The enwrapping condition may be bring in form

$$\sin q = \frac{p\cdot tg\,b - e\cdot\cos q}{a}. \qquad (42)$$

Is obviously that only for a big value of *a*, which means a grinding wheel with big diameter, the characteristically curve of the conical surface, in the helical motion around drill’s axis, is the generatrix of the cone in the *XZ* plane (θ=0). For *a* with a relative small value the characteristically curve of the conical surface is another generatrix ($q \neq 0$) and as following exist the possibility to change the cutting edge form.

The surfaces family generated by grinding wheel:

$$\begin{cases} x = [-u\sin b\,\cos q + a]\cos\Phi - \\ -[-u\sin b\,\sin q + e]\sin\Phi; \\ y = [-u\sin b\,\cos q + a]\sin\Phi + \\ +[-u\sin b\,\sin q + e]\cos\Phi; \\ z = [u\cos b - u_{\max}\cos b] - p\Phi. \end{cases} \tag{43}$$

The conical surfaces family (43) together with the enwrapping condition (41) determines the back face of the helical drill (the sharpened surface).

4.3. The relieving curves

It’s studied the intersection between the back surface and cylinders coaxial with the helical drill’s axis, having the radius r_x,

$$x^2 + y^2 = r_x^2 \tag{44}$$

or:

$$[-u\sin b\,\cos q + a]^2 + [-u\sin b\,\sin q + e]^2 = r_x^2 \tag{45}$$

$$\begin{aligned} &u^2\sin b + a^2 + e^2 - 2\cdot a\cdot u\cdot\sin b\cdot\cos q - \\ &-2\cdot e\cdot u\cdot\sin b\cdot\sin q = r_x^2. \end{aligned} \tag{46}$$

The variables are: θ, *u* and r_x (discreetly known).

The relieving curve - the intersection between the back face with a cylinder coaxial with the helical drill’s axis indicate that the point on the relieving curve belongs to the tool’s cutting edge is the most advanced point of the relieving curve in the drill’s working sense.

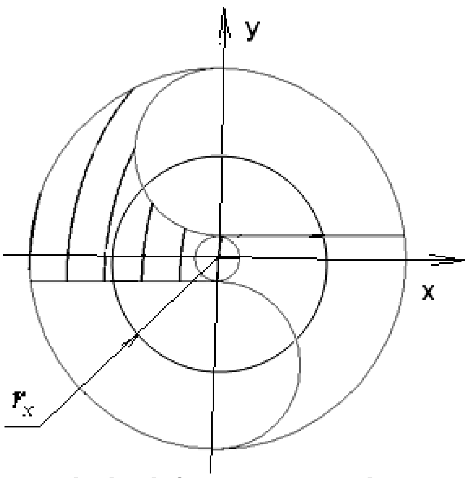


Fig. 4. *The back face generation kinematics. reference systems*

5. Numerical applications

The general form of relieving lines for sharpening with the plane surface of grinding wheel is give by equations:

$$\begin{cases} r_x = \sqrt{u^2\sin^2 c + p^2\cdot tg^2 c}; \\ k = |u\cos c + p\Phi|, \end{cases} \tag{47}$$

where:

k is the relieving value for the cylinder with r_x radius, measured along the *z* axis.

In figure 4, are showed the relieving lines, projected on a plane perpendicularly on the drill’s axis.

The back face of the drill result as equations assembly of active surface family together with the enwrapping condition:

$$\begin{cases} (C)_j \begin{cases} x = [-u\sin c\,\cos q + a]\cos\Phi - \\ -[-u\sin c\,\sin q + e]\sin\Phi; \\ y = [-u\sin c\,\cos q + a]\sin\Phi + \\ +[-u\sin c\,\sin q + e]\cos\Phi; \\ z = [u\cos c - u_{\max}\cos c] - p\cdot\Phi; \end{cases} \\ u^2\cdot\sin^2 c + a^2 + e^2 - 2a\cdot u\cdot\sin c\cdot\cos q - \\ -2e\cdot u\cdot\sin c\cdot\sin q = r_x^2. \end{cases} \tag{48}$$

