

The Influence of the Geometry of the Innovative Spiral Drill Design on the Cutting Process and Tool Durability

Galiya Itybayeva

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
itybaeva.g@tou.edu.kz

Zhanara Mussina

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
Mussinazhanara@gmail.com (corresponding author)

Aizhan Taskarina

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
Taskarinaaizhan@gmail.com

Leila Mussina

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
mussina.lr@teachers.tou.edu.kz

Dinara Iskakova

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
iskakovadinaratou@gmail.com

Tatyana Lub

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
lub.tl@teachers.tou.edu.kz

Ruslan Kussainov

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
kussainov.rb@teachers.tou.edu.kz

Sergey Miller

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan
miller.s@teachers.tou.edu.kz

Assylbek Kassenov

Faculty of Engineering, Toraighyrov University, Pavlodar, Kazakhstan | Kazakh National University of Water Management and Irrigation, Taraz, Kazakhstan
Kassenov.a@tou.edu.kz

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ABSTRACT

Tool manufacturing is a crucial component of industrial and innovative development in the metalworking industry, where the drilling process plays a key role. Traditional twist drills with conventional cutting-edge

designs, including a transverse edge, face several issues during drilling, such as poor chip evacuation and high friction between the tool and the workpiece. These phenomena, in turn, lead to a deterioration in the quality of machined holes and shortened tool life. Existing methods of drill geometry modification only partially address these problems by reducing axial forces and increasing tool durability, but they do not overall improve the drilling process. This study aims to develop and examine a new drill design, a double-point twist drill without a transverse edge. This design facilitates favorable cutting conditions, reduces tool wear, and increases tool durability. Experimental samples of the double-point drill were manufactured at the machine-building company LLP "Format Mach Company" (Pavlodar). The experimental results showed that the double-point drill without a transverse edge significantly improves the drilling process by reducing axial and radial cutting forces, which helps reduce tool wear and increase drill life, confirming the feasibility of this drill design in enhancing the quality of hole machining and the efficiency of production processes in the metalworking industry. The new double-point twist drill without a transverse edge exhibited a 2.2-fold increase in tool life.

Keywords-double-point drill; hole; productivity; edge; durability; precision; quality; roughness

I. INTRODUCTION

The processing of holes, which are subject to stringent requirements for dimensional, geometric, and positional accuracy, is a key area within the metalworking industry. Consequently, investments in advanced tooling and cutting-edge technology are critical for reducing machining time for tight-tolerance holes, lowering tool wear rates, and minimizing overall costs [1, 2]. The most widely used method for creating holes in solid materials is drilling. This machining process occurs under challenging cutting conditions, including difficult chip removal and cutting fluid supply, as well as high friction at the chip-drill flute and chip-workpiece interfaces. Furthermore, the cutting speed varies continuously along the cutting edge, from maximum at the periphery to zero at the drill center. This is compounded by a variable relief angle α , which increases towards the drill center, and a highly negative rake angle at the transverse edge. In standard twist drills, the rake angle γ at the transverse edge is up to minus 57° – 60° . As a result, cutting cannot occur effectively. Instead, the metal at the transverse edge is crushed, extruded, and scraped. In a traditional twist drill, the rake angle varies at different points along the cutting edge, and the cutting speed is not constant. Consequently, at the center of the hole beneath the transverse edge, there is no true cutting action. The workpiece material is instead crushed and extruded towards the periphery where the main cutting edges engage. Thus, the presence of the transverse edge is a fundamental characteristic and a significant disadvantage of conventional twist drill geometry [3, 4]. When drilling, the resultant cutting forces applied to the cutting edges of the drill are typically decomposed into three mutually perpendicular force components (Figure 1):

- Axial force (P_x): acting along the drill axis.
- Tangential force (P_z): acting tangentially to the drill's circumference in the direction of the cutting speed.
- Radial force (P_y): acting along the drill radius.

The axial force P_x overcomes the material's resistance to drill penetration and accounts for about 40% of the total axial force. The tangential forces arise from the resistance of the workpiece material to shearing of the cut layer and create a torque on the drill. The radial forces on the two cutting edges are directed in opposite directions and are mutually balanced if

they are equal in magnitude. Otherwise, they contribute to the retraction of the drill.

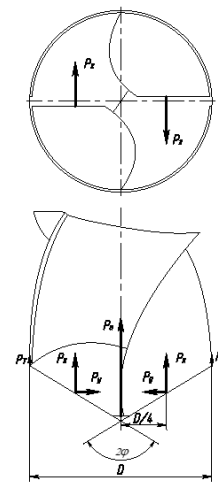


Fig. 1. Schematic representation of the forces acting on a conventional twist drill during drilling.

In addition, the drill is subject to resistance forces arising at the transverse cutting edge, P_n . This force accounts for approximately 57% of the total axial force, with some studies reporting values of up to 65%. There are also friction forces on ribbons PT –3%. To improve cutting conditions, various methods have been developed. These include specialized sharpening techniques for standard drills and sharpening the transverse edge, as well as introducing new, more advanced drill designs [5–8]. One method for reducing axial force involves cutting a groove along the transverse edge. The edge remains on the drill, but in a modified form with reduced rake angles ($\gamma=0^{\circ}$), effectively creating a defined rake angle on each of the two halves. Drills utilizing this principle have proven effective in machining cast iron. Increased drill life can be achieved by using a sharpening technique, which provides a transverse edge of 0.1–0.2 mm.

Experimental studies [9–11] have shown that bridgeless drills with a radial arrangement of the main cutting edges, either along their entire length or partially on the length of the edges adjacent to the center of the drill, provide the best results in terms of productivity, reduction of axial force on the

transverse edge, and wear of the drill. Nevertheless, on these drills, the transverse edge is not completely eliminated but remains in a slightly modified form. Consequently, the forces acting on the transverse edge are not eliminated and the rake angle at the transverse edge decreases, but the negativity persists. These operating conditions of the transverse edge greatly compromise both the processing conditions and the quality of the machined hole.

