TOMSK POLYTECHNIC UNIVERSITY

S. V. Kirsanov

MATERIAL CUTTING AND CUTTING TOOLS

LABORATORY WORKS

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Laboratory work 1: Turning cutters sharpening

Laboratory work objectives:

1. To study the construction and setting-up of a three-roll vice, study grinding machine capabilities and sharpening methods.
2. To check the geometrical parameters of the sharpened cutter.

Equipment:

1. Universal tool grinder 3B642.
2. Three-roll vice.
3. Pendulum angle gauge.

Guidelines

During sharpening, firstly the face of a cutter is ground and then the major and minor flanks are ground. For these purposes the cutter surface is positioned parallel to the working surface of the grinding wheel. The cutter is installed in a three-roll vice with scales A, B and C (Fig. 1.1).

For setting the vices, the cutter angles are preliminary defined according to Table 1.1.

Table 1.1

Cutter geometrical parameters

Cutter	Cutter hand	Angles		
		φ_c	φ_{1c}	λ_c
Turning	Right Left	φ $-\varphi$	φ_1 $-\varphi_1$	λ $-\lambda$
Boring, facing, cutt-off	Right Left	$90^0+\varphi$ $-(90^0-\varphi)$	$90^0+\varphi_1$ $-(90^0-\varphi_1)$	$-\lambda$ λ

Then, according to cutter initial position, vice angles are calculated with the help of the equations given in Table 1.2.

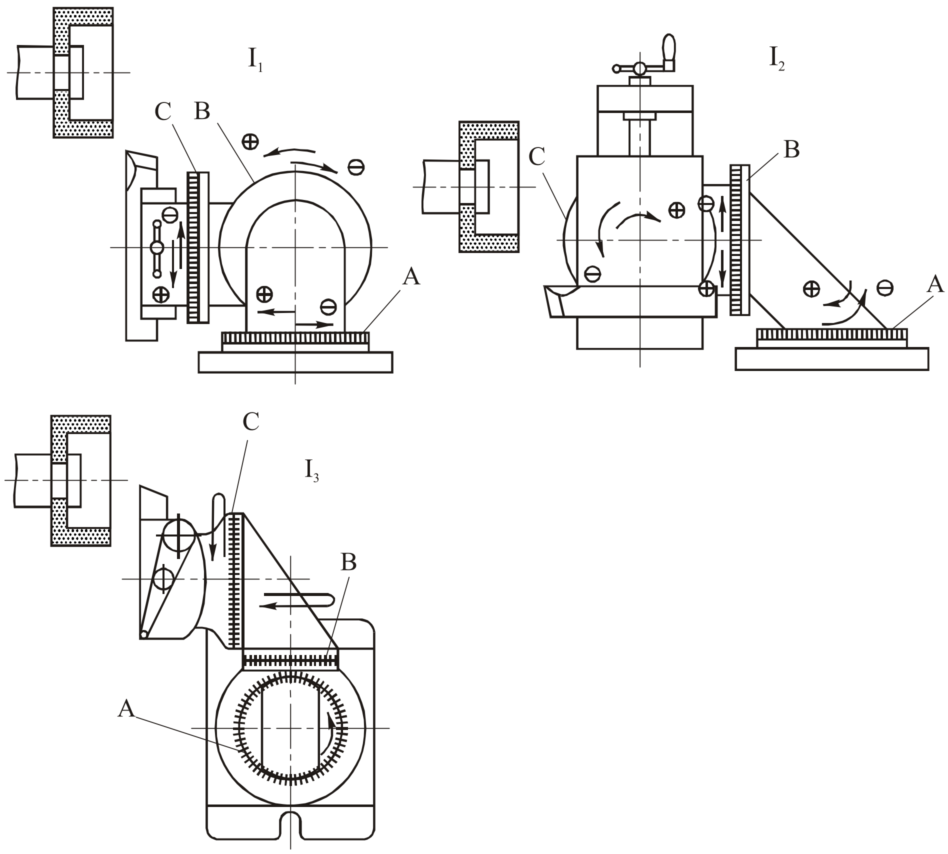

Fig. 1.1 Starting position of a cutter in the three-roll vice

Table 1.2

Approximate equations for three-roll vice set-up

Sharpening	Surface being sharpened	Initial position	Angle,°		
			A	B	C
Wheel periphery	Major flank	i_1	Any	$+\alpha_1$	$+\varphi_c$
	Minor flank	I_1		$+\alpha_1$	$-\varphi_{1c}$
	Face	I_2		$\gamma\sin\varphi_c + \lambda_c\cos\varphi_c$	$\lambda_c\sin\varphi_c + \gamma\cos\varphi_c$
Wheel face	Major flank	I_2	φ_c	$-\alpha\sin\varphi_c$	$+\alpha\cos\varphi_c$
	Minor flank	I_2	$-\varphi_{1p}$	$+\alpha_1\sin\varphi_{1c}$	$-\alpha_1\cos\varphi_{1c}$
	Face	I_1	λ_c	$-\gamma$	φ_c
	Major flank	I_3	$90^0+\alpha$	0	φ_c
	Minor flank	i_3	$90^0+\alpha_1$	0	φ_{c1}
	Face	I_3	$\gamma\cos\lambda_c$	λ_c	φ_c

When setting the grinder for sharpening, the cutter point is positioned 1…3 mm above the wheel axis. The wheel rotation should be directed from the cutting edge to the shank of the cutter.

