Energetically Model of Helical Drill Cutting Edge Form

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ABSTRACT

The helical drill with curved cutting edge are characterized by the fact that the energetically load for a unity length of cutting edge is not directly proportional with the point distance along the cutting edge. So, the wear intensity of these tools is reduced regarding the wear for the straight lined cutting edge drill.

In this paper, is proposed a model for unitary energetically load value determination for the tool's cutting edge, starting from an experimentally known value of the force which appear at the unity length of the tool's cutting edge.

Two curved cutting edge forms are analyzed, regarding a straight lined cutting edge.

Conclusions regarding the optimum form of the cutting edge for this kind of tools are elaborated.

***Keywords**: helical drill, curved cutting edges, unitary energetically load.*

1. Introduction

The helical drill, due it's constructive and functionally particularities, have a non-uniform load of its cutting edge as result of the uneven cutting speed along this edge. The problem is well known and, also, the proposed solutions for compensation of it [1], [2], [4], [5], [6].

Is proposed an analysis of the adequate form of the main cutting edge for the helical drill in order to decrease the energetically unevenness load along this edge.

We accept that the main cutting edge should be a curved line, so the detached chip thickness to be different in the cutting edge's points. So, the chip will be thinner to the tool's periphery, where the main cutting movement speed is bigger and the thickness will increase as the regarded point is closer to the revolution axis, where the main cutting speed is decreased, see fig. 1.

In this way, for the point on the tool's cutting edge, found at r_x radius, regarding the rotation axis, the chip thickness may be approximate with form

$$a_x = s_d \sin c \qquad (1)$$

where:

s_d is the feed on tooth [mm/tooth];

c — the working cutting edge angle value in the regarded point.

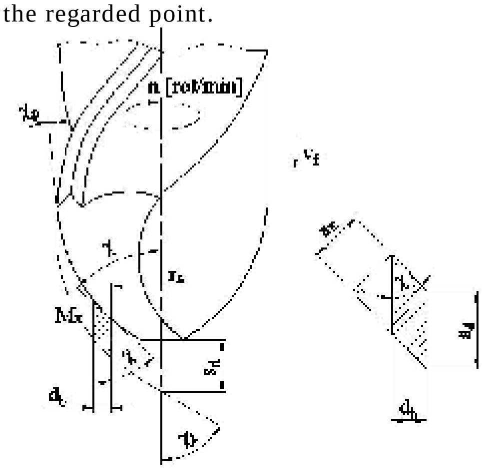

Fig. 1. *Drill curved line cutting edge*

Regarded that are known the dependencies for main cutting force approximation for a cutting edge unitary length, against the chip thickness, is possible to approximate the main cutting edge force, be R_x this, for the detached chip in point M_x at r_x radius to the drill axis:

$$R_x = -162.3 \cdot a_x^2 + 234.4 \cdot a_x + 6.163, \qquad (2)$$

The peripheral speed of M_x point, the main movement speed, is, in principle, on form:

$$v_x = w \cdot r_x, \qquad (3)$$

with r_x the radius of regarded point on the cutting edge;

w - angular speed, in the drill rotation,

$$w = \frac{p\,n}{30} \text{ [rad/s]},\ n \text{ [rot/min]}.$$

In this way, the energy detached on the cutting edge may be approximate

$$E = R_x \cdot v_x \text{ [N·m/s]}, \qquad (4)$$

with r_x measured in meters.

So, the energy for the unitary length of cutting edge, d_b, is

$$q = \frac{E}{\Delta b} \text{ [W/m]} \qquad (5)$$

unitary energetically load of tool’s cutting edge.

Now, is possible to define, for various cutting edge forms, the variation law of the unitary energetically load, along the tool’s main cutting edge.

Note: The recurrence function for the main cutting force value estimation is established, regarding the machined material, from the variation law of detached chip thickness, see **table** 1, [3].