With this goal in mind, a new twist drill design was proposed to eliminate the transverse edge. Therefore, a new metal-cutting tool was designed: a double-edge spiral drill without a transverse edge [12, 13]. Removing the transverse edge on the drill can significantly minimize heat and wear during cutting, leading to enhanced durability of the drills.

II. MATERIALS AND METHODS

When processing holes with a double-edge spiral drill without a transverse edge, in which the source of process instability – the high heating zone – is eliminated, the conditions for cutting and surface formation are improved, and the roughness is significantly reduced. The geometric parameters of the new cross-edge twist drill correspond to the fundamental principles of the cutting theory of the cutting wedge [14, 15]. When using a new cutting tool, the cutting conditions change: the layer of metal being cut, with the thickness of the cut a , is divided into two parts by a groove, unlike in processing with a traditional drill. Instead of a transverse edge on a traditional drill, the new drill has cutting edges whose angles correspond to the fundamental principles of the cutting theory. Changing the type of cutting tool alters the processing method and cutting conditions. This eliminates the source of increased heat generation and improves the quality of the processing. A double-edged twist drill without a transverse edge has design elements that coincide with the elements of a conventional drill: a shank, a neck, two spiral grooves for chip removal, a working part (including the calibrating and cutting zones), a core diameter, and a band on the calibrating part. Design features that distinguish it from its analogue include a cut of the drill tip in a section of half the diameter in the axial part at an angle (directed towards the shank), corresponding to the tip angle (which typically ranges from 30° - 150°). This geometry creates two distinct points and four primary cutting edges: two external (on the periphery of the drill) and two internal (on the tip cut section), separated by a groove offset relative to the drill axis. One of the walls of this groove is located on the axis, allowing the drill to cut off the internal cavity that prevents cutting. Both terminals of the drill are located on the same line, perpendicular to the axis, and in the same axial plane. The main internal cutting edges also lie in the same axial plane. This configuration completely eliminates the transverse edge found on all standard drills, which is a primary source of poor cutting conditions and excessive thrust force. The drill also has a smoothing (guide) tape on the back side of each blade. The design includes versions for both right and left cutting. This description outlines the key design elements of a novel twist drill that eliminates the conventional transverse cutting edge. The main elements and dimensions are shown in Figures 2 and 3, which define the following geometry: the angle 2φ at the apex on the periphery, and 2φ

(angle directed to the shank) on the cut of the front axial part. The key components are:

- Working part of the drill with helical chip flutes $0 \leq \omega \leq 70^\circ$, where ω is the angle of inclination of the helical flute
- Neck
- Tapered shank with Morse taper
- Foot
- a : cut thickness
- $l_1=l_2$: length of outer cutting edges with an angle of 2φ at the top
- l_4 : length of unshortened inner cutting edge with a reverse angle of 2φ at the top
- $\frac{S_0}{2}$: length of cutting edges at half the axial feed (as with traditional drills), where S_0 is the axial feed per drill revolution

To prevent the displacement of the drill axis and the hole due to the asymmetry of the cutting edges ($l_3 < l_4$), guide and smoothing strips 15 are made on the drill feathers near the chip grooves. The reverse cutting edge of normal length ensures complete removal of chips to the axis of the hole being machined. On the right projection in Figure 3, the marks from the point of the front surface on the chip flute of the drill are conventionally shown by a dashed line. The transverse edge of the specified drill is eliminated, a groove is cut, one wall of which coincides with the axis or is slightly offset relative to the axis. This will eliminate the force arising on the transverse edge of a standard drill, leading to optimized cutting forces, reduced heat generation, and improved surface finish quality (Figure 4).

The proposed dimensions for the groove, based on the drill diameter, are provided in Table I, and the proposed sharpening angles are displayed in Table II. The inclination angle of the separating groove (ψ) should be between 45° and 50° . For processing carbon steel, the optimal sharpening angle range is 116° - 120° , as specified in GOST 4010-77.

TABLE I. PROPOSED GROOVE DIMENSIONS FOR THE DOUBLE-EDGE TWIST DRILL

Drill diameter D [mm]	Groove length l_k [mm]	Groove width b_k [mm]
to 10	2-3	0.5-1
10-30	3-4	1-1.5

TABLE II. PROPOSED SHARPENING ANGLES

2φ [°]	ν [°]	$2\varphi^{\sim}$ [°]	η [°]
150	105	150	105
140	110	140	110
120	120	120	120
100	130	100	130
90	135	90	135
60	150	60	150
40	160	40	160
30	165	30	165

2φ is the point angle, ν is the rake angle, and η is the clearance angle.

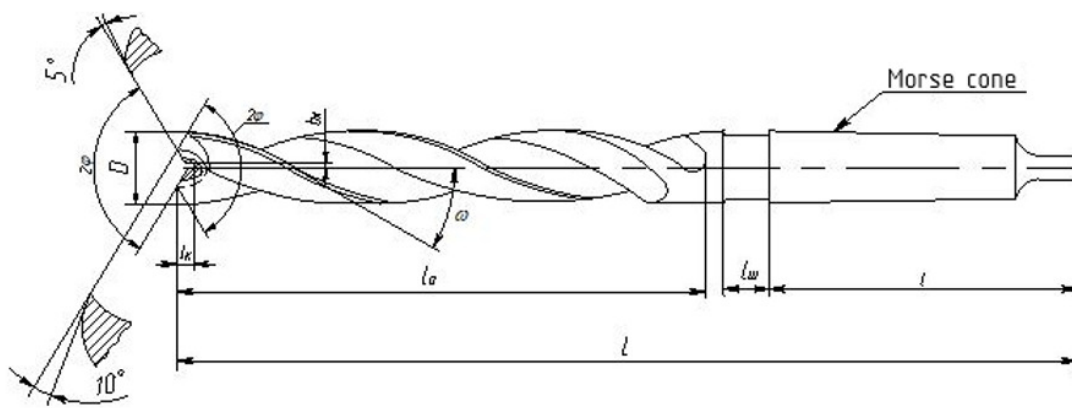


Fig. 2. Double tip twist drill without cross edge.