When the cutter is sharpened, the geometry of the cutter is checked and the results are written into Table 1.3.

Finally, the conformance of the sharpened angles values to the specified by the drawing values is checked.

Table 1.3

Designated in drawing	$\gamma°$	$\gamma_1°$	$\alpha°$	$\alpha_1°$	$\varphi°$	$\varphi_1°$	$\lambda°$
Sharpened							

Procedure

1. According to the cutter angles φ, φ_1, λ, denoted in the drawing, define the φ_c, φ_{1c}, λ_c angles with the help of Table 1.1.
2. Using the equations given in Table 1.2, calculate the angles for the three-roll vice scales A, B and C.
3. Mount the cutter on the universal tool grinder in initial position with the grinding wheel clamped in the spindle.
4. Set the vice according to the calculated values and sequentially grind the face, major flank and minor flank of the cutter.
5. Check the ground angles α, γ, α_1, γ_1, φ, φ_1 and λ with the pendulum angle gauge and write them into Table 1.3.
6. Compose a report with the procedure, results, sharpening schematic, grinder capabilities, grinding wheel and gauge characteristics described. Make conclusion about the correspondence of the sharpened cutter geometrical parameters to the drawing specifications.

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Laboratory work 2: Twist drills sharpening

Laboratory work objectives:

1. To study the method of double-plane sharpening of a twist drill.
2. To check the geometrical parameters of the sharpened twist drill.
3. To conclude about the correspondence of the sharpened twist drill geometrical parameters to the drawing specifications.

Equipment:

1. Universal tool grinder 3B642.
2. Universal sharpening head.
3. Universal angle gauge.
4. Dial indicator with a magnetic stand.
5. Grinding wheel.
6. Twist drill.

Guidelines

The double plane sharpening of the drill flanks is performed on the universal tool grinders with the use of a universal sharpening head. This method of sharpening produces uniform clearance angles in normal sections along the lips. The drills of less than 3 mm in diameter are single plane sharpened, and drills of more than 3 mm in diameter are double plane sharpened, with planes R and F produced (Fig. 2.1).

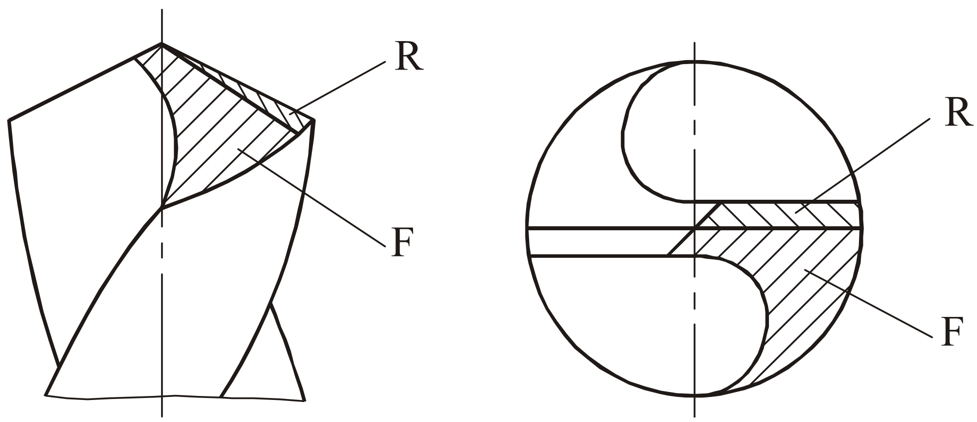


Fig. 2.1 Clearance surfaces in the form of the planes

Equations for calculation of the sharpening head angles are given in Table 2.1:

Table 2.1

Equations for calculation of the sharpening head angles

Head mounting position	For grinding *R* surface	For grinding *F* surface
I	$\theta_H = 0$; $\mathrm{tg}\theta_B = \mathrm{tg}\theta \cdot \mathrm{tgE}$; $\mathrm{tg}\theta_\Gamma = \mathrm{tgE} \cdot \cos\theta_H$.	$\theta_H = 0$; $\mathrm{tg}\theta_B = \mathrm{tgE}(2\mathrm{ctg}\psi - \mathrm{tg}\theta)$; $\mathrm{tg}\theta_\Gamma = \mathrm{tgE} \cdot \cos\theta_H$
II	$\theta_B = 0$; $\mathrm{tg}\theta_H = \mathrm{tg}\theta$; $\mathrm{tg}\theta_\Gamma = \mathrm{tgE} / \cos\theta_H$.	$\theta_B = 0$; $\mathrm{tg}\theta_H = \mathrm{tg}\theta \cdot 2\mathrm{ctg}\psi$; $\mathrm{tg}\theta_\Gamma = \mathrm{tgE} / \cos\theta_H$.
III	$\theta_\Gamma = 0$; $\mathrm{tg}\theta_H = \mathrm{ctg}\theta$; $\mathrm{tg}\theta_B = \mathrm{tgEtg}\theta / \cos\theta_H$.	$\theta_\Gamma = 0$; $\mathrm{ctg}\theta_H = \mathrm{ctg}\psi - \mathrm{tg}\theta$; $\mathrm{tg}\theta_B = \mathrm{tgE}(2\mathrm{ctg}\psi - \mathrm{tg}\theta) / \cos\theta_H$.