Table 1.
Unitary force at broaching for 1 mm chip width

Tooth increased height a₂	**Refined steel** [daN]	
	HB ≤ 220	HB>220
0.02	10.5	12.5
0.03	13.6	16.1
0.04	15.8	18.7
0.05	18.1	21.6
0.06	19.5	23.2
0.07	21.7	25.8
0.08	23.5	28.
0.09	25.5	30.4
0.10	27.3	32.5
0.11	29.4	35
0.12	31.5	37.5
0.13	33.6	39.8
0.14	35.7	42.5
0.15	37.9	45
0.16	39.8	47.2
0.18	43.6	52
0.20	47.3	56.2
0.22	50.3	60
0.24	53.1	63.2
0.26	56.1	66.6
0.28	58.8	70
0.30	61.5	73

Obviously, these “unitary forces” as experimental values are defined for free orthogonal cutting, which is substantially different to the regarded case. Thus, qualitative information about the adequate form of drill cutting edge may be obtained using these “unitary forces”.

The unitary energetically load variation law proof, along the tool’s cutting edge for various forms of helical drill cutting edge, may be made regarded the geometrical chip thickness, regarded the variation law of the main working cutting edge angle, fig. 2.

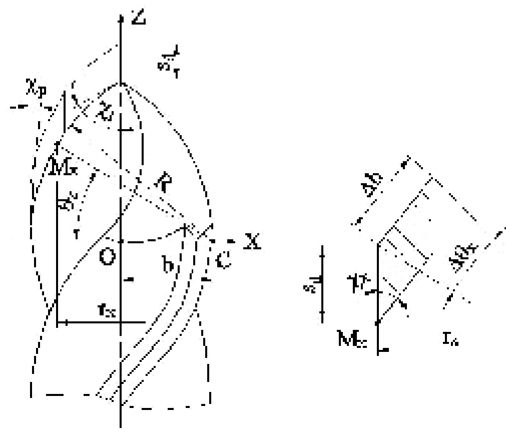

Fig. 2. *Circle arc cutting edge*

2. Curved cutting edge with circle arc profile

For the regarded cutting edge form, the values are defined [1]:

D is the drill’s external diameter [mm];

R - circular profile’s radius for cutting edge,

$$R = 1.05 \cdot D \text{ [mm]}; \qquad (6)$$

c_v, c_p - working cutting edge angle at drill’s top and periphery.

The circle arc cutting edge equations are:

$$X = -R\cos q_x + R\cos c_v;$$
$$Y = 0; \qquad (7)$$
$$Z = R\sin q_x;$$

θ_x - angular variable;

$c_p \le q_x \le c_v$ and R circle arc radius.

Obviously, the cutting edge length, for a variation with angle θ_x,

$$\Delta b = R \cdot \Delta q_x, \qquad (8)$$

and, also, at chip thickness,

$$a_x = s_d \sin c_x \text{ [mm]}. \qquad (9)$$

c_x is the working cutting edge angle, in M_x point on the cutting edge ($c_x = q_x$).

The point's radius on cutting edge is:

$r_x = -R\cos q_x + R\cos c_v$ [mm], see (7).

In this way, is possible to define the unitary energetically load variation law as:

$$q_{(x)} = \frac{R_{(x)} \cdot r_x}{\Delta b} \cdot K \, , \qquad (10)$$

K a value for transformation, which don't depend to the regarded variables (r_x, θ_x).

Note: The $q_{(x)}$ value is the energetically load of drill cutting edge, but the $q_{(x)}$ function's value should not be regarded else than in qualitative means.

The circular form of cutting edge may be obtained for sharpening by the thoroid proceeding of the helical drill (patent RO 113723C), [2], fig. 3, or thoroidal proceeding (patent RSR 80173), see fig. 4.

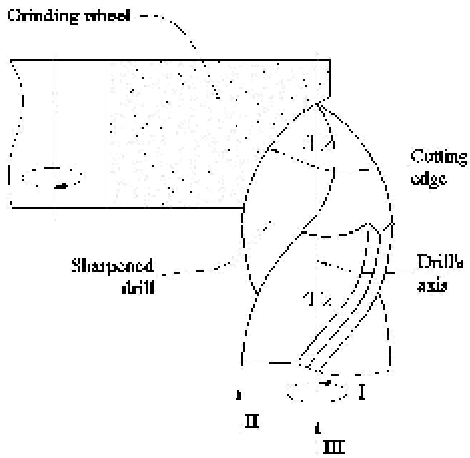

Fig. 3. *Helical sharpening kinematics: I, II—helical movement; III—technological feed [2]*

