Appendix
to practice works “Cutting of materials & cutting tools”

THE COMMON DATA
about cutting modes choic

The inquiry (hand-book) data about cutting modes is developed with using of official publications for cutting by cutting tools from a **high-speed steel** (**HSS**) (red-hard steel) and from a **cemented carbides** (**CC**). They are ***used*** for application of tools with best values of geometrical parametres of a cutting part. Finish sharpening is made: for tools with **cemented carbides** by diamond grinding wheels, and with **high-speed steel** – by elbor (cubic boron nitride (CBN)) grinding wheels.

At assignment of cutting modes it is necessary to take into account character (kind) of machining, type and sizes of the cutting tool, material of its cutting part, material and blank condition, type and an equipment condition.

Elements of cutting modes is usually fixed in the next order.

Depth of cut t: at rough (preliminary) machniing (handling) depth of cut is fixed whenever possible maximum, equal to all machining stock or greatest its parts; at finish machniing – depending on requirements of processed sizes because with increasing t the cutting force is also increased, including its radial component P_y that results increasing of an elastic deformation of system **MATP** (**machine tool – attachment – tool – part**) and decreasing of machniing accuracy.

Feeding (feed rate) s: at rough processing the greatest possible feed is fixed, proceeding from **rigedness** and strength of **MATP** system, drive power of the machine tool, strength of cemented carbide plate (**replacable insert**) and other restricting factors, including demanded roughness of the processed surface; at a finish machining – depending on demanded degree of accuracy (grade of tolerance) and roughness of the processed surface.

Cutting speed v is calculated under the empirical formulas fixed for each type of machining which have a general view

$$v_{table} = \frac{C_v}{T^m \times t^x \times s^y}. \qquad (1)$$

Values of factor (coefficient) C_v and the power exponents containing in this formula as well as the cutting tool life T, applied to the given aspect of machining, are specified in tables for each type of machining. Calculated with use of the table data cutting speed v_{table} (v_t) considers concrete values of cut depth t, feed s and tool life T also it is actual at certain table values of some other factors. Therefore for determine of the actual value of cutting speed taking into account concrete values of the mentioned factors correction factor K_v is used. Then the actual value of cutting speed $v = v_t\ K_v$, where K_v – product of some factors. Major of them, the common for various aspects of handling, are:

K_{mv} – the factor considering strength or hardness of processed material (tab. 1);
K_{sv} – the factor considering a surface condition of blank (tab. 5);
K_{tv} – the factor considering quality of a cutting tool material, its type if it differs from the conditions specified in the common table (tab. 6).

1. Correction factor K_{mv} considering influence of the physicomechanical properties of processed material for cutting speed

Worked stock	The settlement formula
Steel	$K_{mv} = K_g \left(\frac{750}{\sigma_u}\right)^{n_v}$
Gray cast iron	$K_{mv} = \left(\frac{190}{HB}\right)^{n_v}$
Malleable cast iron	$K_{mv} = \left(\frac{150}{HB}\right)^{n_v}$

Notes: 1. σ_u and HB – the actual parametres characterising the processed material for which cutting speed is calculated. σ_u ($\sigma_в$) – ultimate tensile strength (UTS) of the processed material (for steels); HB – hardness of material (for cast irons).

2. Factor Kg characterising group of a steel about machinability, and an exponent n_v see in tab. 2.

2. Values of factor Kg and power exponent n_v in the formula for calculation of machinability factor K_{mv} which is shown in tab. 1

Material	Factor Kg for cutting tool material		Power exponents n_v at machining					
			by cutters		by drills, cor-drills, reamers		by mills	
	HSS	CC	HSS	CC	HSS	CC	HSS	CC
Carbon steels (C < 0.6 %), σ_u, MPa:								
< 450	1.0	1.0	-1.0		-0.9		-0.9	**1.0**
450 - 550	1.0	1.0	1.75		-0.9		-0.9	
> 550	1.0	1.0	1.75		0.9		0.9	**1.0**
Improved and high machinability carbon steels	1.2	1.1	1.75	**1.0**	1.05	**1.0**	1.45	
Carbon steels with Cr	0.85	0.95	1.75		0.9		1.35	
High carbon (C> 0.6 %) allowed steels,								
Cr & Ni; Cr & Mo & Va;	0.8	0.9	1.5		0.9		1.35	
Cr & Mn; Cr & Mn & Si;	0.7	0.8	1.25		0.9		1.35	
HSS	0.6	0.7	1.25		0.9		1.0	
Gray cast iron	---	---	1.7	1.25	1.3	1.3	0.95	1.25
Malleable cast iron	---	---	1.7	1.25	1.3	1.3	0.85	1.25

Note: HSS – high-speed steel; CC – cemented carbide.

