COMPARATIVE ANALITICAL MODELS FOR SHARPENING OF MULTI-FLUTE DRILLS WITH CURVED CUTTING EDGES

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ABSTRACT

In this paper, are presented analytical models of the flank faces of multi flute drills. It is analised quantitatively differences regarding the sharpening quality by variation law of flank angle along the major cutting edge. They are presented numerical examples.

KEYWORDS: hyperboloidal sharpening, numerical modeling, multi flute drills, curved cutting edges, models for sharpening.

1. Introduction

For helical drills with curved cutting edges, created in order to uniformize the unitary energetically load along the major cutting edge, \cite{1,2,3}, (see figure 1) were imaginated some specifically sharpening methods: thoroidal sharpening \cite{3}, as so as, for multi flute drills, variants of conical sharpening \cite{4}; cylindrical \cite{5} and hyperboloidal sharpening \cite{1}.

![Fig. 1. Multi flute drill with curved cutting edge](image)

Between these sharpening methods, regarding the generation kinematics and the results of flank face of the drill’s major cutting edge are some differences.

If it is assured the same geometry of the major cutting edge — the same variation law of the tool cutting edge angle, along the major cutting edge, the specifically sharpening method (cylindrical, conical or hyperboloidal) may lead to different values of the flank angle along the cutting edge and, in the same time, of the reliev flank surface, as it is presented by analytical models of the sharpening methods for straight lined cutting edge drills \cite{2}.

This paper propose an analytical modelling of the geometrical surface which represent the flank faces of the curved cutting edge drills, for three of the presented methods (hyperboloidal, cylindrical and conical), the determination of the flank angle value, along the major cutting edge and, based onto specifically software, the numerical determination of the variation law for the flank angle value along the major cutting edge, in order to make a comparison between the proposed sharpening methods.

The comparison between the sharpening process is made in conditions of the identically geometry of the major cutting edge, for all of the three proposed sharpening methods.

The analytical modelling, with numerical finalization of the flank angle value variation law, along the major cutting edge, may constitute a way to characterize other sharpening methods, as so as, for the evaluation of the reliev of the flank surface, as major aspect in order to establish the sharpening method quality.

2. Sharpening methods kinematics

It is analized the kinematics of sharpening methods for helical drills with curved cutting edges on type: hyperboloidal sharpening; conical sharpening and cylindrical sharpening.
In figure 2, is presented the generation kinematics for hyperboloidal sharpening and the position of the sharpened drill regarding this surface.

The sharpening method using a hyperboloidal surface consist in the successive forming of the hyperboloidal surfaces of the flank faces a, b, c, using an external cylindrical surface d of a grinding wheel, which execute a rotation A around it’s own axis.

The flank surface sharpening of a cutting edge is made by composing a swing motion B of the drill, of which axis is perpendicularly to the swing axis and is excentrical with value e regarding this axis, with an axial feed and intermittent motion C, which assure the relieving of the flank surface, at a single positioning of the sharpened drill. In order to sharpening the flank surfaces b and c of the another teeth of the drill is necessary to rotate the drill with 120°, and respectively 240°, resulting a circle arc cutting edge f.

The sharpening method using a conical surface consist in the successive forming of the conical surfaces of the flank faces a, b, c, using an frontal surface d of a grinding wheel, which execute a rotation A around it’s own axis, figure 3.

The flank surface sharpening of a cutting edge is made by composing a swing motion B of the drill, of which axis is perpendicularly to the swing axis and motion C, which assure the relieving of the flank surface, at a single positioning of the sharpened drill.

Fig. 2. The generation kinematics for hyperboloidal sharpening
The sharpening method using a cylindrical surface consist in the successive forming of the cylindrical surfaces of the flank faces \( a, b, c \), using a plane surface \( d \) of a grinding wheel, which execute a rotation \( A \) around its own axis, figure 4.