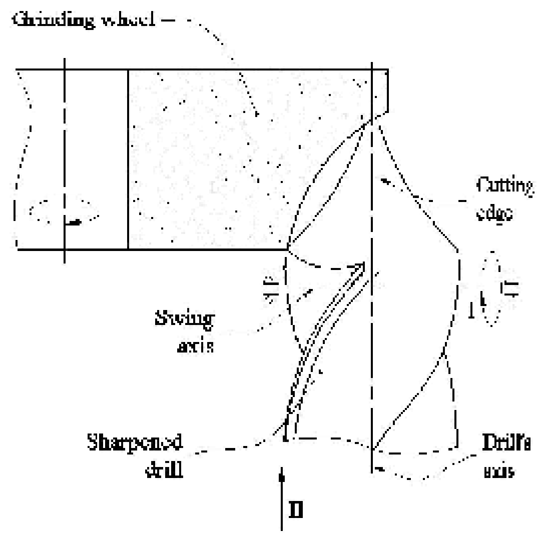

Fig. 4. *Thoroidal sharpening kinematics: I—revolving motion; II—technological feed [4]*

The two sharpening proceedings, patented in Romania, assure a curved line form, which allow modifying the main working cutting edge angle between imposed limits.

Frequently, a sharpening possibility assures a variation law of the main working cutting edge between limits:

$c_t = 60^{\circ}$ to $c_p = 12^{\circ}$, see fig. 2, [2], [4].

In Fig. 5, are presented the variation law for the unitary energetically load, against the drill radius, for a drill with curved cutting edge, with characteristics:

$R = 1.05 \cdot D$; $b = 0.502 \cdot D$,

D is the drill external diameter.

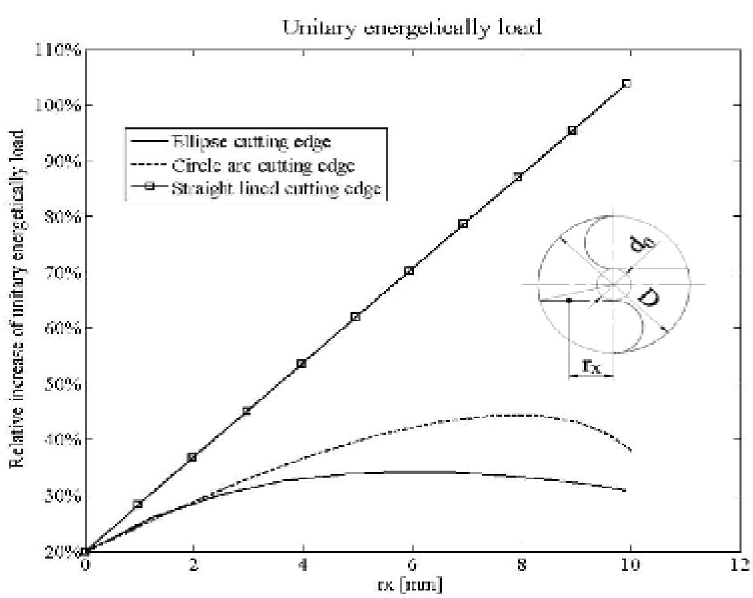

Fig. 5 *Unitary energetically load variation law*

3. The elliptical form of cutting edge

Is analyzed an elliptical cutting edge, see figure 6, as alternative for cutting edge of helical drill with curved line cutting edge.

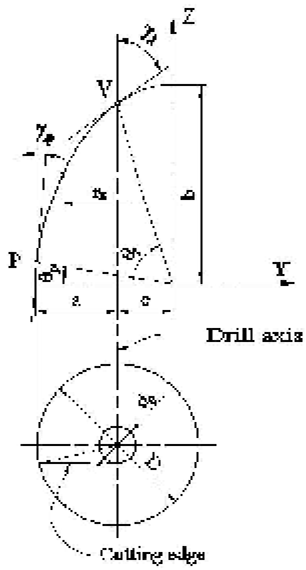

Fig. 6. *Elliptical cutting edge*

Is defined the ellipse:

$$\begin{aligned} Y &= a\cos q; \\ Z &= b\sin q, \end{aligned} \qquad (11)$$

with θ variable and a and b ellipsis half-axis.