3. Correction factor K_{mv} considering influence of physicomechanical properties of heat resisting and corrosion resistance steels and alloys for cutting speed

Mark of steel or an alloy	σ_u, MPa	Average value of factor K_{mv},	Mark of steel or an alloy	σ_u, MPa	Average value of factor K_{mv},
12Х18Н9Т	550	1.0	ХН60ВТ	750	0.48
13Х11Н2В2МФ	1100 – 1460	0.8 - 0.3	ХН77ТЮ	850-1000	0.40
14Х17Н2	800 - 1300	1.0 - 0.75	ХН77ТЮР		0.26
13Х14Н3В2ФР	700 - 120	0.5 - 0.4	ХН35ВТ	950	0.50
37Х12Н8Г8МФБ	---	0.95 - 0.72	ХН70ВМТЮ	1000-1250	0.25
45Х14Н14В2М	700	1.06	ХН55ВМТКЮ	1000-1250	0.25
10Х11Н20Т3Р	720 - 800	0.85	ХН65ВМТЮ	900-1000	0.20
12Х21Н5Т	820 - 10000	0.65	ХН35ВТЮ	900-950	0.22
20Х23Н18	600-620	0.80	ВТ3-1; ВТ3	950-1200	0.40
31Х19Н9МВБТ		0.40	ВТ5; ВТ4	750-950	0.70
15Х18Н12С4ТЮ	730	0.50	ВТ6; ВТ8	900-1200	0.35
ХН78Т	780	0.75	ВТ14	900-1400	0.53 - 0.43
ХН75МБТЮ	---	0.53	12Х13	600-1100	1.5 - 1.2
			30Х13; 40Х13	850-1100	1.3 - 0.9

4. Correction factor K_{mv} considering influence of physicomechanical properties of copper and aluminium alloys for cutting speed

Copper alloys	K_{mv}	Aluminium alloys	K_{mv}
The heterogeneous		Silumin and cast alloys (quanched), σ_u = 200 … 300 MPa,	0.8
HB> 140	0.7	*HB*> 60;	
HB 100 … 140	1.0	Duralumin (quanched), σ_u = 400 **…** 500 MPa, *HB*> 100	0.8
Leaden at heterogeneous structure	1.7	Silumin and cast alloys, σ_u = 100 … 200 MPa, *HB <65*	1.0
Copper	8	Duralumin, σ_u = 300 … 400 MPa, *HB* <100	1.0
Alloys with lead content >15 %	12	Duralumin, σ_u = 200 … 300 MPa	1.2

5. Factor K_{sv} considering influence a surface condition of blanks

Without a rim	With a rim				
	Rolled workpiece	Forged workpiece	Steel and cast iron castings with a rim		Copper aluminium alloys
			The normal	Strongly soiled	
1.0	0.9	0.8	0.8 – 0.85	0.5 – 0.6	0.9

6. Correction factor K_{tv} considering influence of cutting tool material

Material	Values of factor K_{tv}, depending on the mark of cutting tool material						
Carbon steel	T5K12B 0.35	T5K10 0.65	T14K8 0.8	T15K6 1.00	TT17K6 1.15	T30K4 1.4	BK8 0.4
Noncorrosive and heat-resistant steels	BK8 1.0	T5K10 1.4	T15K6 1.9	P18 0.3	----		
Hardened (quenched) steel	*HRC* 35-50				*HRC* 51-62		
	T15K6 1.0	T30K4 1.25	BK6 0.85	BK8 0.83	BK4 1.0	BK6 0.92	BK8 0.74
Gray and malleable cast iron	BK8 0.83	BK6 1.0	BK4 1.1	BK3 1.15	BK3 1.25	----	----
Steel, cast iron, copper and aluminium alloys	P6M5 1.0	BK4 2.5	BK6 2.7	9XC 0.6	ХВГ 0.6	У12А 0.5	----

Cutting tool life *T* is the period (duration) of operation of the cutting tool to dull (allowable wear-out). At multytool machining the tool life *T* should be increased, because machine tool idle times is increased for cutting tool **rechanging**??. It depends first of all on simultaneously working tools, a time in cut ratio by time of a working stroke, tool material, an equipment type. At multimachine service the tool life *T* it is necessary to increase with increasing of served machine tools quantity.

Tool life at multytool machining

$$T_{mt} = T \times K_{Tmt}, \quad (2)$$

and at multimachine service

$$T_{ms} = T \times K_{Tms} \quad (3)$$

where *T* – tool life of the limiting tool (with the least tool life); K_{Tt} – factor of tool life changing at multytool machining (tab. 7); $K_{мс}$ – factor of tool life changing at multimachine service (tab. 8).

7. Factor of tool life changing K_{Tmt} depending on quantity of simultaneously working tools at average on uniformity of their work

Quantity of working tools	1	3	5	8	10	15
K_{Tmt}	1	1.7	2	2.5	3	4

Note: 1. At uniform work of tools factor K_{Tmt} increase in 2 times.
2. At tool work with the great non-uniformity factor K_{Tmt} diminish on 25 … 30 %.