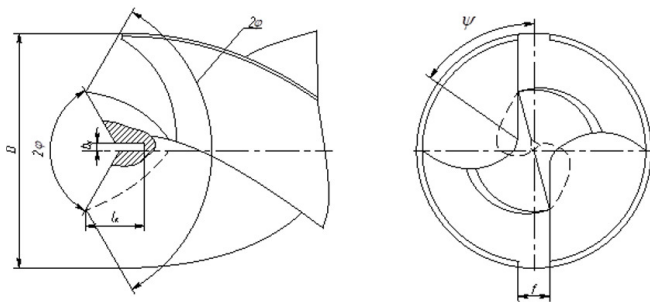


Fig. 3. Structural elements of the double-edge twist drill without a transverse edge (schematic section of dividing groove shown).

The main distinguishing feature of the method of drilling holes with a double-edge twist drill without a transverse edge is the absence of a transverse edge and its replacement with internal cutting blades in compliance with the fundamental provisions on the geometry of the cutting edge with positive front and back angles.

Figure 4 presents a diagram of the forces acting on a double-edge twist drill without a cross edge: P_{ao} is the component of the axial force acting on the outer cutting edges, P_{ai} is the component of the axial force acting on the internal cutting edges, $P_{a\Sigma}$ represents the total component of the axial forces acting on the cutting edges, P_{ro} is the radial force acting on the outer cutting edges, and $P_{r\Sigma}$ is the total radial cutting force. The radial forces at the outer edges are balanced. P_{rfl} is the radial cutting force on full length inner cutting edge, P_{rice} represents the radial cutting force on the inner cutting edge shortened by cutting a groove, b is the groove width, and ΔK is the cutting edge shortening. At ΔK , the radial cutting force is not balanced. This may cause the hole to break apart in diameter [16]. To prevent breakage in mass and large-scale production, it is necessary to apply processing using jig bushings. Figure 5 shows a diagram of drilling a hole with a double-vertex drill without a transverse edge and the dimensions are equal to a quarter of the diameter (0.25D). The diameter of the drill is divided by two formed vertices, corresponding to the lengths of the four cutting edges 1, 2, 3, 4.

Axial force P_a , acting on a drill without a transverse edge, consists of two forces acting on each drill blade:

$$P_a = P_a^{1-3} + P_a^{2-4} \tag{1}$$

where P_a^{1-3} is the component of the axial force acting on the drill blade with edges 1-3 and P_a^{2-4} is the component of the axial force acting on the drill blade with edges 2-4.

To assess the degree of equilibrium of forces acting on the cutting edges of a double-edge spiral drill without a transverse edge, this work introduces concepts and notations for specific forces acting per unit length of the cutting edges. It should be borne in mind that cutting edges of the same length are equally loaded, and the projected length of the cutting edge makes it possible to conveniently evaluate forces without considering the angle of inclination of the cutting edges, using the principle of proportionality of lengths.

In Figure 5, the total axial force on a drill without a transverse edge is calculated by:

$$P_a = 0.3 \cdot P_{ac} \tag{2}$$

where P_{ac} is the axial force acting when drilling on a cross-edge drill. The axial force is determined by:

$$P_a = 10 \cdot C_p \cdot D^q \cdot S^y \cdot K_p \cdot H \tag{3}$$

For the axial force acting on a drill without a transverse edge, we have:

$$P_a = 3 \cdot C_p \cdot D^q \cdot S^y \cdot K_p = A \cdot S^y \cdot H \tag{4}$$

An analysis of the axial forces acting on the cutting edges is presented to determine the force balance of a drill without a transverse edge. For this purpose, the following parameters are defined:

1. The specific component of the axial cutting force per unit length of the drill diameter (projected cutting-edge $l_{\Sigma np}$).
2. Specific component of the axial cutting force per unit length of the cutting edges of the drill l_{Σ} along its diameter in the Y-axis direction, considering the inclination angle of the cutting edges φ and λ , as illustrated in Figure 5.

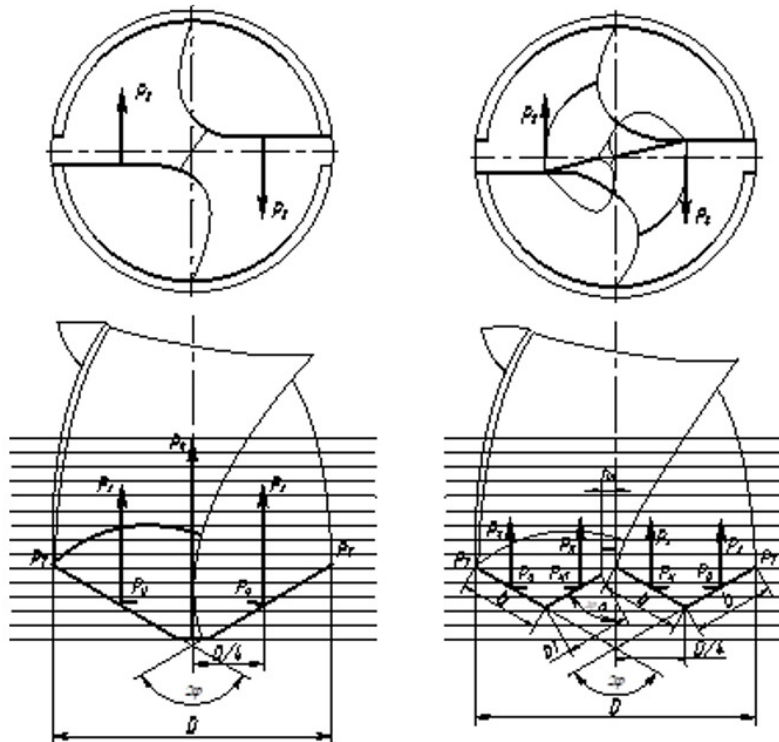


Fig. 4. Diagram of forces acting on a double-edge twist drill.