The ellipse form identification is made based on conditions:

- working cutting edge angles at tool's top and periphery,

$$\tan q_t = -\frac{b}{a}\tan c_t; \qquad (12)$$

$$\tan q_p = -\frac{b}{a}\tan c_p; \qquad (13)$$

- the c segment value defining the drill axis regarding the ellipse axis,

$$a \cdot \cos q_t = c; \qquad (14)$$

- the P point coordinates on the cutting edge,

$$\sqrt{\frac{D^2}{4} - \frac{d_0^2}{4}} + c = a\cos q_p. \qquad (15)$$

The four equations system contains five unknown values.

Is imposed the ellipse large half-axis value which constitute the cutting edge

$$b = 1.8 \cdot D, \text{ arbitrary value,} \qquad (16)$$

D is the external drill diameter.

In this way, the system becomes determinate.

The elementary cutting edge segment length,

$$ds = \sqrt{dx^2 + dy^2} \qquad (17)$$

where, see (9), are defined

$$dx = [-a\sin q]dq,\ dy = [b\cos q]dq, \qquad (18)$$

or, for small elementary length,

$$\Delta s = \sqrt{(a \cdot \sin q)^2 + (b \cdot \cos q)^2} \cdot \Delta q. \qquad (19)$$

So, in the current point on the cutting edge, the chip thickness for a s_d feed value on tooth,

$$a_x = s_d \sin c_x. \qquad (20)$$

The regarded point radius on the cutting edge is

$$r_x = a\cos q_x - c. \qquad (21)$$

see also (14).

Is defined the unitary energetically load on cutting edge as (see (10) and (19)):

$$q(x) = K\frac{R(x)r_x}{\Delta s}. \qquad (22)$$

4. Software for cutting edge unitary energetically load determination

It was elaborated dedicated software for unitary energetically load determination along the cutting edge, software which:

- establish the curved cutting edge form;
- draw the dependency of unitary energetically load against the radius r_x;
- calculate the relative decrease of the unitary energetically load regarding the straight lined cutting edge tool.

The input data for this software is the b ellipse half-axis, and with the equations:

$$\begin{aligned} \cos q_t &= \frac{a}{\sqrt{a^2 + b^2\tan^2 c_t}}; \\ \cos q_p &= \frac{a}{\sqrt{a^2 + b^2\tan^2 c_p}}; \\ \frac{a}{\cos q_t - \cos q_p} &= \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{d_0}{2}\right)^2}, \end{aligned} \qquad (23)$$

is determined the a value.

In fig. 5, are presented, the variation laws of unitary energetically load along the main cutting edges for the two cutting edge forms, the circular form and the ellipse form.

Also, in fig. 7, are presented the relative unitary energetically load, regarding the straight lined cutting edge drill (regarded as 100 % level). Is obviously that a curved cutting edge with ellipse form assure the most reduced unitary energetically load and, as follows, an improved wear behavior.

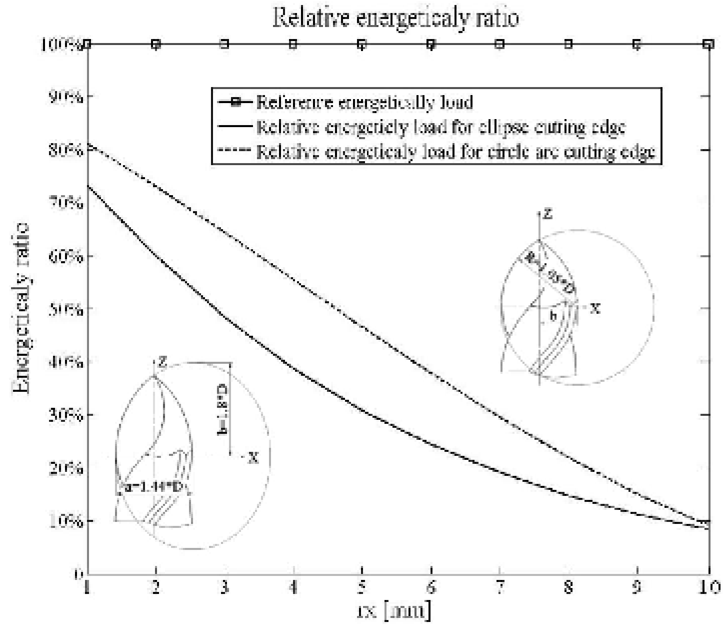

Fig. 7. *Relative decrease of the unitary energetically load of curved cutting edge against the straight lined cutting edge*