8. Factor of tool life changing K_{Tms} in dependence on quantity of simultaneously served machine tools

Quantity of served machine tools	1	2	3	4	5	6	7 and more
K_{Tms}	1.0	1.4	1.9	2.2	2.6	2.8	3.1

9. A correction factor *Kmp* for steels and cast irons, considering influence of quality of a worked stock on power dependences

Worked stock	The formula	Exponent *n* at definition		
		Component P_z of cutting force at cutting by cutter	Torque *M* and axial force P_o at drilling, redrilling and a core drilling	Tangential component P_z at milling
Carbon and allowed steels σ_u, MPa: ≤600 >600	$K_{mp} = \left(\frac{\sigma_u}{750}\right)^{n_v}$	0.75/0.35 0.75/0.75	0.75/0.75 0.75/0.75	0.3/0.3 0.3/0.3
Gray cast iron	$K_{mp} = \left(\frac{HB}{190}\right)^{n}$	0.4/0.55	0.6/0.6	1.0/0.55
Malleable cast iron	$K_{mp} = \left(\frac{HB}{150}\right)^{n}$	0.4/0.55	0.6/0.6	1.0/0.55

Note: in numerator – exponent values *n* for CC, in a denominator – for HSS.

10. The correction factor K_{mp} considering influence of quality of copper aluminium alloys on power dependences

Copper alloys	K_{mp}		Aluminium alloys	K_{mp}
The geterogeneous: *HB* 120	1.0		Aluminium and silumin	1.0
HB> 120	0.75		Duralumin, σ_u ($\sigma_в$), МПа:	
The homogeneous	1.8 – 2.2		250	1.5
Copper	1.7 – 2.1		350	2.0
Alloys with lead content >15 %	0.25 – 0.45		> 350	2.75

Force of cutting. Its principal component P_z (tangential component of resultant cutting force *R*) defining power N_e spent for cutting and a torque *M* of the machine tool spindle usually is meant cutting force. Power dependences are calculated under empirical formulas, values of factors and apparent exponents in which for various aspects of machining are reduced in corresponding tables.

Calculated with use of the table data power dependences consider concrete technological parametres (depth of cutt, feed, width of milling, etc.) and are actual at defined values of some other factors. Their values corresponding to actual cutting conditions be received by multiplication of factor K_P – the common correction factor considering changed in comparison with table cutting conditions, representing product of some factors. Major of them is the factor K_{mp} considering quality of a worked stock which value for a steel and cast iron are specified in table 9, and for copper and aluminium alloys – in table 10.

TURNING

Depth of cutt *t*: at rough turning and absence of power limitations of the equipment, ruggedness of MATP system is accepted equal to machining stock; at finish cutting the machining stock is cut off for two strokes and more. On each subsequent stroke it is necessary to fix less depth of cutt, than on the previous. At parametre of have processed surface roughness Ra = 3.2 microns inclusively t = 0.5 … 2.0 mm; at 3.2> Ra> 0.8 microns, t = 0.1 … 0.4 mm.

Feed *s*: at rough turning feed is fixed as much as possible admissible on power of the equipment, ruggedness of MATP system, cutting insert (plate) strength and shank strength. Recommended feeds from the point of view of MATP system ruggedness at rough external turning are specified in tab. 11, and at a rough boring – in tab. 12.

The maximum feed values at steel 45 (C 1020) turning, admissible strength of a CC plate are specified in tab. 13.

Depending on demanded parametres of **have processed** surface roughness and nose radius of a cutter as much as possible admissible feeds are specified in tab. 14.

At cutting of slots and cut-off operation value of cross feed depends on properties of blank material, the sizes of a slot and machining diameter (tab. 15).

At shaped turning operations recommended feeds are specified in tab. 16.

11. Feeds at rough external turning for cutters with cemented carbide inserts and high-speed steels

Diameter of a part, mm	The shank size of cutting tool, mm	**Workpiece material** (worked stock)							
		Carbon steel, allowed and heat-resistance				Cast irons and copper alloys			
		Feed *s*, mm/rev, at depth of cut *t*, mm							
		To 3	Over 3 to 5	Over 5 to 8	Over 8 to 12	To 3	Over 3 to 5	Over 5 to 8	Over 8 to 12
To 20	Fr. 16 × 25 to 25 × 25	0.3-0.4	—	—	—	—	—	—	—
20 … 40	Fr. 16 × 25 to 25 × 25	0.4-0.5	0.3-0.4	—	—	0.4-0.5	—	—	—
40 … 60	Fr. 16 × 25 to 25 × 40	0.5-0.9	0.4-0.8	0.3-0.7	—	0.6-0.9	0.5-0.8	0.4-0.7	—

60 … 100	Fr. 16 × 25 to 25 × 40	0.6-1.2	0.5-1.1	0.5-0.9	0.4-0.8	0.8-1.4	0.7-1.2	0.6-1.0	0.5-0.9
100…400	Fr. 16 × 25 to 25 × 40	0.8-1.3	0.7-1.2	0.6-1.0	0.5-0.9	1.0-1.5	0.8-1.9	0.8-1.1	0.6-0.9

Notes: 1. The lower values of feeds correspond to the less shank sizes of a cutting tool and to stronger worked stocks, the upper values of feeds – to the greater shank sizes of a cutting tool and to less strong worked stocks.
2. At machining of heat-resistant steels and alloys the feed over 1 mm/rev is not applied.
3. At machining of interrupted surfaces and at operations with blows table values of feeds should be diminished by factor 0.75 – 0.85.
4. At machining of hardened (quenched) steels table values of feeds should be diminished with factor 0.8 for the steel with *HRC* 44–56 and with factor 0,5 for the steel with *HRC* 57–62.