For the equations given above:

$$\mathrm{tg}\theta = \frac{\mathrm{tg}\alpha\mathrm{tg}\varphi - \sin\mu}{\cos\mu},$$

where α is the clearance angle on the drill periphery; 2φ is the point angle; ψ is the chisel edge angle;

$$\sin\mu = \frac{d}{D};\ \varepsilon = 90^\circ - \varphi;$$

where d is the web thickness; D is the drill diameter.

The θ_A, θ_B, θ_C angles are measured from the adopted initial position of the sharpening head (Fig. 2.2).

Procedure

1. Double plane sharpening
   - using the equations given in Table 2.1, calculate the angles of the sharpening head set-up;
   - mount a twist drill in initial position on the grinder (Fig. 2.2), mount a grinding wheel in spindle;
   - adjust the angles of the sharpening head and grind the plane *R* on both lands of the drill, then, readjust the head for grinding the plane *F* on both lands of the drill.

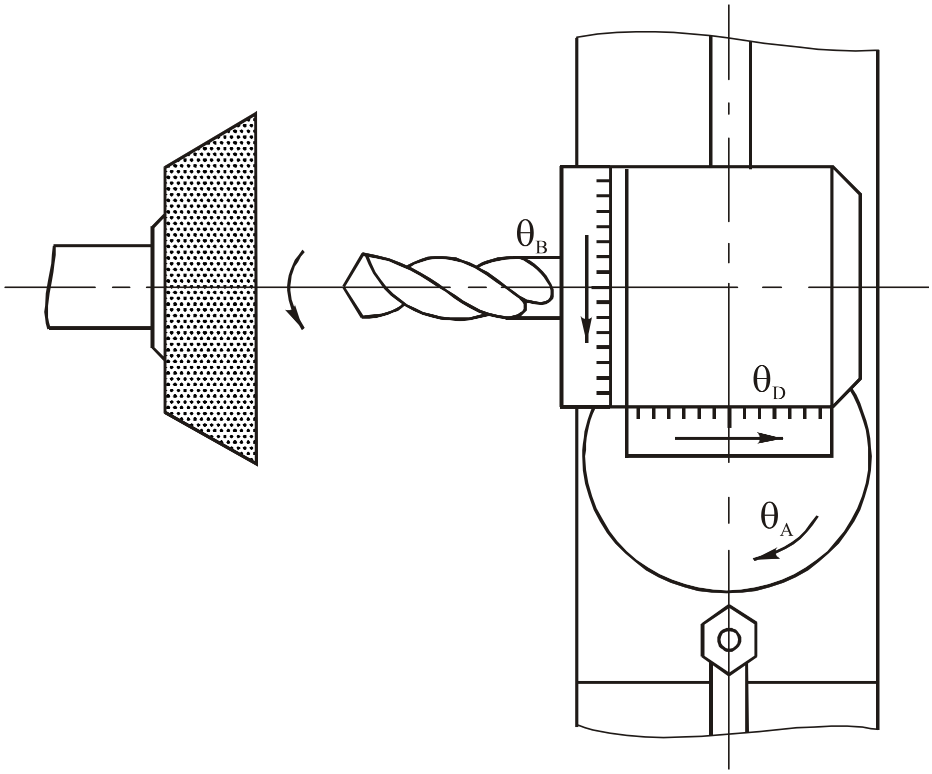


Fig. 2.2 Initial position of the universal sharpening head

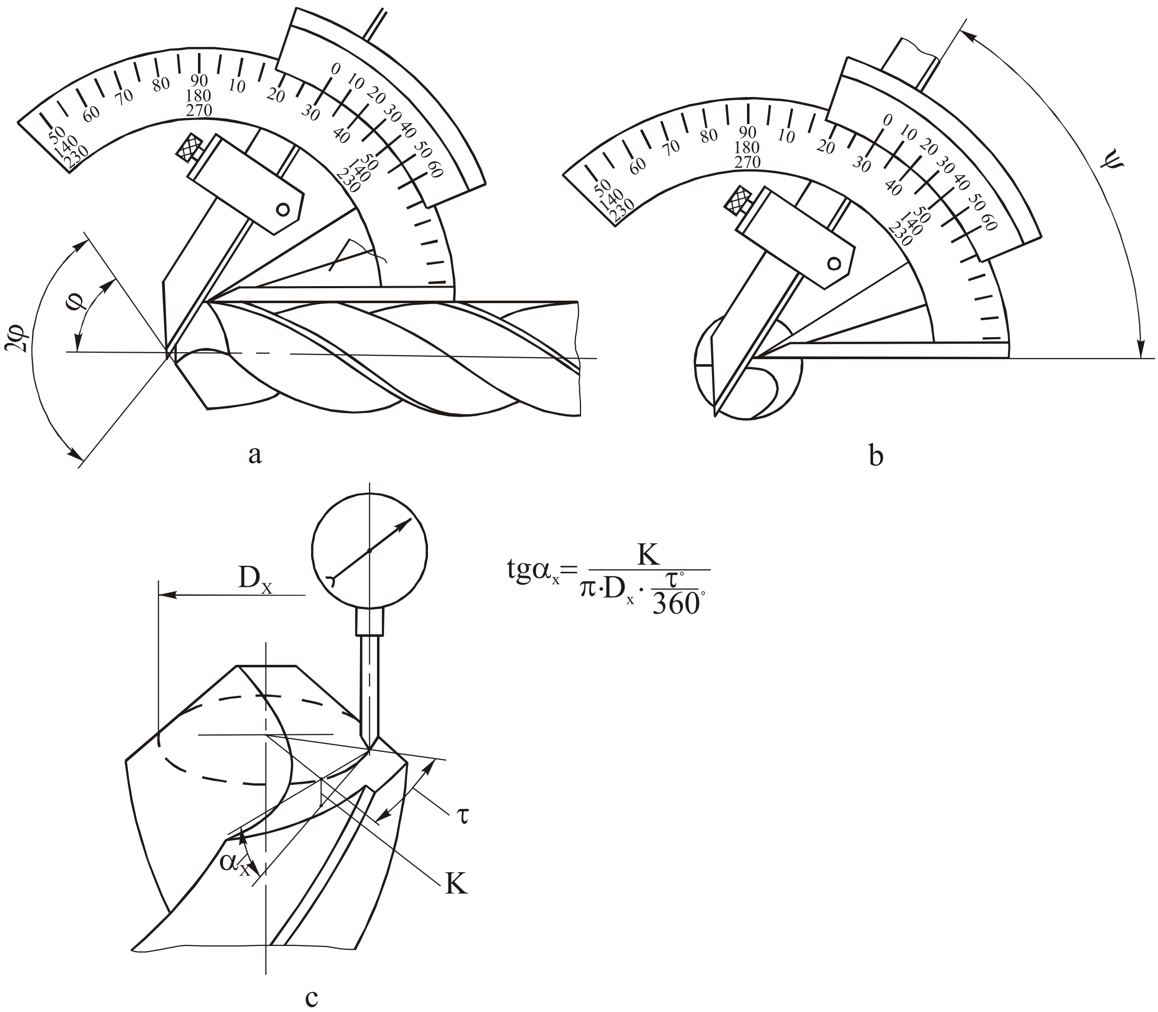
2. Check the basic parameters of the drill: point angle 2φ, chisel edge angle ψ, clearance angle α_x, lips run-out Δ_{rad} (Fig. 2.3). The results should be written into Table 2.2.