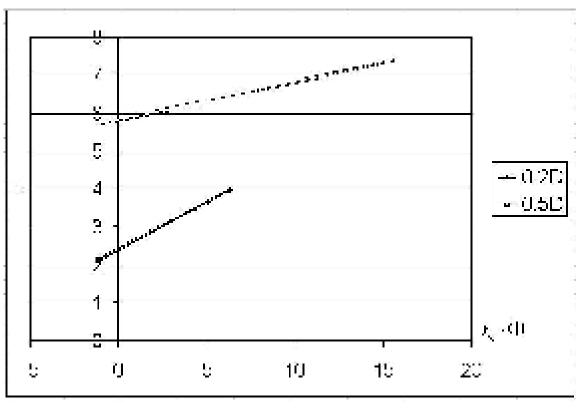


Fig. 5. *Relieving curves for drill’s sharpening with the plane face of grinding wheel*

Note:
D is the helical drill diameter.

In table 1 and figure 5, are showed the relieving lines coordinates for two values of cylinder radius r_x (see figure 4), drawn for the simplified analytical model.

Table 1.

$r_x = 0.2 \cdot D$ [mm]		$r_x = 0.5 \cdot D$ [mm]	
$r_x \cdot \Phi$ [mm]	k [mm]	$r_x \cdot \Phi$ [mm]	k [mm]
-1.2188	1.777	-1.2029	5.566
-0.9687	1.8395	-0.6392	5.6223
-0.7186	1.902	-0.0755	5.6787
M	M	M	M
3.7825	3.0273	10.071	6.6933
4.0326	3.0898	10.635	6.7497
4.2827	3.1523	11.198	6.8061

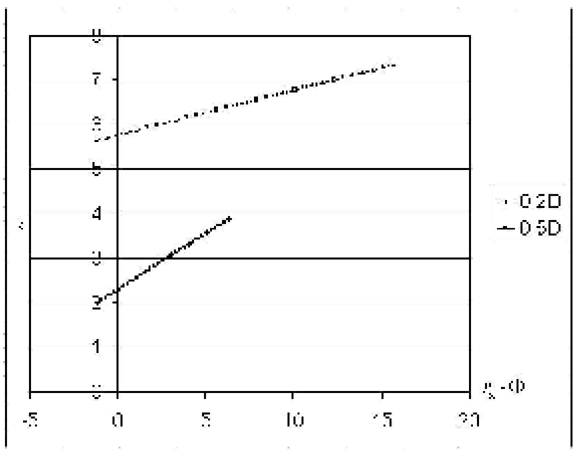


Fig. 6. *Relieving curves for drill's sharpening with a conical grinding wheel*

In table 2 and figure 6, are showed the relieving lines coordinates for two values of cylinder radius r_x (see figure 4), drawn for the helical sharpening by enwrapping with the conical face of the grinding wheel.

Table 2.

$r_x = 0.2 \cdot D$ [mm]		$r_x = 0.5 \cdot D$ [mm]	
$r_x \cdot \Phi$ [mm]	k [mm]	$r_x \cdot \Phi$ [mm]	k [mm]
-1.2188	2.0047	-1.2029	5.6532
-0.9687	2.0672	-0.6392	5.7096
-0.7186	2.1297	-0.0755	5.766
M	M	M	M
4.0326	3.3176	10.635	6.837
4.2827	3.3801	11.198	6.8933
4.5327	3.4426	11.762	6.9497
4.7828	3.5051	12.326	7.0061
5.0329	3.5676	12.889	7.0625

Being known the relieving curves of the back face, exist the possibility to determine the back angle's variation law, along the main cutting edge, in principle as angle between the tangent at the relieving line, in a point belongs to the main cutting edge, and the crossing plane of the drill's axis (see figure 7).