12. Feeds at a rough boring with cemented carbide inserts and with high-speed steel

Cutter or shank		**Workpiece material** (worked stock)							
Diameter of cutting tool cross-section or sizes of a rectangular shank, mm	Cutter or mandrel sweep, mm	Carbon steels, allowed and heat-resistance				Cast irons and copper alloys			
		Feed *s*, mm/rev at depth of cut *t*, mm							
		To 2	3	5	8	To 2	3	5	8
Lathe and turret lathe machines									
10	50	0.08	—	—	—	0.12-0.16	—	—	—
12	50	0.1	0.08	—	—	0.12-0.2	0.12-0.18	—	—
16	80	0.1-0.2	0.15	0.1	—	0.2-0.3	0.15-0.25	0.1-0.18	—
20	100	0.5-0.3	0.15-0.25	0.12	—	0.3-0.4	0.25-0.35	0.12-0.25	—
25	125	0.25-0.5	0.15-0.4	0.12-0.2	—	0.4-0.6	0.3-0.5	0.25-0.35	—
30	150	0.4-0.7	0.2-0.5	0.12-0.3	—	0.5-0.8	0.4-0.6	0.25-0.45	—
40	200		0.25-0.6	0.15-0.4	—	—	0.6-0.8	0.3-0.8	—
40 × 40	150 300		0.6-1.0 0.4-0.7	0.5-0.7 0.3-0.6	—	—	0.7-1.2 0.6-0.9	0.5-0.9 0.4-0.7	0.4-0.5 0.3-0.4
60 × 60	150 300		0.9-1.2 0.7-1.0	0.8-1.0 0.5-0.8	0.6-0.8 0.4-0.7	—	1.0-1.5 0.9-1.2	0.8-1.2 0.7-0.9	0.6-0.9 0.5-0.7

Notes: 1. Upper limits of feeds are recommended for smaller cutting depth at machining of less strong materials, lower - for greater depth and stronger materials. 2. See notes 2 – 4 in tab. 11.

13. Feeds, mm/rev, admissible by strength of CC inserts, at turning of carbon steels by cutters with the main angle in the plan φ =45 °

Insert thickness, mm	Depth of cut *t*, mm, to			
	4	7	13	22
4	1.3	1.1	0.9	0.8
6	2.6	2.2	1.8	1.5
8	4.2	3.6	3.0	2.5
10	6.1	5.1	4.2	3.6

Notes: 1. Depending on mechanical properties of a steel for the table feeds values use a correction factor **1.2** at σ_u = 480 … 640 MPa; **1.0** at σ_u = 650 … 870 МПа and **0.85** at σ_u = 870 … 1170 MPa.
2. At cast iron machining a table value of feeds multiply by factor 1.6.
3. A table value of feeds multiply by a correction factor 1,4 at φ = 30°; 1.0 at φ = 45°; 0.6 at φ = 60° and 0.4 at φ = 90°.
4. At machining with blows (striking) feeds diminish by 20 %.

14. Feeds, mm/rev, at turning

Surface roughness parametre, micron		Nose radius of a cutter tip *r*, mm					
Ra	*Rz*	0.4	0.8	1.2	1.6	2.0	2.4
0.63 1.25 2.50	-	0.07 0.10 0.144	0.10 0.13 0.20	0.12 0.165 0.246	0.14 0.19 0.29	0.15 0.21 0.32	0.17 0.23 0.35
-	20 40 80	0.25 0.35 0.47	0.33 0.51 0.66	0.42 0.63 0.81	0.49 0.72 0.94	0.55 0.80 1.04	0.60 0.87 1.14

Notes: feeds are given for machining of steels with σ_u = 700 … 900 MPa and cast irons;
for steels with σ_u = 500 … 700 MPa a table value of feed multiply by a correction factor 0.45;
for steels with σ_u = 900 … 1100 MPa a table value of feed multiply by a correction factor 1.25.

15. Feeds, mm/rev, at turning of slots and cut-of operations for lathe and turret lathe machines

Diameter of machining, mm	Width of a cutting tool, mm	Blank material	
		Carbon steels, allowed and heat-resistance	Cast irons and copper alloys
To 20	3	0.06-0.08	0,11-0.14
20 … 40	3 - 4	0.1-0.12	0.16-0.19
40 … 60	4 - 5	0.13-0.16	0.20-0.24
60 … 100	5 - 8	0.16-0.23	0.24-0.32
100 … 150	6 - 10	0.18-0.26	0.3-0.4
150	10 - 15	0.28-0.36	0.4-0.55

Notes: 1. At cutting-off of a continuous blank with diameter more than 60 mm at cutting tool approach to a blank axis to 0,5 radiuses should be diminished table feed values on 40 – 50 %.

2. For the quenched constructional steel table values of feed should be diminished on 30 % at *HRC* <50 and on 50 % at *HRC*> 50.