Table 2.2

Drawing specification	*D*, mm	2φ, degrees	ψ, degrees	α_x, degrees	Δ_{rad}, mm	ω, degrees
Sharpened values						

Make conclusion about the correspondence of the sharpened twist drill geometrical parameters to the drawing specifications.

3. Compose a report, containing laboratory work procedure, grinding schematics, grinder capabilities, grinding wheel and measuring instruments characteristics.



$$tg\alpha_x = \frac{K}{\pi \cdot D_x \cdot \frac{\tau^\circ}{360^\circ}}$$

Fig. 2.3 Measurement of the twist drill geometry

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Laboratory work 3: Study of end mills design

Laboratory work objectives:
1. To study the construction and geometric parameters of end mill.
2. To study construction and measurement principles of the measuring gages.
3. To make a conclusion about the correspondence of the sharpened end mill geometrical parameters to the specifications.

Equipment:
1. Vernier caliper.
2. Micrometer.
3. Pendulum angle gauge.
4. Clamping device and an indicator stand.
5. Rake gauge K-60-6.
6. Device for checking cone generator nonlinearity.

Guidelines

Milling cutters are a group of cutting tools that have very large diversity of designs, shapes and sizes. The typical, widely used cutters are end mills, plain cutters, face mills and side cutter. The considered end mills have pointed teeth. These cutters are widely used to machine narrow planes, slots and curved contours. The end mills come in solid, welded and indexable types.

End mills are manufactured in two types: with straight shank of 3-20 mm in diameter and with a tapered shank (Morse taper) of 14-80 mm in diameter (Fig. 3.1). These cutters can be made with chip breaking notches on the cutting edges, and with variable circumferential tooth pitch.

To increase rigidity the end mills should have a core thickness increasing from the end to the shank. In case the end mill works with horizontal feed for machining slots, the end teeth are undercut at the minor cutting edge angle.

The major cutting edges 1 (Fig. 3.1), which remove the stock, are located on the periphery and minor cutting edges 2 are located at the end. Basic geometric parameters of the cutters are: rake angle γ; major clearance angle α; minor clearance angle α_1; major cutting edge angle φ, which is equal to 90° for cutters with major cutting edges located on the periphery; cutting edge angle φ_0 of the transition cutting edge 3; minor cutting edge angle φ_1; helix angle ω.