The sharpening of the flank surface of a cutting edge is made by composing the swing motion \( B \) of the drill, of which axis may be activated with angle \( \pi - \beta \) and excentrical with value \( e \) regarding an axis \( z \), parallel with the plane face of the grinding wheel, with an axial feed and intermittent motion \( C \), which assure the relieving of the flank surface, at a single positioning of the sharpened drill.

The cutting edge form result as ellipse \( \beta \neq 0 \) and is circle if \( \beta = 0 \).

3. The analitical model of back angle

3.1. The hyperboloidal model

It is accepted that, the hyperboloidal rotation surface is generated by a straight line that belongs to the reference system \( X_1Y_1Z_1 \) which has the following parametric equations, figure 2:
The plane's equation \( P_M \) - parallel plane with the drill's axis (\( X_2 \) axis) is (5):

\[
P_M : \begin{cases} 
Y_2 = \sqrt{r^2 + \frac{d_0^2}{4}} \cdot \cos \beta_x + \left( Z_2 - \frac{d_0}{2} \right), \\
\sin \beta_x = 0,
\end{cases}
\]

with

\[
\beta_x = \arcsin \left( \frac{d_0}{2 \cdot r_x} \right).
\]

The hyperboloidal surface is related to the \( X_2Y_2Z_2 \) system through the transformation, see figure 2:

\[
\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = \begin{bmatrix} X \\ Y - e \\ Z - \frac{d_0}{2} \end{bmatrix}.
\]

Thus, the equations of the hyperboloidal surface – forming the back face of the main curvilinear edge of the drill, in the \( X_2Y_2Z_2 \) system, have the configuration:

\[
\begin{align*}
X_2 &= u \cdot \sin \lambda \cdot \cos \phi - R_0 \cdot \sin \phi; \\
Y_2 &= u \cdot \sin \lambda \cdot \sin \phi + R_0 \cdot \cos \phi; \\
Z_2 &= u \cdot \cos \lambda.
\end{align*}
\]

with \( u \) and \( \phi \) - independent variable parameters.

The sizes \( R_0, e, \lambda, d_0 \) are definable as constructive sizes (technological constants).

The intersection of surfaces – the measuring plane (5) and the hyperboloid (8) – both defined in the same system of reference, leads to the condition (9):

\[
\begin{align*}
0 &= u \cdot \sin \lambda \cdot \sin \phi + R_0 \cdot \cos \phi - \sqrt{r^2 + \frac{d_0^2}{4}} \cdot \cos \beta_x + u \cdot \cos \lambda \cdot \sin \beta_x, \\
H_0 &= \frac{R_H - e^2}{\tan \lambda} - \frac{d_0}{2}.
\end{align*}
\]

Independent variable parameter \( u \) is:

\[
u = \frac{-R_0 \cdot \cos \phi + e + \sqrt{r^2 - \frac{d_0^2}{4}} \cdot \cos \beta_x}{\sin \lambda \cdot \sin \phi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}.
\]

The equations of the hyperboloidal surface in the \( X_2Y_2Z_2 \) system becomes (12):
3.2. The conical model

For conical model, see figure 3, from the equations (8), for

$\alpha = \frac{d_{0}}{2}$, and

$R_0 \neq 0$, and

$H_0 = \frac{R_H}{\tan \lambda} \cdot \frac{d_{0}}{2}$

(13)

on obtain the conical surface:

$X_2 = u \cdot \sin \lambda \cdot \cos \varphi$

$Y_2 = u \cdot \sin \lambda \cdot \sin \varphi - e$

$Z_2 = u \cdot \cos \lambda + \frac{d_{0}}{2}$

(14)

The similar condition (9) for conical model it is:

$u \cdot \sin \lambda \cdot \cos \varphi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}} = 0$

$\cos \beta_x + u \cdot \cos \lambda \cdot \sin \beta_x = 0$

Independent variable parameter $u$ is:

$u = \frac{e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

(15)

$X_2 = \frac{-R_0 \cdot \cos \varphi + e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Y_2 = \frac{-R_0 \cdot \cos \varphi + e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Z_2 = \frac{-R_0 \cdot \cos \varphi + e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