3. At operation by the cutting tools fixed in a turret, table values should be multiplied by factor 0.8.

16. Feeds, mm/rev, at shaped turning

Width of a cutting tool, mm	Diameter of blank, mm			
	20	25	40	60 and more
8	0,03 - 0,09	0,04 - 0,09	0,04 - 0,09	0,04 - 0,09
10	0,03 - 0,07	0,04 - 0,085	0,04 - 0,085	0,04 - 0,085
15	0,02 - 0,05	0,035 - 0,075	0,04 - 0,08	0,04 - 0,08
20	—	0,03 - 0,06	0,04 - 0,08	0,04 - 0,08
30	—	—	0,035 - 0,07	0,035 - 0,07
40	—	—	0,03 - 0,06	0,03 - 0,06
50 and more	—	—	—	0,025 - 0; 055

Note: less feeds should be used for more difficult and deep profiles and hard metals,
big – for simple profiles and soft metals.

Cutting speed *v*, m/min: at external direct both cross-section turning and a boring calculation is made under the empirical formula (1), and at cut-off, procutting and shaped turning with radial feed – under the formula (4)

$$v_{table} = \frac{C_v}{T^m \times s^y} \times K_v. \qquad (4)$$

Average tool life for singl tool machining is equal 30 – 60 minutes. Values of factors and power exponents for formulas (1) and (4) are specified in table 17.

Factor K_v is product of the factors considering influence of a blank material by K_{mv} (see tab. 1 - 4), surface conditions K_s (tab. 5), cutting tool material K_t (tab. 6 see).

At multytool machining and multimachine service the cutting tool life should be inreased, using factors from tables 7 and 8.

The account of cutting tools geometrical parametres influence is executed by introduction of factors from table 18.

17. Values of factor C_v and power exponents in formulas of cutting speed at machining by cutters

Kind of machining	Cutting tool material	Feed, mm\rev	Factor and power exponents			
			C_v	*x*	*y*	*m*
Machining of carbon steels, $\sigma_в$ = 750 MPa						
External longitudinal turning by **through passage**? cutter	T15K6*	$s \le 0.3$ $0.3 < s \le 0.7$ $s > 0.7$	420 350 340	0.15	0.20 0.35 0.45	0.20
The same, cutting tools with an additional edge	T15K6*	$s \le t$ $s > t$	292 292	0.30 0.15	0.15 0.30	0.18 0.18
Cut-off operation	T5K10* P18 **	—	47 23.7	—	0.80 0.66	0.20 0.25
Shaped turning	P18 **	—	22.7	—	0.50	0.30
	T15K6*	—	244	0.23	0.30	0.20

Threading by a cutter	P6M5	Rough strokes: $P \leq 2$ mm *2* mm	 14.8 30	 0.70 0.60	 0.30 0.25	 0.11 0.08
	P6M5	Finish strokes	41.8	0.45	0.30	0.13
Rotational threading	T15K6*	—	2330	0.50	0.50	0.50
Machining of gray cast iron, HB 190						
External longitudinal turning by **through passage**? cutter	BK6	$s \leq 0.40$ $s > 0.40$	292 243	0.15 0.15	0.20 0.40	0.20 0.20
External longitudinal cutter with an additional blade	BK6 **	$s > t$ $s \leq t$	324 324	0.40 0.20	0.20 0.40	0.28 0.28
Cut-off operation	BK6*	—	68.5	—	0.40	0.20
Нарезание a fastening thread	BK6*	—	83	0.45	—	0.33
Machining of malleable cast iron, HB 150						
External longitudinal turning by **through passage**? cutter	BK8 *	$s \leq 0.40$ $s > 0.40$	317 215	0.15 0.15	0.20 0.45	0.20 0.20
Cut-off operation	BK6*	—	86	—	0.4	0.20
Machining of copper haterogeneous alloys of average hardness, HB 100 – 140						
External longitudinal turning by **through passage**? cutter	P18*	$s \leq 0.20$ $s > 0.20$	270 182	0.12 0.12	0.25 0.30	0.23 0.23
Machining of silumin and foundry aluminium alloys, σ_u = 100 - 200 MPa, *HB <65;* *Duralumin,* σ_u = 300 - 400 MPa, *HB* ≤ 100						
External longitudinal turning by **through passage**? cutter	P18*	$s \leq 0.20$ $s > 0.20$	485 328	0.12 0.12	0.25 0.50	0.28 0.28

* Without cutting fluids; ** With cutting fluids.

Notes: 1. At an internal machining use a correction factor 0.9.

2. At machining of carbon and heat-resistance steels and steel castings by HSS cutters without cutting fluids use a correction factor for cutting speed **0.6 (~~0.8~~)**.

3. At cut-off operation of carbon steels and steel castings and procutting by cutters with cemented carbide T15K6 with cutting fluids use a correction factor 1.4.

4. At shaped turning deep and an intricate shape use a correction factor 0.85.

5. At machining of the heat treated steels by HSS use a correction factor: at normalization – 0.95; at an annealing – 0.9; at improvement – 0.8.