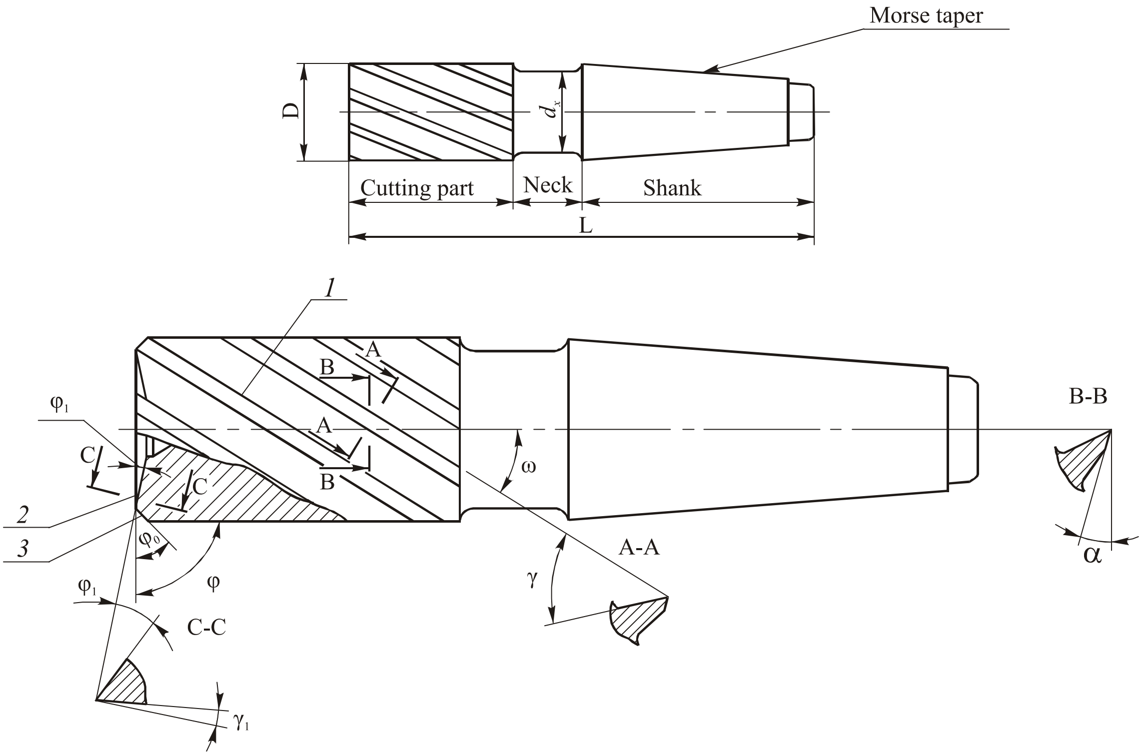

Fig. 3.1 End mill

Roughness parameters for the rake and clearance surfaces of HSS milling cutters R_a=0.63. For some types of cutters the roughness parameter R_a=1.25 is also applicable.

The run-out of the cutting edges shouldn't exceed values given in Table 3.1.

Table 3.1

Cutter type	Cutter diameter, mm	Radial run-out of edges, mm		Axial run-out, mm
		adjacent	opposite	
Solid end mill	to 16 over 16	0.03 0.03	0.06 0.06	0.03 0.04
Solid plain cutter	from 40 to 100	0.03	0.06	--

The geometrical parameters of the milling cutters shouldn't differ from the specified ones more than 1°.

Procedure

1. Study construction of the given cutter, make a sketch of the cutter.
2. Measure geometric parameters of the cutter (cutting part diameter D, neck diameter d, length of the cutting part, neck, shank, core thickness).
3. Measure angles of the cutting part. The obtained results for every tooth should be presented in Table 3.2.

Table 3.2

№	Angles and run-outs	Tooth number			
		1			
1.					
2.					

4. Check run-out of the peripheral and end cutting edges (Fig. 2, a, b). Measurement results write into Table 3.2.

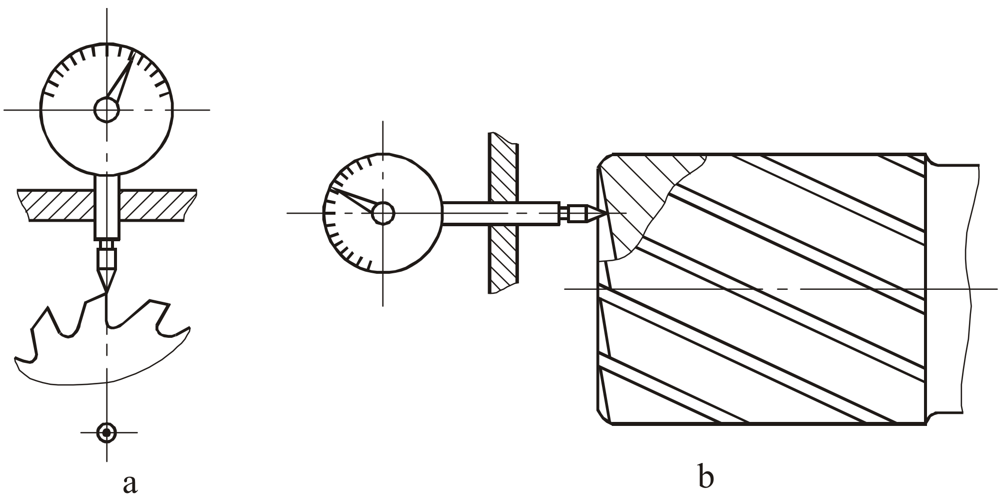

Fig.3.2 Schematic for measuring cutting edges run-out

5. Check nonlinearity of the shank taper.
6. Plot the following relations: $\alpha = f(N_{\text{tooth}})$; $\gamma = f(N_{\text{c}})$; $\omega = f(N_{\text{c}})$; $\varphi_1 = f(N_{\text{c}})$; $\alpha_1 = f(N_{\text{c}})$; $\delta_A = f(N_{\text{c}})$; $\delta_R = f(N_{\text{c}})$ (Fig. 3.3).

7. Analyze and compare the results with the specified values, given in the drawing; reveal the causes of the deviations and make a conclusion about the correspondence of the sharpened end mill geometrical parameters to the specifications.