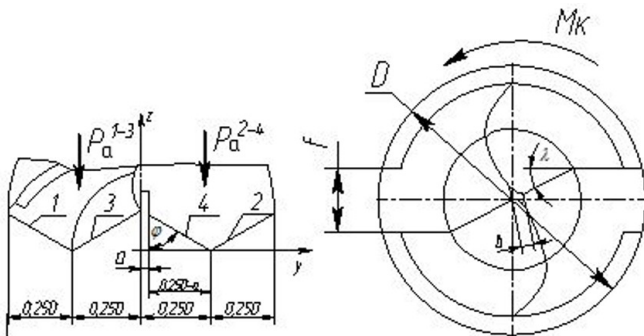


Fig. 5. Drilling holes with a double-edge twist drill without a cross edge.

The total projected length of the drill cutting edges without transverse edge:

$$l_{\Sigma pl} = l_{1pl} + l_{2pl} + l_{3pl} + l_{4pl} = 0.25D + 0.25D + 0.25D + (0.25D - a) = D - a \quad (5)$$

The total length of the drill cutting edges without the transverse edge:

$$l_{\Sigma} = 0.25D + \frac{0.25D}{\cos \phi \cos \lambda} + \frac{0.25D - a}{\cos \phi \cos \lambda} + 0.25D = 0.5D + \frac{0.25D(1 - \alpha)}{\cos \phi \cos \lambda} = B \quad (6)$$

In the first case, the specific axial force per unit length of the cutting edge is defined as:

$$P_{as} = \frac{P_{o6}}{l_{\Sigma np}} = \frac{3 \cdot C_p \cdot D^q \cdot S^y \cdot K_p}{D - a} \quad (7)$$

Accordingly, in the second case, the specific axial force is defined as:

$$P_{as} = \frac{P_{o6}}{l_{\Sigma}} = \frac{3 \cdot C_p \cdot D^q \cdot S^y \cdot K_p}{0.5D + \frac{0.25D(1 - \alpha)}{\cos \phi \cos \lambda}} \quad (8)$$

For the selected cutting conditions (one material, a given diameter), the feed is the only variable that influences the specific axial force. Therefore, the mathematical model for the specific cutting force for the two above cases can be expressed in the following form:

In the first case:

$$P_{as} = \frac{P_{o6}}{l_{\Sigma np}} = \frac{3 \cdot C_p \cdot D^q \cdot K_p}{D - a} \cdot S^y = A \cdot S^y, \quad \text{N/mm} \quad (9)$$

where $\frac{3 \cdot C_p \cdot D^q \cdot K_p \cdot S^y}{D - a} = A = \text{const}$

In the second case:

$$P_{as} = \frac{P_{o6}}{l_{\Sigma}} = \frac{3 \cdot C_p \cdot D^q \cdot K_p}{0.5D + 0.25D(1 - \alpha)} \cdot S^y = B \cdot S^y, \quad \text{N/mm} \quad (10)$$

where $\frac{3 \cdot C_p \cdot D^q \cdot K_p}{0.5D + 0.25D(1 - \alpha)} = B = \text{const}$

Expression for the axial forces of a double-edge twist drill without a transverse edge acting on a blade with cutting edges 1 and 3:

$$P_a^{1-3} = P_{as} \cdot 0.5D = 0.5 \cdot A \cdot S^y \cdot D = C \cdot S^y \cdot N \quad (11)$$

where $C = 0.5 \cdot A \cdot D$

Expression for the axial forces of a double-edge twist drill without a transverse edge acting on a blade with cutting edges 2 and 4:

$$P_a^{2-4} = P_{as} \cdot (0.5D - a) = A \cdot S^y \cdot (0.5D - a) = E \cdot S^y \cdot N \quad (12)$$

where $E = A \cdot (0.5D - a)$

Thus, the feathers of a double-edge twist drill without a transverse edge are subject to forces that are not equal:

$$P_a^{1-3} = C \cdot S^y > E \cdot S^y = P_a^{2-4} \quad (13)$$

The difference in axial forces creates a bending moment at the tops of the cutting part of the drill, $M_b = (P_a^{1-3} - P_a^{2-4})25D$, which contributes to the withdrawal of the drill during drilling. Its magnitude needs to be investigated.

For further analysis, it is also necessary to introduce the concept of shear forces in the transverse direction (perpendicular to the drill axis) acting on the cutting edges, and the concept of shear forces and specific shear force acting on the projected length of the cutting edge along the direction of the drill axis (Figure 6).

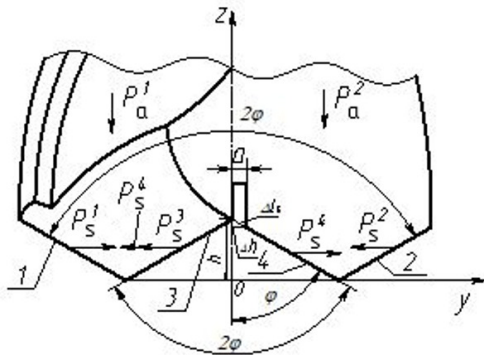


Fig. 6. Specific shear forces acting on the projected length of the cutting edge along the direction of the drill axis.

As shown in Figure 6, the shear forces on the blade of a drill with cutting edges 1 and 3 are:

- P_s^1 : Shear force acting in the transverse direction on the cutting edge 1 of a double tip twist drill without cross edge.
- P_s^3 : Shear force acting in the transverse direction on cutting edge 3 of a double tip twist drill without cross edge.

These forces are equal in magnitude but opposite in direction ($P_s^1 = P_s^3$). As a result, the drill blade with cutting edges 1 and 3 is balanced against shear in the transverse direction.