18. The correction factors considering influence of a cutting tool geometrical parametres for cutting speed

The main angle in the plan φ °	Factor $K_{\varphi v}$	Auxiliary angle in the plan φ_1 °	Factor $K_{\varphi 1v}$	Nose radius at a cutter tip *r* *, mm	Factor K_{rv}
20	1.4	10	1.0	1	0.94
30	1.2	15	0.97	2	1.0
45	1.0	20	0.94	3	1.03
60	0.9	30	0.91	—	—
75	0.8	45	0.87	*5*	1.13
90	0.7	—	—	—	—

* It is considered only for cutting tools with high-speed steel.

Finishing turning has series of the features distinguishing it from rough and in-process turning, therefore recommended cutting modes at thin (diamond) turning on high-speed lathes of increased accuracy and boring machine tools are reduced separately in tab. 19.

Cutting modes at turning of quenched steels by cemented carbide cutters are reduced in tab. 20.

Cutting modes at turning and a boring work of cast irons, quenched steels and cemented carbide by the cutters equipped with polycrystals of aggregates 01 (elbor-R), 05, 10 (geksanit-R) and 10D (two-layer plates with a working layer from geksanit-R) are reduced in tab. 21.

19. Cutting modes at thin turning and a boring work

Blank material	Cutting tool material of a working part	Surface roughness *Ra*, micron	Feed *s*, mm/rev	Cutting speed *v*, m/min
Steel: σ_u <650 MPa σ_u = 650 - 800 MPa σ_u > 800 MPa	T30K4	1.25 – 0.63	0.06 – 0.12	250 - 300 150 - 200 120 - 170
Cast iron: *HB* 149 - 163 *HB* 156 - 229 *HB* 170 - 241	BK3	2.5 – 1.25	0.06 – 0.12	150 – 200 120 – 150 100 - 120
Aluminium alloys and babbit	BK3	1.25 – 0.32	0.04 – 0.1	300 - 600
Bronze and brass	BK3		0.04 – 0.08	180 - 500

Notes: 1. Depth of cut is equal 0.1 – 0.15 mm.
2. Preliminary stroke with depth of cut of 0.4 mm improves the geometrical shape of the maachined surface.
3. Smaller values of a surface roughness correspond to smaller feed.

20. Cutting modes at turning of quenched steels by cutters with cemented carbide inserts

Feed *s*, mm\rev	Width of procutting, mm	Hardness of workpiece, *HRC*									
		35	39	43	46	49	51	53	56	59	62
		Cutting speed *v*, m/min									
External longitudinal turning											
0,2	—	157	135	116	107	83	76	66	48	32	26
0,3		140	118	100	92	70	66	54	39	25	20
0,4		125	104	88	78	60	66	45	33	—	—
0,5		116	95	79	71	53	—	—	—		
0,6		108	88	73	64	48					
Slot procutting											
0,05	3	131	110	95	83	70	61	54	46	38	29
0,08	4	89	75	65	56	47	41	37	31	25	19
0,12	6	65	55	47	41	35	30	27	23	18	14
0,16	8	51	43	37	32	27	23	—	—	—	—
0,20	12	43	36	31	27	23	20				

Notes: 1. Depending on depth of cut for a table cutting speed value use a correction factor: 1.15 at t = 0.4 – 0.9 mm; 1.0 at t = 1 – 2 mm and 0.91 at t = 2 – 3 mm.
2. Depending on surface roughness for a table cutting speed value use a correction factor: 1.0 for Rz = 10 microns; 0.9 for Ra = 2.5 microns and 0.7 for Ra = 1,25 microns.
3. Depending on the cemented carbide mark for a table cutting speed value use a correction factor K_{tv}

Hardness of workpiece	*HRC* 35 - 49				*HRC* 50 - 62		
Cemented carbide mark	T30K4	T15K6	BK6	BK8	BK4	BK6	BK8
Factor K_{tv}	1.25	1.0	0.85	0.83	1.0	0.92	0.74

4. Depending on the main angle in the plan of a cutting tool use correction factors: 1.2 at φ> 45 °; 0.9 at φ = 60 °; 0.8 at φ = 75 °; 0.7 at φ = 90 °.
5. At operation without cutting fluides for a table cutting speed value use correction factor 0.9.

21. Cutting modes at turning and a boring by cutters with plates equipped with an **compound** on the basis of a cubic boron nitride

Workpiece material	Character of machining	Mark of an **compound**	Depth of cut *t*, mm	Feed *s*, mm/rev	Cutting speed *v*, m/min
Quenched steels, *HRC* 40 - 58	Without blow	01; 05	0.05 – 3.0	0.03 – 0.2	50 – 160
	With blow	10; 10D	0.05 – 1.0	0.03 – 0.1	40 – 120
Quenched steels, *HRC* 58 - 68	Without blow	01	0.05 – 0.8	0.03 – 0.1	50 – 120
	With blow	10; 10D	0.05 – 0.2	0.03 – 0.07	10 – 100
Gray and high-tensile cast irons, *HB* 150 - 300	Without blow	05; 01	0.05 – 3.0	0.05 – 0.3	300 – 1000
	Without blow	10; 10D; 05; 01	0.05 – 3.0	0.05 – 0.15	300 – 700
Bleached quenched cast irons, *HB* 400 - 600	Without blow	05; 01	0.05 – 2.0	0.03 – 0.15	80 – 200
	With blow	10; 10D	0.05 – 1.0	0.05 – 0.1	50 – 100
Cemented carbides BK15, BK20, BK25, etc., *HRA* 80 - 86	Without blow, palpation is supposed	10; 10D; 01	0.05 – 1.0	0.03 – 0.1	5 – 20