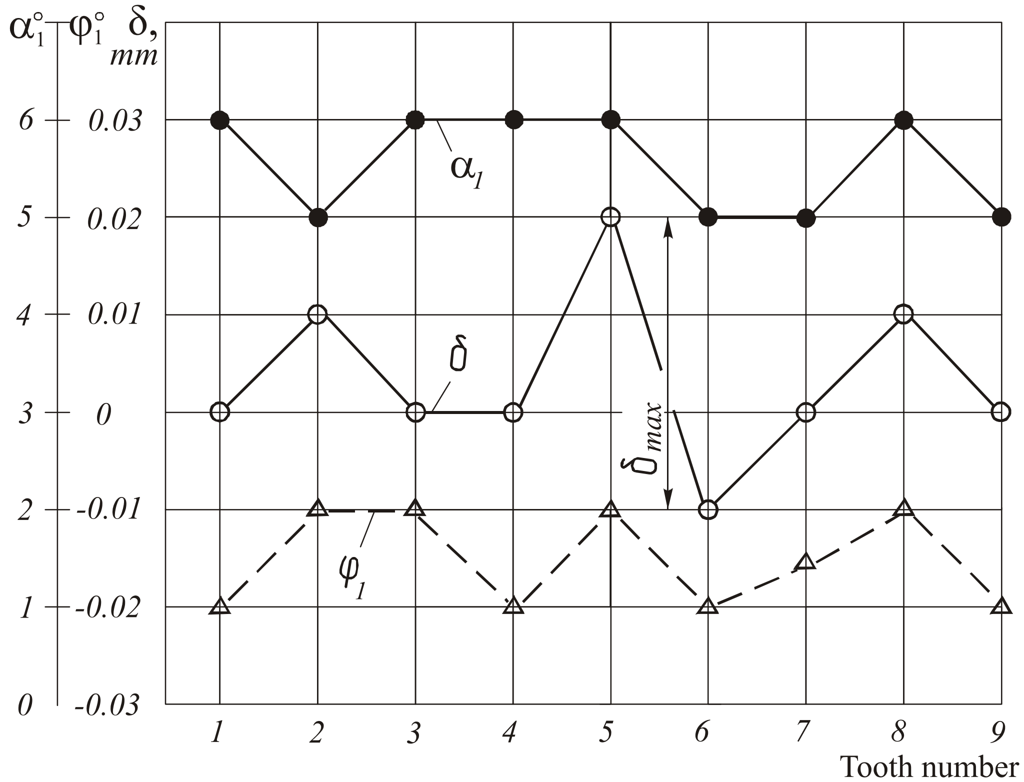

Рис.3. Пример графического построения исследованных зависимостей

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Laboratory work 4: Study of tap design

Laboratory work objectives:
1. To study the construction and geometric parameters of a tap set.
2. To study the procedure of the tap geometrical parameters measurement.
3. To make a conclusion about the correspondence of the tap geometrical parameters to the specifications.

Equipment:
1. Vernier caliper.
2. Pendulum angle gauge.
3. Rake gauge K-60-6.
4. Toll maker microscope.
5. Dial indicator in a stand.
6. Clamping device.
7. A set of taps.

Guidelines

Tap is a cutting tool used for cutting internal thread. A tap is a screw turned into a cutting tool by machining flutes, creating cutting edges, relieving the teeth to create positive clearance angle. The flutes form rake surfaces, cutting edges and space for chip accommodation and removal.

Figure 1 shows a tap, which consists of the cutting part 1, the sizing part 2 and the shank 3.

The cutting part of a tap is a conical surface with threads, which profile is gradually increasing to full height on the sizing part.

The cutting edge angle φ of a tap depends on the tap purpose, allowance a_z, flute number z and thread pitch.

The φ angle can be defined by the following equation:

$$tg\varphi = (a_z \cdot z) / P .$$

The rake angle of a tap is selected depending on the workpiece material in the range from 0° to 25° (for medium hardness steel γ=10°).

Clearance angle α is produced by relieving the cutting part by a grinding wheel. Sizing part of a tap is used for sizing and burnishing the thread. This part forms a thread and provides the required dimensional accuracy and surface finish, and is a stock for the cutting edges regrinding.

To reduce friction and oversize of a hole, the sizing part is slightly back tapered, i.e. the major, pitch and minor diameters of the thread are somewhat reduced toward the shank. Back taper is equal to 0.05...0.10 mm per 100 mm of length.