Consider the blade of a double-edge twist drill without cross edge, with cutting edges 2 and 4. As portrayed in Figure 5, cutting edge 4 is shortened by cutting a groove with a width

a along the Y-axis, one wall of which coincides with the axis of the drill. Therefore the shear force on the cutting edge 4 will be reduced by an amount proportional to the width of the grooves, and then:

$$P_s^4 < P_s^2 \quad (14)$$

where P_s^2 is the shear force acting in the transverse direction on the cutting edge 2 of a double tip twist drill without cross edge, P_s^4 is the shear force acting in the transverse direction on the cutting edge 4 of a double tip twist drill without cross edge.

The difference between these applied forces will cause the drill to shift to the left during operation. This shear force can be determined both theoretically, based on the calculated specific shear force, and verified experimentally. Moreover, the width of the cut groove must be chosen as small as possible, to reduce the shear force. The magnitude of this force is given by:

$$P_s^4 = \frac{\Delta l_4}{h \cdot \cos \phi} \quad (15)$$

Thus, the drill blade with cutting edges 2 and 4 is not balanced against the shear force resulting from shortening the cutting edge 4. Considering the entire drill as a whole, the analysis can proceed to the kinematic interaction of all cutting edges during drill operation. In Figure 6, cutting edges 1 and 2, located symmetrically on the drill periphery, are completely balanced. This means that the shear forces on these cutting edges under the same conditions are equal in magnitude and opposite. Cutting edges 3 and 4 are also operate under the same conditions. The relationship $P_s^4 < P_s^3$ causes the drill to shift to the left during operation. This was established earlier from the force imbalance on the blade containing cutting edges 2 and 4.

Figure 7 presents the design of a double-edge twist drill without a transverse edge, which is balanced against transverse (Y-axis) shear forces. This is achieved by shortening cutting edge 2 on the periphery by a length a .

In this design, the drills are protected from shear forces in the direction of the axis Y drill feathers are loose:

$$P_s^1 = P_s^3; P_s^4 = P_s^2 \quad (16)$$

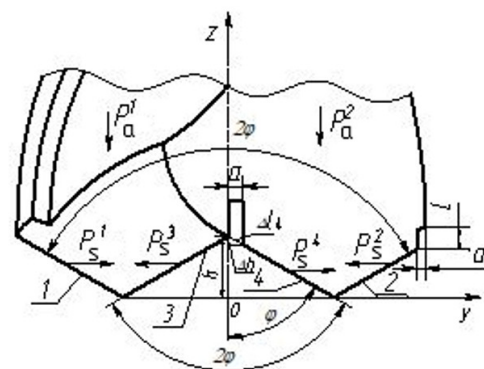


Fig. 7. Design of a double-edge twist drill without a transverse edge, free from shear force along the Y axis.

Further analysis (Figure 8) shows that during the operation of a double-pointed drill without a transverse edge, which is free from shear force along the Y axis, a torque arises from the action of two unequal tangential forces.

Figure 6 illustrates the forces acting on the drill feathers and a diagram of shear forces' occurrence: 1 – Outer cutting edge at full length, 2 – Outer cutting edge on a drill blade with a shortened inner edge, 3 – Internal cutting edge on the same drill blade, and 4 – Inner cutting edge on the other drill blade with a slotted groove of width a .

The groove between edges 3 and 4 is designed for cutting blind hollows and distributing the cutting work between them. After machining a groove of width a on cutting edge 4 in the axial part of the drill, the force balance between the internal cutting edges (3 and 4) is disrupted. The mechanism is: The length of cutting edge 3 remains unchanged and the length of cutting edge 4 is reduced by the groove. Therefore, the shear force on the edge 3 (P_s^3) becomes greater than the shear force on edge 4 (P_s^4) by an amount proportional to the groove width a . This imbalance creates a transverse force. For the entire drill to be balanced, this force from edges 3 and 4 must be counteracted by an equal and opposite force from the other blade (edges 1 and 2). This is achieved by a corresponding design modification on the opposite blade, as depicted in Figure 7. The shear forces acting on the cutting edges in Figure 6 are denoted as: P_s^1 is the shear force acting on the cutting edge 1; P_s^2 is the shear force acting on the cutting edge 2; P_s^3 is the shear force acting on the cutting edge 3; P_s^4 is the shear force acting on the cutting edge 4.

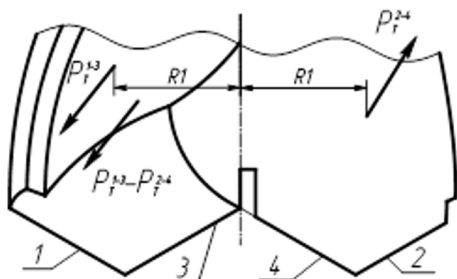


Fig. 8. Tangential forces P_T^{1-3} and P_T^{2-4} , acting on the feathers of a double-edge twist drill without a transverse edge.

Due to their symmetrical operation and the action of forces, the shear forces on cutting edges 1 and 2 are oppositely directed, equal in magnitude, and balanced:

$$P_s^1 = P_s^2 \tag{17}$$

After machining a groove of width a on cutting edge 4, its effective length is reduced. This results in a decrease in its shear force, denoted as ΔP_s^4 . This decrease in force on edge 4 creates an imbalance. The shear force on the uncut edge 3 is now greater than the force on the edge 4, leading to a transverse force that shifts the drill to the left. The force reduction ΔP_s^4 is calculated as: $\Delta P_s^4 = P_{ss}^4 \cdot \Delta h = \frac{P_s^4 \cdot \Delta h}{h}$, where the corresponding reduction in the projected length is

$\Delta h = \Delta l_4 \cdot \cos \phi$. When using a double-edge twist drill without a cross-edge, as shown in Figure 6, a shear force acts on the cutting part, making it difficult to drill at the beginning of the drill. To mitigate this, pre-drilling can be used to a depth equal to half the diameter of the hole to center the drill. This disadvantage is offset by improved cutting conditions, higher applicable cutting speeds, and increased drill life [17].