(16)

and the conical surface becomes:

$X_2 = \frac{e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Y_2 = \frac{e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Z_2 = \frac{e + \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \varphi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

3.3. The cylindrical model

For cylindrical model, see figure 4, from the equations (8), for

$R_0 = 0$, and

$H_0 = \frac{R_H}{\tan \chi_p - \cos \chi_t} \cdot \frac{d_{0}}{2}$

(17)

$R_0 = R_H \cdot \sin \chi_p - \cos \chi_t$

(18)

$e = R_H \cdot \cos \chi_t$

(19)

$H_0 = -\frac{d_{0}}{2}$

(20)

on obtain the cylindrical surface:

$X_2 = -R_H \cdot \sin \phi$

$Y_2 = R_H \cdot \cos \phi - e$

$Z_2 = u + \frac{d_{0}}{2}$

(21)

The similar condition (9) for cylindrical model it is:

$R_0 \cdot \cos \phi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}} = 0$

$\cos \beta_x + u \cdot \sin \beta_x = 0$

Independent variable parameter $u$ is:

$u = \frac{R_0 \cdot \cos \phi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \phi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

(22)

$X_2 = \frac{R_0 \cdot \cos \phi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \phi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Y_2 = \frac{R_0 \cdot \cos \phi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \phi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

$Z_2 = \frac{R_0 \cdot \cos \phi - e - \sqrt{r_x^2 - \frac{d_{0}^2}{4}}}{\sin \lambda \cdot \sin \phi \cdot \cos \beta_x + \cos \lambda \cdot \sin \beta_x}$

(23)
Independent variable parameter $u$ is:

$$u = \frac{-R_0 \cdot \cos \varphi + e + \sqrt{r_x^2 - \frac{d_0^2}{4}} \cdot \cos \beta_x}{\sin \beta_x}$$  \hspace{1cm} (24)$$

and the cylindrical surface becomes:

$$X_2 = -\frac{D^2 - d_0^2}{4 \cos \varphi_p - \cos \varphi_l} \cdot \sin \varphi;$$

$$Y_2 = \frac{D^2 - d_0^2}{4 \cos \varphi_p - \cos \varphi_l} \cdot \sin \varphi \cdot \cos \varphi - e;$$ \hspace{1cm} (25)

$$Z_2 = \frac{-R_0 \cdot \cos \varphi + e + \sqrt{r_x^2 - \frac{d_0^2}{4}} \cdot \cos \beta_x}{\sin \beta_x} + \frac{d_0}{2}.$$ 

The ensemble of equations created from the setting surface (8), (14), (22) and respectively conditions (9), (15), (23) and the equations of the intersection curves of the setting surfaces with the measuring plane $P_M$, see figure 5 which is defined the $\alpha_r$ angle.

4. Numerical applications

They are presented applications of the algorithm for the determination of the flank angle for the three sharpening methods, in the conditions of the respecting major cutting edge geometry.

$\varphi_p = 5^\circ ; \varphi_l = 60^\circ ; D_b = 20 \text{ mm}; d_0 = 2,4 \text{ mm}.$

In figures 6, 7 and 8, are presented the values for the flank angle, along the major cutting edge for all of the three presented methods.
5. Conclusions

The presented method allows determining the value of the flank angle, along the major cutting edge, according to the accepted definition. For all of the analysed sharpening method, the flank angle has values according to the tool’s type requirements. The hyperboloidal method assures the largest value of the flank angle at drill periphery. The constructive parameters modification, the increasing of the working cutting edge angle, at drill periphery, $\kappa_p$, and at drill top, $\kappa_t$, as so as the core diameter of drill, $d = 0.12 \cdot D$, has influence to the law of flank angle variation.

Acknowledgement
The authors gratefully acknowledge the financial support of the Romanian Ministry of Education, Research and Innovation through grant PN II_ID_791/2008.

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