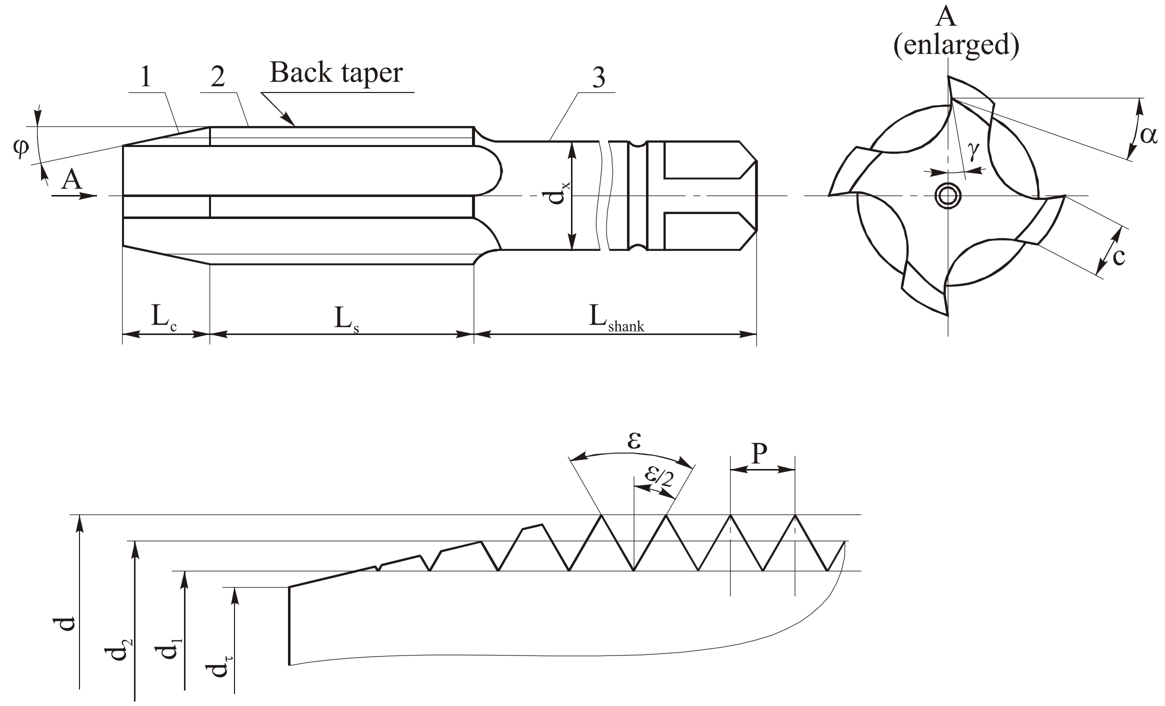

Fig. 4.1 Tap

Taps for metric threads are made of 1, 2, 3 and 4 grades of accuracy. Depending on the degree of accuracy, the tolerances for major, pitch and minor diameters, pitch and half angle of the tap thread are adopted.

To reduce the threading forces and increase thread accuracy the taps are used in sets, which may consist of two or three taps.

The run-out of the cutting part major diameter shouldn't exceed 0.03 mm for taps of up to 24 mm in diameter and 0.04 mm for taps of more than 24 mm in diameter. Deviation of the rake angle (and the major cutting edge angle) should not exceed ±2°. Deviation of the clearance angle α should not exceed ±10°.

Procedure

1. Study construction of the given tool, make a sketch.
2. Check the geometrical parameters of the taps of the set (l_c, l_s, l_{shank}, d_{shank}).

3. With the help of toll maker microscope, measure the geometric parameters, given in Table, of the cutting part of the tap (Fig. 4.2).

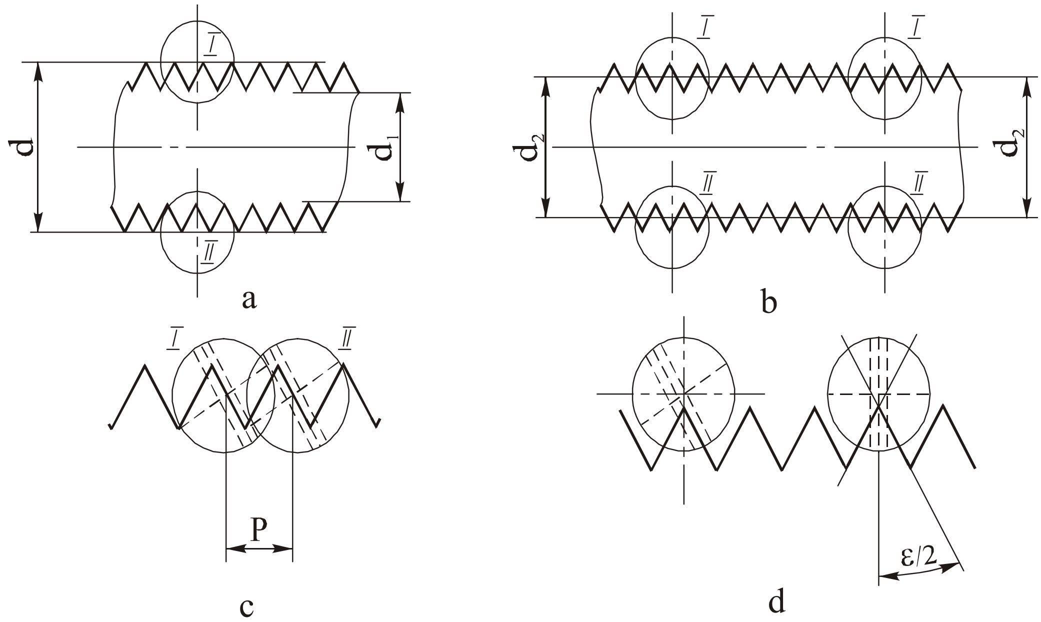

Fig. 4.2 Schemes for measurement of: (a) major and minor diameters; (b) pitch diameter; (c) pitch; (d) half angle of thread

4. Measure the back taper of the major and pitch diameters of the taps of a set.
5. Check the radial run-out of the taps cutting edges.
6. Measure the rake angles and radial relief *k* on the major diameter of the sizing part edges.
7. With the measured data calculate load distribution between the taps of a set.

The load per tap from a set is determined by the portion of the thread allowance area that is being removed by the given tap. For calculating the thread allowance area the diameter d_c of the starting hole for tapping is used (Fig. 4.3).

The area of the thread allowance for each tap is calculated as:

$$S = \frac{L_1 + L_2}{2} \cdot \frac{d - d_c}{2},$$

where L_1 and L_2 – width of the thread profile measured on diameters d and d_c respectively.