5. Conclusions

The estimation modality of the unitary energetically load of the tool's cutting edge, in the presented form allow a qualitative estimation of the process. Actually, the modality may show, based on the made supposition, the cutting value for the length unity of the cutting edge, regarding the chip thickness, experimentally known may be extended for drilling.

The curved line of the cutting edge lead to the unitary energetically load decreasing along the cutting edge in sense that, at points at the drill periphery, the energy for a length unity of the cutting edge is decreased.

The peripheral working cutting edge angle increasing have important influence regarding the unitary energetically load along the cutting edge — circle arc for which exist sharpening proceedings.

Also, was proof that the ellipse form of the cutting edge has an advantage regarding the circle arc cutting edge.

Thus, we can appreciate that not all ellipse form may be used as cutting edge of curved lines drill.

Using an ellipse cutting edge assume to realize a new drill's flute type as so as the conception of a specifically sharpening proceeding of this.

We can imagine a sharpening proceeding for drills with ellipse cutting edge.

The sharpening kinematics is presented in fig. 8, cutting edge belongs to the conical surface with axis different from the sharpened drill's axis.

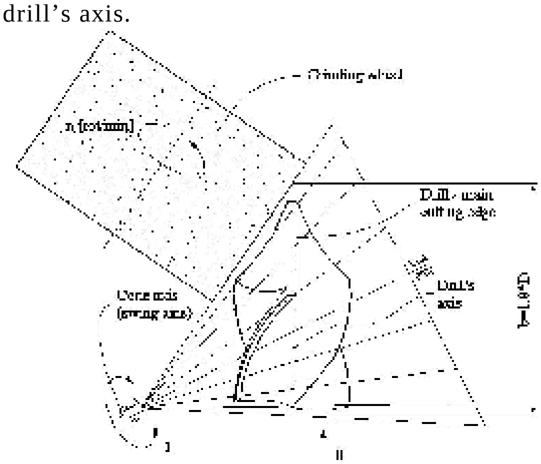

Fig. 8. *Conical sharpening kinematics: I - Swing movement; II - Technological feed*

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Model energetic al formei muchiei de aşchiere a burghiului elicoidal

Rezumat

Burghiele elicoidale cu tăişuri curbe se bucură de proprietatea că încărcarea energetică ce revine unei unităţi de lungime a tăişului nu este direct proporţională cu distanţa punctului de pe tăiş. Astfel, intensitatea de uzare a acestor scule este mult diminuată în raport cu cea măsurabilă la burghiele cu tăişuri rectilinii.

În lucrare, se propune un model pentru determinarea mărimii încărcării energetice a tăişului sculei, pornind de la o mărime cunoscută experimental - forţa ce revine unităţii de lungime a tăişului sculei.

Sunt analizate două forme de tăiş curbiliniu, comparativ cu un tăiş rectiliniu standard.

Sunt elaborate concluzii privind forma muchiei de aşchiere a unei astfel de scule.

Modèle de la forme de l'arête de coupe du foret hélicoïdal

Résumé

Le foret hélicoïdal avec courbe de pointe se caractérise par le fait que l'énergie de charge pour une unité de longueur de l'arête de coupe n'est pas directement proportionnelle à la distance du point en le long de cette arête. Ainsi, l'usure de ces outils est réduite.

Dans le présent article, est proposé un modèle, à partir d'une valeur, connue expérimentalement, de la force qui apparaît à l'unité de longueur de la mèche de charge unitaire énergiquement.

Deux formes courbes de la mèche sont analysées.

Conclusions en ce qui concerne la forme optimale de la mèche pour ce genre d'outils sont mis au point.