Cutting force, N. It is accepted to decompose resultant cutting force R on the component forces directed on coordinate axes of the machine tool (tangential P_z, radial P_y and axial P_x). At external longitudinal and cross turning, a boring work, cut-off operations, procutting of slots and shaped turning these components are calculated by the formula

$$P_{z,\,y,\,x} = 10 C_p t^x s^y v^n K_p \qquad (5)$$

At cut-off operations, procutting and shaped turning t is the length of a cutter edge.

Rated C_p and power exponents x, y, n for concrete (rated) conditions of machining for each of cutting force component are shown in tab. 22.

The correction factor K_p represents product of some factors ($K_p = K_{мp} K_{\varphi p} K_{\gamma p} K_{\lambda p} K_{rp}$), considering actual conditions of cutting. Numerical values of these factors are reduced in tab. 9, 10 and 23.

Cutting power, kW, is calculated under the formula

$$N = \frac{P_z v}{1020 \times 60} \qquad (6)$$

At simultaneous operation of several cutting tools effective power is defined as total power of separate tools.

22. Values of factor C_p and power exponents for cutting force formula at turning

Worked stock	Cutting tool material	Machiing kind	Factor C_p and power exponents in formulas for components											
			Tangential P_z				Radial P_y				Axial P_x			
			C_p	x	y	n	C_p	x	y	n	C_p	x	y	n
Carbon steels σ_u = 750 MPa	CC	External longitudinal both cross turning and boring	300	1.0	0.75	-0.15	243	0.9	0,6	-0,3	339	1,0	0,5	-0,4
		External longitudional turning by cutters with an additional edge	384	0.90	0.90	-0.15	355	0.6	0.8	-0.3	241	1.05	0.2	-0.4
		Cutting-off and procutting	408	0.72	0.8	0	173	0.73	0.67	0	—	—	—	—
		Threading by cutter	148	—	1.7	0.71	—	—	—	—	—	—	—	—
	HSS	External longitudinal, undercutting and boring	200	1.0	0.75	0	125	0.9	0.75	0	67	1.2	0.65	0
		Cutting-off and procutting	247	1.0	1.0	0	—	—	—	—	—	—	—	—
		Shaped turning	212	1.0	1.0	0	—	—	—	—	—	—	—	—
12X18H9T *HB* 141	CC	External longitudinal both cross turning and boring of heat- resistance steel	204	1.0	0.75	0	—	—	—	—	—	—	—	—
Gray cast iron, *HB* 190	CC	External longitudinal both cross turning and boring	92	1.0	0.75	0	54	0.9	0.75	0	46	1.0	0.4	0
		External longitudional turning by cutters with an additional edge	123	1.0	0.85	0	61	0.6	0.5	0	24	1.05	0.2	0
		Threading by cutter	103	—	1.8	0.82	—	—	—	—	—	—	—	—
	HSS	Cutting-off and procutting	158	1.0	1.0	0	—	—	—	—	—	—	—	—
Malleable cast iron, *HB* 150	CC	External longitudinal both cross turning and boring	81	1.0	0.75	0	43	0.9	0.75	0	38	1.0	0.4	0
		External longitudional turning by cutters with an additional edge	100	1.0	0.75	0	88	0.9	0.75	0	40	1.2	0.65	0
		Cutting-off and procutting	139	1.0	1.0	0	—	—	—	—	—	—	—	—
Copper haterogeneous alloys, *HB* 120	HSS	External longitudinal both cross turning and boring	55	1.0	0.66	0	—	—	—	—	—	—	—	—
		Cutting-off and procutting	75	1.0	1.0	0	—	—	—	—	—	—	—	—
Aluminium and silumin		External longitudinal both cross turning and boring	40	1.0	0.75	0	—	—	—	—	—	—	—	—
		Cutting-off and procutting	50	1.0	1.0	0	—	—	—	—	—	—	—	—

23. The correction factors considering influence of cutter geometrical parametres on cutting force components at turning of steels and cast irons

Parametres		Cutting tool material	Correction factors			
The name	Magnitude		Designation	Value of factor for components		
				Tangential P_z	Radial P_y	Axial P_x
Main angle in the plan φ °	30	CC	$K_{\varphi p}$	1.08	1.30	0.78
	45			1.0	1.0	1.0
	60			0.94	0.77	1.11
	90			0.89	0.50	1.17
	30	HSS	$K_{\varphi p}$	1.08	1.63	0.70
	45			1.0	1.0	1.0
	60			0.98	0.71	1.27
	90			1.08	0.44	1.82
Face (side rake) angle γ °	-15	CC	$K_{\gamma p}$	1.25	2.0	2.0
	0			1.1	1.4	1.4
	10			1.0	1.0	1.0
Face (side rake) angle γ	12 - 15	HSS	$K_{\gamma p}$	1.15	1.6	1.7
	20 - 25			1.0	1.0	1.0
Angle of main cutting edge inclination λ °	-5	CC	$K_{\lambda p}$	1.0	0.75	1.07
	0				1.0	1.0
	5				1.25	0.85
	15				1.7	0.65
Nouse radius *r*, mm	0,5	HSS	K_{rp}	0.87	0.66	1.0
	1,0			0.93	0.82	
	2,0			1.0	1.0	
	3,0			1.04	1.14	
	4,0			1.10	1.33	

SHAPERING, SLOTTING

Depth of cutting. At all kind of shaping, planing and slotting depth of cutting is determined the same as at turning.

