Influence of forms and geometric parameters of sharpening of the chisel edge on the cut chip thickness throughout the cutting edges of a twist drill

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Abstract. The problem of deep drilling in difficult-to-cut materials, especially when manufacturing aircraft and rocket and space technology products, is exists. In this study, the features of increasing the efficiency of drilling by sharpening of the chisel edge are discussed. The cut chip thickness value is calculated; determined the geometric parameters when drilling by twist drills with various sharpening of the chisel edge. It is found, that the positive rake angle along the chisel edge, which was shaped by circular sharpening, provides stability of the cutting process and self-centering of the twist drill in the hole.

1. Introduction
At present, there is a significant problem of drilling deep holes in difficult-to-cut materials. Many enterprises are trying to solve this problem by using the expensive carbide tools, and that leads to a significant increase in the cost of tooling. At the same time, many of these enterprises have tool and cutter grinding machines with CNC, which can sharpen the cutting tools. In this way, for the manufacture of cutting tools on its own, it is necessary to develop its design with geometric features and manufacturing technology.

2. Formulation of the problem
Increasing the efficiency of drilling is possible by changing the geometric parameters of cutting and sizing part of twist drill, by selection of cutting modes and using of methods for increasing wear resistance of the cutting part [1-12]. Vinogradov’s A A and Rodin’s P P researches showed that the correlation between the type of chip and the variation in the cut chip thickness throughout the cutting edges of the drill. The cut chip thickness is shortest distance from the rake face of the tool to the outer surface of the currently cut metal layer. The constancy of the cut chip thickness throughout the cutting edge affects the stability of the cutting process and the accuracy of the hole.

Formation by sharpening the positive rake angle, and cutting close to the chisel edge with a cut chip thickness close to feed per tooth, increases the self-centering of the drill in the workpiece. Increasing the self-centering of the drill reduces the deviation value when penetrating the workpiece, thus increasing the accuracy of the machining.

With a varying value of the cut chip thickness throughout the cutting edge, shorter chips are formed, which changes the cutting process. Vinogradov’s A A research show that chip breaking increases the changing value of cutting force, leading to a reduction in processing precision.
3. Theory
To study the influence of the form of sharpening, an analytical study was made of the variation in the cut chip thickness. Chip thickness, measured in the orthogonal section N-N at an arbitrary point A of the cutting edge of the drill is determined by the equation (1) obtained by Rodin P R.

\[ a = \frac{s}{2} \cdot \frac{1}{\sqrt{1 + \left(\frac{1}{\tan \varphi \cdot \cos \tau}\right)^2}}. \]  

where \( \tau \) – is the angle between cutting speed vector \( V \) and feed direction \( S \), \( \varphi \) – is the half point angle.

The angles \( \tau \) and \( \varphi \) were determined at an arbitrary point A according to the scheme shown in Figure 1.

4. Experimental results
The study of the variation in the cut chip thickness was carried out using drills with the following geometric parameters: angle \( 2\varphi \) is 115°, the length of the chisel edge is 0.05d, reduced to the required length by sharpening of the edges of the form A, B, C and circular sharpening. To exclude the formation of a crater hole on the rake face of the tool (Figure 2), the circular sharpening and sharpening of forms A and C were shaped on the 0.4R of the rake face of the drill. The form B was...
shaped by sharpening the rake face to the periphery of the drill by a plane with an incision of rake face of 0.05 mm.

For the comparative analysis, the variation in the cut chip thickness using the drill without sharpening was additionally investigated (Figure 2).

The values of the cut chip thickness determinate by (1) as a function of the distance from the measured point Rx to the drill axis for various forms of sharpening is presented in Table. 1

Figure 2. Change in the cut chip thickness when drilling without sharpening
The cut chip thickness decreases from 0.42\(S_{rev}\) to 0.41\(S_{rev}\) at a distance from 1R to 0.85R, and then increases to 0.42\(S_{rev}\) at a distance of 0.4R when drilling without sharpening. The decrease in the cut chip thickness from 0.41\(S_{rev}\) to 0.38\(S_{rev}\) at a distance from 0.4R to 0.15R from the drill axis is associated with an increase in the angle \(\tau\) and a decrease in the angle \(\varphi\) (Figure 5, Figure 6). At a distance of 0.2R to 0.05R, the cut chip thickness increases from 0.38\(S_{rev}\) to 0.5\(S_{rev}\). A preliminary study allows us to conclude that a significant change in the cut chip thickness occurs at a distance from 0.4R to 0.05R.

**Figure 3.** Change in the cut chip thickness when drilling by drills with A (a) and B (b) forms of sharpening of the chisel edge.
When sharpen form A, the chisel edge is grinding with the formation of a concave surface (Figure 3, a). The cut chip thickness when using drills with A form of sharpening increases from 0.44S\textsubscript{rev} to 0.43S\textsubscript{rev} with an increase in the angle \( \tau \) and \( \phi \) at a distance from 0.4R to 0.15R at the junction of the concave surface and the cutting (Figure 6). A decrease in the cut chip thickness from 0.44S\textsubscript{rev} to 0.41S\textsubscript{rev} at a distance 0.15R-0.1R from the drill axis is caused by a decrease of angle \( \tau \) and \( \phi \) (Figure 5, Figure 6). The analysis of the A form of sharpening allows to conclude that the significant change in the cut chip thickness occurs at a distance from 0.44S\textsubscript{rev} to 0.41S\textsubscript{rev}, which corresponds to the concave surface (Figure 7).