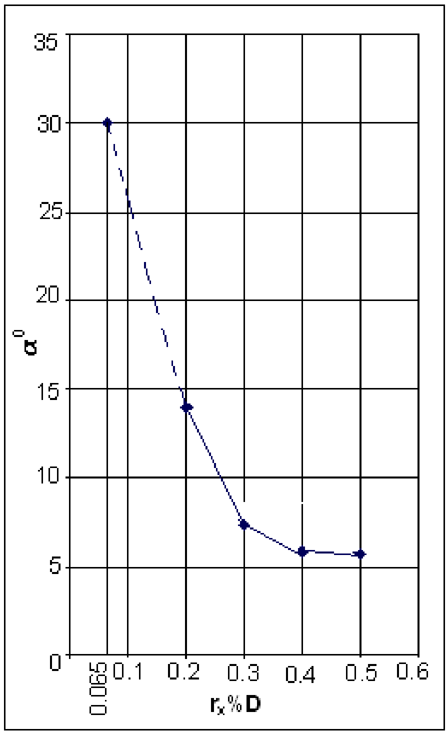


Fig. 7. *The back angle along the drill's main cutting edge*

6. Conclusions

The modeling method for the drill's back face as result of the generation of these with the peripheral surface of the grinding wheel, allow a rigorous representation of the back face forming process.

The model reveals that not in all cases the contacts between the in-plane face of the grinding wheel is a straight line identical with the tool's main cutting edge.

The back face form regarded by the relieving value of these is rigorously accentuated by the proposed method.

For small values of sharpened helical surface pitch, isn't important discrepancy regarding the simplified analytical model for the helical drill's geometry study.

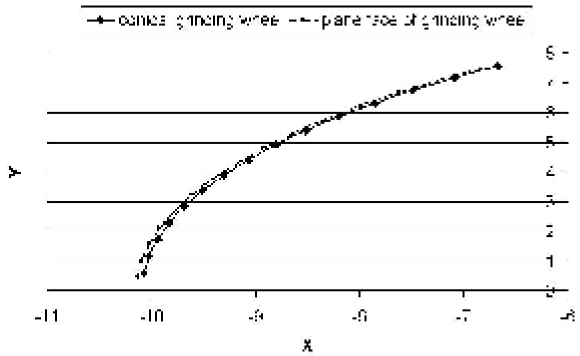


Fig. 8. *Relieving curves projection on plane perpendicularly to the drill’s axis*

In figure 8, is presented the same relieving curve, calculated by the simplified model and the new proposed model. The two curves are different, fact that explains the straightness errors of the sharpened drill’s cutting edge.

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O nouă abordare a studiului ascuţirii burghielor elicoidale

Rezumat

În lucrare, se prezintă o modelare, pe baza principiilor înfăşurării suprafeţelor, a procedeului de ascuţire elicoidală a feţei de aşezare a burghielor. Sunt analizate, prin comparare cu modelul generatoarei liniare, câteva metode cunoscute de ascuţire: ascuţirea elicoidală utilizând faţa plană a discului abraziv şi similar, ascuţirea elicoidală utilizând o suprafaţă activă conică a discului abraziv.

Au fost discutate diferenţele între curbele de detalonare determinate prin cele două metode: modelul generatoarei liniare şi modelul prin înfăşurare, ca explicaţie a nerectilinităţii tăişurilor burghielor ascuţite prin aceste procedee. Sunt prezentate, în baza unor produse soft dedicate, exemple numerice.

Une nouvelle approche pour étudier affûtages des forés hélicoïdaux

Résumé

Dans cette ouvrage, est présenté, sur la base des principes généraux de surfaces enveloppe, une modélisation de la face arrière du tranchant de la fore aiguisé par hélicoïdal procéder. Il est analysé, en ce qui concerne la ligne droite génératrice modèle, certaines des méthodes déjà connues: affûtages avec une surface plane, affûtages avec une surface conique.

Le spécifiquement des problèmes de cette analyse ont été examinés: la variation de la loi pour l'angle d'inclinaison le long de la pointe, la face arrière du tranchant.

Ont présentée les exemples numériques.