Figure 7 presents the design of a double-edge twist drill without a transverse edge, where the shear forces on both blades are balanced. This balance is achieved by sharpening the cutting edge 2 by an amount equal to the width of the groove between the cutting edges 3 and 4:

$$P_s^1 = P_s^2 = P_s^3 = P_s^4 \tag{18}$$

Figure 8 displays the tangential forces P_T^{1-3} and P_T^{2-4} , acting on the blades of a double-edge twist drill without a transverse edge, which create a cutting resistance torque. Since $P_T^{1-3} > P_T^{2-4}$, the magnitude of this torque is proportional to the force difference: $P_T^{1-3} - P_T^{2-4}$, acting on a pen with cutting edges 1 and 3, as illustrated in Figure 9. To increase the durability of a double-vertex spiral drill without a transverse edge, several modifications to the cutting edges are proposed: the tips of the drill on each blade can be relieved (Figure 10) or rounded with a radius (Figure 11). Alternatively, the tip angle on the outer cutting edges (1 and 2) can be made equal to 180° (Figure 12), optionally with rounded corners (Figure 13). Meanwhile, the internal cutting edges (3 and 4) are formed along the generatrices of a cone with a negative apex angle. Similar designs of the cutting part of a double-edge spiral drill without a transverse edge can also be used for a double-edged feather drill [18].

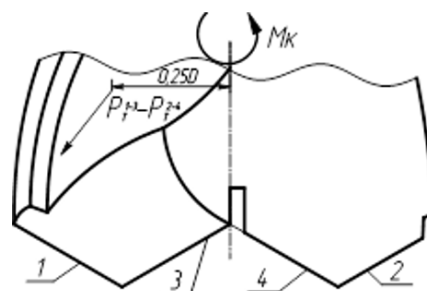


Fig. 9. Torque and shear force when working with a double-edge drill without a cross edge.

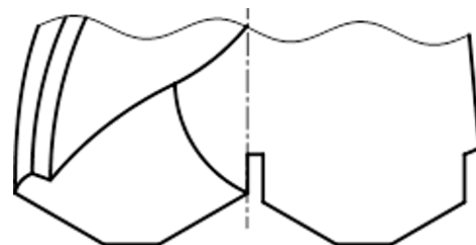


Fig. 10. Double tip twist drill without cross edge with cut off tips.

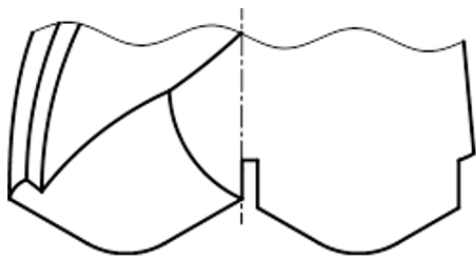


Fig. 11. Drill design with rounded tips.

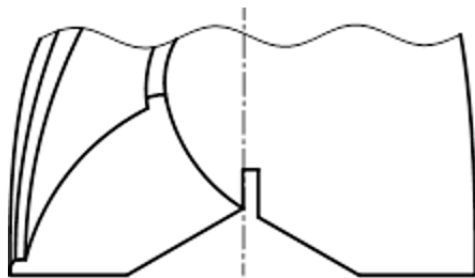


Fig. 12. Twist drill without a transverse edge, with a reverse angle at the tip and outer edges at an angle of 180°.

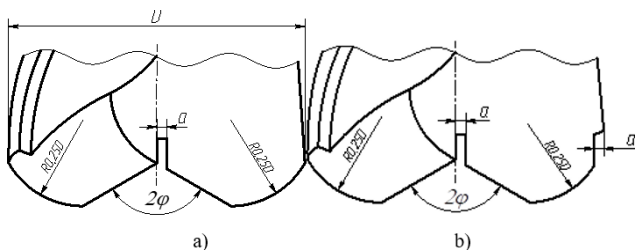


Fig. 13. Twist drill without cross edge, with (a) reverse angle at the tip and (b) rounded outer edges.

III. EXPERIMENTAL PART AND DISCUSSION

Prototypes of a double-vertex spiral drill without a transverse edge were manufactured in three standard sizes (diameters of 13.5 mm, 19.5 mm, and 29.5 mm) by "Format Mach Company", a machine-building enterprise in Pavlodar LLP. These prototypes were subsequently tested in the training and production workshops of the Faculty of Metallurgy, Mechanical Engineering, and Transport at Toraigrov University, under the supervision of the Department of Mechanical Engineering and Standardization (Figure 14).



Fig. 14. Prototypes of double-edge twist drills without a transverse edge.

Production tests of prototypes were carried out at the LLP "Factory of non-standardized equipment" under the conditions given in Table III.

When processing holes with a 13.5 mm diameter double-edge spiral drill (without a transverse edge), the regrinding time was 42 min. For a standard drill, the regrinding time was 20 min. This presents a 2.2-fold increase in regrinding time (Figure 15).

TABLE III. TEST CONDITIONS

Equipment	Material	Processing length L , mm	Processing diameter D , mm	Rotational speed n , rev/min		Cutting feed S , mm/rev.	
Vertical drilling machine model 2H135	Steel 55C2*	15; 30; 45	13.5	275	140	0.32	0.15
		20; 40; 60	19.5	195	100	0.32	0.15
		30; 60; 90	29.5	140	68	0.32	0.15
Screw-cutting lathe model 1A616	Steel 55C2*	15; 30; 45	13.5	280	140	0.3	0.08
		20; 40; 60	19.5	224	112	0.3	0.08
		30; 60; 90	29.5	180	90	0.3	0.08

* according to GOST 14959-2016

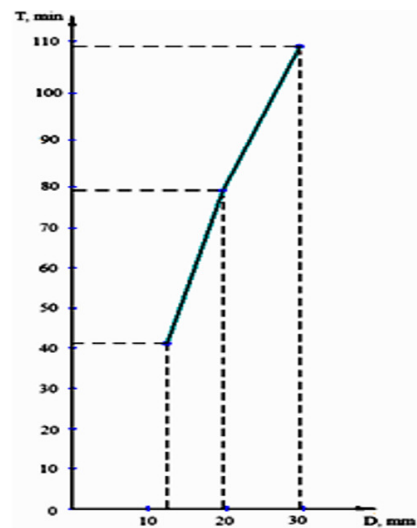


Fig. 15. Lifetime graph of double tip twist drill without cross edge.