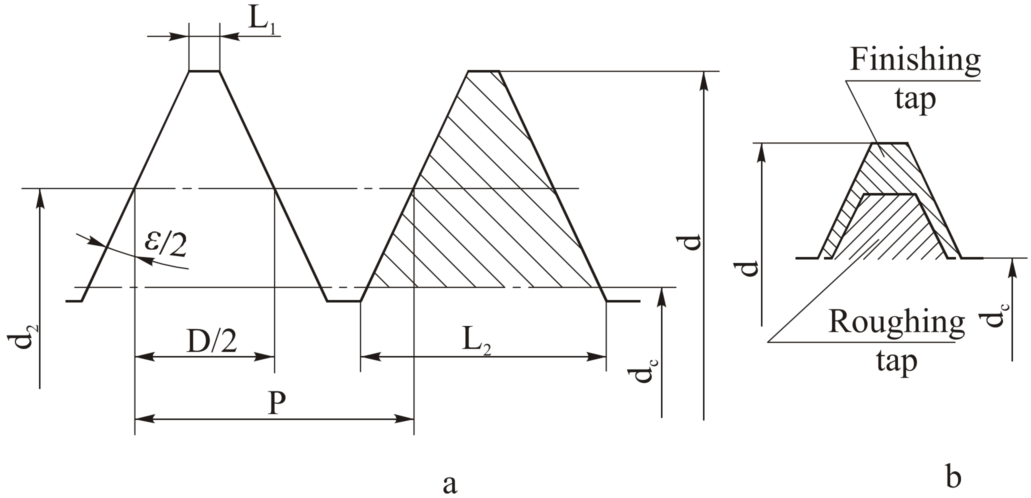

Fig. 4.3 Schematics for load calculation:
(a) thread profile area; (b) load distribution between the taps

Width of the thread profile crest:

$$L_1 = p/2 - (d - d_2)\,\mathrm{tg}(\varepsilon/2).$$

Width of the thread profile root:

$$L_2 = p/2 - (d_2 - d_c)\,\mathrm{tg}(\varepsilon/2).$$

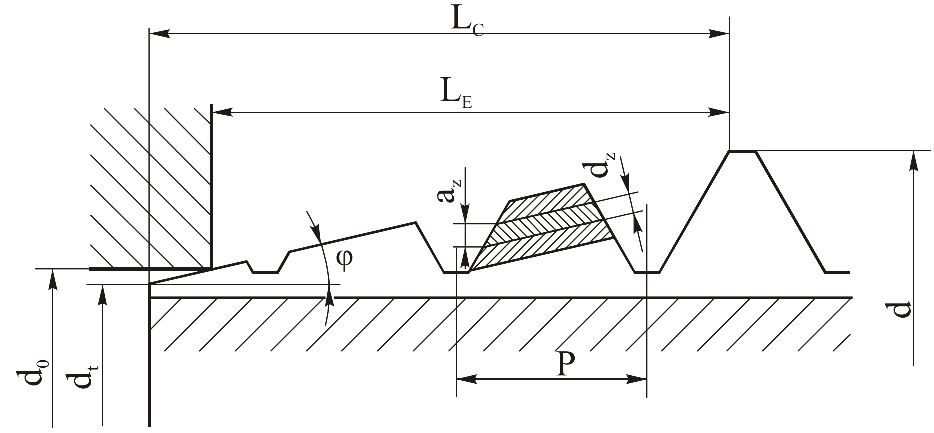

Fig. 4.4 Diagram for chip thickness calculation

Load distribution between taps of a set is calculated as follows (Fig. 4.4):

– for roughing tap – $(S_{\text{rough}}/S_{\text{finish}})\cdot 100\%$;
– for finishing tap – $[(S_{\text{rough}}-S_{\text{finish}})/S_{\text{finish}}]\cdot 100\%$,
where $S_{\text{rough.}}$, S_{finish} – thread allowance area of the roughing and finishing taps respectively.

8. Calculate the uncut chip thickness per cutting edge of a tap:

$$a_z = (p/z)\cdot tg\varphi.$$

Make conclusion about the applicability of the taps for cutting thread with specified surface finish requirements (R_z=20, R_a=2,5). Such roughness parameters are ensured if the uncut chip thickness is within the a_z=0.02-0.12 mm.

9. The results of measurements and calculations should be recorded according to Table. Then the results should be analyzed in terms of correspondence of the tap to the specified parameters requirements.

Table

Tap parameter	Measurement or calculation results for taps	
	roughing	finishing
LENGTHES: cutting part l_c sizing part l_s shank l_{shank}		
DIAMETERS: major d pitch d_2 minor d_1 end d_T shank d_{shank}		
HALF-ANGLE OF THREAD right $(\varepsilon/2)_{right}$ left $(\varepsilon/2)_{left}$		
Thread angle ε		
Cutting taper angle φ		
Thread pitch p		
Rake angle γ		
Radial relief value k_z		
Tooth width c		
Load distribution between the taps of a set, %		
Thickness of the layer being removed by each tooth		
Back taper		
Maximum run-out		

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Educational Edition

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РЕЗАНИЕ МАТЕРИАЛОВ И РЕЖУЩИЙ ИНСТРУМЕНТ

Методические указания

к выполнению лабораторных работ по дисциплине «Резание материалов и режущий инструмент»

На английском языке

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