A special feature of the B form of sharpening is a constant angle \( \phi \) (Figure 3, b). The cut chip thickness when using drill with B form of sharpening decreases from 0.42S\textsubscript{rev} to 0.41S\textsubscript{rev}, which is explained by an increase in the angle \( \tau \) at a distance from 0.4R to 0.1R (Figure 5).

When shaped the C form, the chisel edge is grinded by the straight surface of the grinding wheel (Figure 4, a). The cut chip thickness with the C form of sharpening decreases from 0.41S\textsubscript{rev} to 0.40S\textsubscript{rev} and from 0.43S\textsubscript{rev} and 0.41S\textsubscript{rev} with minima at the points 0.3R and 0.1R (Figure 7).

When shaped circular sharpening, the chisel edge grinded by the grinding wheel with the formation of a convex surface (Figure 4, b). The cut chip thickness increases from 0.41S\textsubscript{rev} to 0.42S\textsubscript{rev}, that is explained by an increase in the angle \( \tau \) and \( \phi \) at a distance from 0.4R to 0.3R. Consideration of the circular sharpening allows us to conclude that a significant change in the cut chip thickness occurs at a distance from 0.44S\textsubscript{rev} to 0.41S\textsubscript{rev}, which is associated with the convex surface of the sharpening of the chisel edge. The cut chip thickness varies in steps from 0.42S\textsubscript{rev} to 0.5S\textsubscript{rev} at a length from 0.2R to
0.05R. With a convex surface obtained by grinding, the cut chip thickness increases throughout the chisel edge.

**Table 1.** The determined values of the cut chip thickness at the corners φ and τ angle for various forms of sharpening

| Form of sharpening the chisel edge | Without sharpening | Form A | Form B | Form C | Circular sharpening |
|-----------------------------------|-------------------|--------|--------|--------|-------------------|
| | $R_1$ | $S_x$ | φ, ° | τ, ° | $S_x$ | φ, ° | τ, ° | $S_x$ | φ, ° | τ, ° | $S_x$ | φ, ° | τ, ° |
| 1 | 0.42 | 57.3 | 0 | 0.42 | 57.3 | 0 | 0.42 | 57.3 | 0 | 0.42 | 57.3 | 0 | 0.42 | 57.3 | 0 |
| 0.85 | 0.41 | 55.4 | 0.41 | 0.41 | 55.4 | 0.41 | 0.41 | 55.4 | 0.41 | 0.41 | 55.4 | 0.41 | 0.41 | 55.4 | 0.41 |
| 0.75 | 0.41 | 55.35 | 0 | 0.41 | 55.35 | 0 | 0.41 | 55.35 | 0 | 0.41 | 55.35 | 0 | 0.41 | 55.35 | 0 |
| 0.6 | 0.41 | 55.29 | 0.53 | 0.41 | 55.29 | 0.53 | 0.41 | 55.29 | 0.53 | 0.41 | 55.29 | 0.53 | 0.41 | 55.29 | 0.53 |
| 0.4 | 0.41 | 56.24 | 6.48 | 0.41 | 56.24 | 6.48 | 0.41 | 56.24 | 6.48 | 0.41 | 56.24 | 6.48 | 0.41 | 56.24 | 6.48 |
| 0.3 | 0.38 | 51.32 | 17.14 | 0.41 | 56.22 | 17.14 | 0.41 | 56.22 | 17.14 | 0.41 | 56.22 | 17.14 | 0.41 | 56.22 | 17.14 |
| 0.2 | 0.38 | 53.23 | 29.31 | 0.42 | 58.2 | 20.56 | 0.42 | 58.2 | 20.56 | 0.42 | 58.2 | 20.56 | 0.42 | 58.2 | 20.56 |
| 0.15 | 0.39 | 59.3 | 42.36 | 0.44 | 63.15 | 21.24 | 0.42 | 57.5 | 13.41 | 0.43 | 59.5 | 16.23 | 0.45 | 67.32 | 24.53 |
| 0.1 | 0.44 | 76.8 | 63.13 | 0.42 | 57.22 | 9 | 0.42 | 57.5 | 17.24 | 0.41 | 58.2 | 24.3 | 0.46 | 70.45 | 28.4 |
| 0.05 | 0.5 | 90 | 83.27 | 0.5 | 90 | 16.2 | 0.5 | 90 | 54.14 | 0.5 | 90 | 59.36 | 0.5 | 90 | 17.24 |

**Figure 5.** Variation in the angle φ for drills with various forms of sharpening of the chisel edge
5. Discussion
As a result of the study, it was found that the curve of the dependence of the cut chip thickness throughout the cutting edge from the periphery to the axis of the drill with a circular sharpening increase slightly, therefore, in the drilling process a continuous ship is formed, i.e. the continuous ship
caused by a convex surface. The drops in the graph (Figure 7) for A, B and C form increase the tendency to breaking and formation of the dis-continuous chip. In drills with B and C forms of sharpening, the tendency to dis-continuous chip formation is higher than that of a drill with the A form of sharpening. A significant change in the cut chip thickness in the drill without sharpening is compensated for by any of the compared forms of sharpening (Figure 7). These results explain the practical data of the type of chips obtained when drilling a titanium alloy Vt3-1 (Ti-6Al-1.5Cr-2.5Mo-0.5Fe-0.3Si) (Figure 8).

![Figure 8. Change in the chips obtained when drilling a titanium alloy with different forms of sharpening a drill: a) the A form; b) the B form; c) the C form; d) the circular sharpening.](image)

**Conclusion**

The large cut chip thickness and the positive rake angle throughout the chisel edge, which was shaped by circular sharpening, provides stability of the cutting process and self-centering of the drill in the hole due to the value of the cut chip thickness to 0.45-0.475S at the chisel edge.

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