An experimental setup was utilized to determine the cutting forces acting on the drill (Figure 16 (a)). It consists of a ZET 058 strain gauge measuring system (Figure 16 (b)), Kistler force sensors (Multi-component dynamometers 9272, Dynoware 2825A software), a tool holder (Figure 16 (c)), connecting cables, and strain gauges.



Fig. 16. Experimental setup for determining cutting forces.

Kistler force sensors are devices based on the piezoelectric effect of quartz. These sensors are ideal for measuring cutting

force in metal processing and other dynamic measurements in any given direction, regardless of the point at which the load is applied.

After machining the holes with twist and double-point twist drills, the hole diameter accuracy and surface roughness were examined. To measure the accuracy of the hole processing, an instrumental horizontal microscope IKG 3 and indicator bore gauges with inserts were used. The surface roughness was measured utilizing a ZETLAB model 259 profilometer.

The results of production tests of samples processed with metal-cutting tools are:

- Twist drills:

The holes had a diametrical accuracy of 0.21-0.33 mm (12–13 accuracy grade, according to GOST 25346-2016) and a surface roughness of $Rz=20-80 \mu\text{m}$ (corresponding to roughness classes 3 and 5, according to GOST 25346-2016).

- Double-edge twist drills:

The holes had a diametrical accuracy of 0.11-0.13 mm (11th grade of accuracy, according to GOST 25346-2016) and a surface roughness $Ra=2.5-10 \mu\text{m}$ (corresponding to roughness classes 4 and 6, according to GOST 2789-73).

Based on the data obtained, graphs were constructed showing the deviation in the hole diameter as a function of spindle rotation speed and cutting feed (Figures 17 and 18).

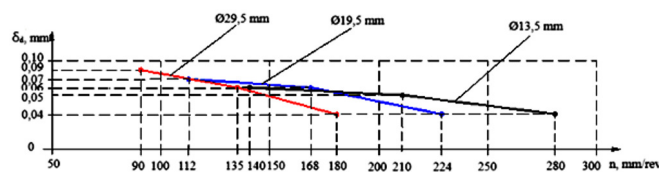


Fig. 17. Dependence of the accuracy of diametrical dimensions on the spindle speed.

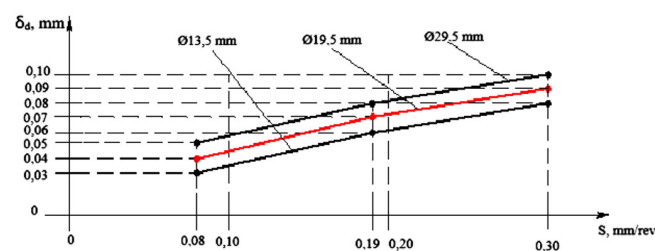


Fig. 18. Dependence of the accuracy of diametrical dimensions on cutting feed.

As can be seen from the graphs, the deviations of diametrical dimensions decrease with increasing spindle speed and increase with increasing cutting feed. The deviations in the shape of the holes in the cross section were determined using a bore gauge, and the results were drawn up in the form of pie charts. The surface roughness of the holes was measured by deploying the contact method using a profilometer.

The measurement accuracy of the processed samples is confirmed by certificates from two laboratories: The Technical Control Department of Pavlodar Machine-Building Plant JSC and the accredited testing laboratory of the Pavlodar branch of the National Center for Expertise and Certification JSC.

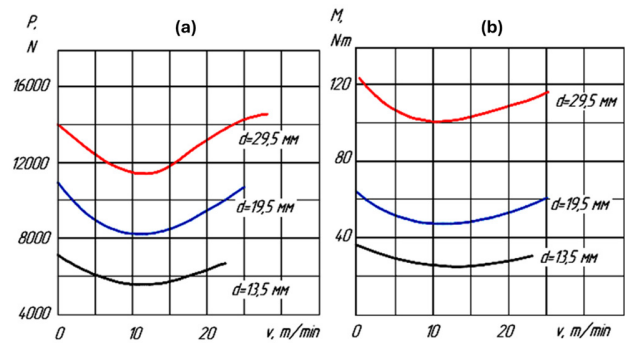


Fig. 19. Influence of drill diameter on: (a) axial force and (b) torque when drilling steel 55C2.

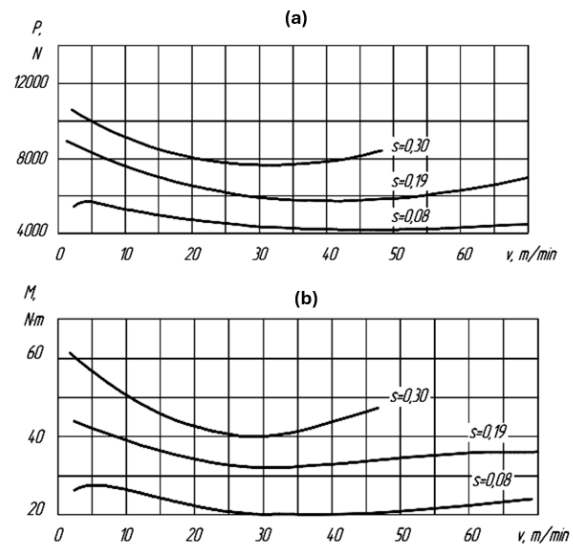


Fig. 20. Influence of Lubricant-Coolant Fluid during drilling of steel 55C2.

Experimental studies show that using a two-blade spiral drill without a transverse edge significantly improves hole surface quality. Specifically, surface roughness, the depth of the defective layer, and the breakdown of the holes are reduced. This is due to more favorable cutting conditions compared to conventional spiral drills with a cruciform edge. Eliminating the cruciform edge reduces the loads on the tool, thereby increasing its service life.

The present study utilized methods from the plan of experiments, mathematical statistics, and optimization theory. The experimental data were processed and analyzed using computer software for graphing mathematical relationships and approximating data points.

A sharpening procedure for the proposed drill was developed, along with a set of optimal geometric parameters.

These developments are designed to increase drill durability and machining accuracy.

IV. PATENTS

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V. CONCLUSIONS

The theoretical and experimental studies demonstrate that the double-edge twist drill without a transverse edge is significantly more efficient than twist drills with a transverse edge. The proposed drill has optimal cutting conditions, leading to increased drill life. This is primarily due to reduced temperature and tool wear in the cutting zone, resulting from more uniform mechanical and thermal stresses along the cutting edges. Consistent positive rake and clearance angles across the entire edge further contribute to this stability. Consequently, the study drill allows for higher cutting speeds and offers greater economic efficiency.

Compared to standard twist drills, the use of the double-edge drills with the proposed sharpening methods yielded a clear improvement in key performance metrics: hole diameter accuracy improved by 1-2 quality grades (COST 25346-2026), surface roughness was reduced by 1-2 classes, and most significantly, tool durability increased by a factor of 2.2.

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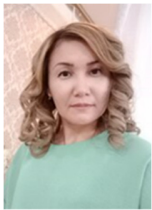
AUTHORS PROFILE



G. T. Itybayeva, Candidate of Engineering Sciences, Associate professor. She was born in 1961 in Kazakhstan. Education: Karaganda Polytechnic Institute of the Order of the Red Banner of Labor, specialty "Mechanical Engineering" (1984). She defended her Candidate's dissertation entitled "Improving the quality of processing cylindrical holes using a new countersink-broaching design" supervised by Professors T.M. Mendebayev and N.S. Dudak (Almaty) (2010). She holds patents for 13 inventions, about 100 scientific papers and teaching materials.



Zh. K. Mussina, Candidate of Engineering Sciences, Associate professor. She was born in 1976, Kazakhstan. Education: S. Toraigyrov Pavlodar State University, degree in Metal-cutting Machines and Tools (1998). She defended her Candidate's dissertation entitled "Technology and Equipment for Mechanical and Physical-Technical Processing" (Almaty) (2010). She has innovative patents, published scientific papers and methodological developments of about 100.



A. Zh. Taskarina, PhD, Associate professor. She was born in 1984, Kazakhstan. Education: S. Toraigyrov Pavlodar State University, degree in Mechanical Engineering Technology (2020). She defended her doctoral dissertation for a scientific degree Doctor of Philosophy (PhD) (Almaty, 2014) on the topic "Ensuring high accuracy of hole processing using prefabricated reamers". She has patents for 16 inventions, 109 research papers, and teaching materials.



L. R. Mussina, Doctoral student in the field of Mechanical Engineering, lecturer (Assistant). She was born in 1999 in Kazakhstan. In 2021 she graduated from Toraigyrov University in the educational program 5B071200 - "Mechanical Engineering", and in 2023 she graduated from the Master's program at Toraigyrov University in the educational program 7M07103 - "Mechanical Engineering". Her scientific publications include 1 article in a journal recommended by CQAFS&HE MS&HE RK, 4 articles in foreign and domestic scientific journals, and 7 articles in the collections of scientific conferences of Toraigyrov University.



D. A. Iskakova, Doctoral student in the field of Mechanical Engineering under the supervisor Professor Kasenov A.Zh. She was born in 1981 in Kazakhstan. She holds a degree in "Engineering Technology" (2004) and a Master's degree in the educational program 6N071600 Instrument engineering (2006), both from S. Toraigyrov Pavlodar State University. She holds patents for 16 inventions and 5 teaching materials.

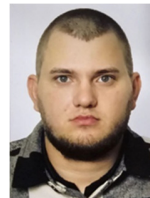


T. L. Lub, Doctoral student in the field of Mechanical Engineering. She was born in 1995 in Kazakhstan. Education: S. Toraigyrov Pavlodar State University, specialty "Mechanical Engineering" (2016). In 2018, she completed the Master's program at S. Toraigyrov Pavlodar State University in the educational program 6M071200 – Mechanical Engineering. She holds 2 invention patents and 1 utility model patent, is the author of 5 teaching manuals, and has published 2 articles indexed in Scopus. Her academic supervisors are Professor A. Zh. Kassenov and Associate Professor Zh. K. Mussina.



invention.

R. B. Kussainov, Doctoral student in the field of Mechanical Engineering. His supervisor is Professor Musina Zh.K. He was born in 1978 in Kazakhstan. He holds a degree in "Mechanical Engineering Technology" (2005) from S. Toraigyrov Pavlodar State University. In 2023, he graduated from the magistracy of the University of Toraigyrov, the direction of scientific and pedagogical, according to the educational program 7M07103 "Mechanical Engineering". He has one patent for one



S. A. Miller, He was born in 1995 in Kazakhstan. Education: S. Toraigyrov Pavlodar State University, specialty 5B071200 "Mechanical Engineering" (2017), in 2019 – Master's degree from S. Toraigyrov Pavlodar State University in the direction 6M071200 "Mechanical Engineering". He holds patents for 3 utility models.



A. Zh. Kassenov, Candidate of Engineering Sciences, Associate Professor. He was born in 1980, Kazakhstan. Education: S. Toraigyrov Pavlodar State University, degree in Mechanical Engineering Technology (2002). He defended his Candidate's dissertation entitled: Development of Technology and Design of the Countersink-Broaching for Processing Cylindrical Holes" supervised by Professors T.M. Mendebayev and N.S. Dudak (Almaty) (2010). He holds patents for 18 inventions and is the author of 125 research papers and teaching materials.