Feed. At rough shaping and planing feed *s*, mm/double stroke (**mmpdst**), is selected maximum from acceptable values on tab. 11, 13 in accordance to cut depth, shank cross-section value, strength of an insert; at finish shaping – from tab. 14, at cutting-off and slots procutting – from tab. 15.

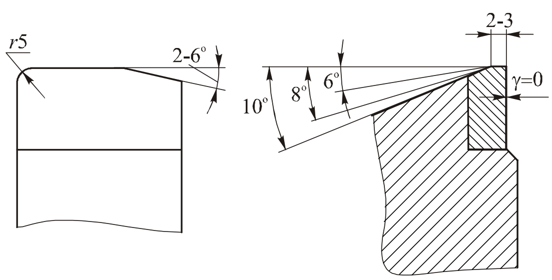


Fig. 1. A tool shaper for finish machining

Cutting modes for planing of plains by wide cutter (fig. 1) are shown in tab. 24. At shaping of plains by through passage cutters, at procutting of slots and cut-off machining cutting speed is calculated by correspondent formulas for turning with introduction of an additional correction factor $K_{sh\,v}$ considering a shock load.

24. Cutting modes at planing of plains on cast iron parts by wide cutters with BK8 inserts

Character of machining	The workpiece surface area, m^2	Quantity of strokes *i*	Depth of cutt *t*, mm	Feed *s*, mm/double stroke	Cutting speed *v*, m/min
Semifinish Rz = 40 - 10 microns	—	1	To 2	10-20	14-18
Finish Ra = 2.5 – 1.25 microns: preliminary stroke	—	1	0,15 - 0,3	10 - 20	5 - 15
finish stroke	6	1 - 2	0,05 - 0,1	12 - 16	15
	8				11
	12				7
	17				55
	22				4

Notes: 1. An workpiece surface to moisten with kerosene.

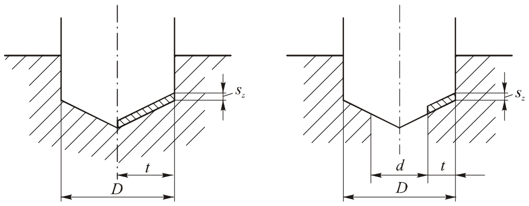
	Values of factor $K_{sh\ v}$		
Machine tool type	Planer	Shaper	Slotter
K_{yv}	1.0	0.8	0.6

Cutting force. Components of cutting force are calculated by the same formula as for turning. **Cutting power** is calculated by the same formula as for turning at similar conditions.

DRILLING, REDRILLING, CORE-DRILLING, REAMING

Depth of cut ***t*****.** At drilling depth of cutting $t = 0.5\ D$ (fig. 2, *a)*, at redrilling; a core-drilling and reaming $t = 0.5\ (D - d)$ (fig. 2, *b)*. s

Feed *s*. At a drilling without limitation factors it is selected as much as possible admissible feed on a drill strength (tab. 25). At redrilling of holes the feed is recommended 2 times more as for drilling. At presence of limitation factors feeds for drilling and for redrilling can be equal. They are calculated taking into account the corresponding correction factors in the notes to the table and data of others table.



a *b*

Fig. 2. The cutting schem at drilling (*a*) and redrilling (*b*)

Feeds at a core-drilling are shown in tab. 26, and at reaming – in tab. 27.

Cutting speed. Cutting speed, m/min, at drilling

$$v = \frac{C_v D^q}{T^m s^y} K_v, \tag{7}$$

and at redrilling, a coredrilling, reaming

$$v = \frac{C_v D^q}{T^m t^x s^y} K_v. \tag{8}$$

Values of factors C_v and power exponents are specified for drilling in tab. 28, for redrilling, core-drillings and reaming – in tab. 29, and values of cutting tool life *T* – in tab. 30.

The common correction factor for cutting speed, considering actual conditions of cutting,

$$K_v = K_{Mv} \times K_{tv} \times K_{lv}, \tag{9}$$

where K_{Mv} – the factor considering the workpiece material (tab. 1 - 4); K_{tv} – the factor considering the cutting tool material (tab. 6); K_{lv} – the factor considering depth of drilling (tab. 31). At redrilling and a core-drilling of molten or stamped holes correction factor K_{sv} (tab. 5) is used in addition.

25. Feeds, mm/rev, at drilling of a steel, cast iron, copper and aluminium alloys by HSS drills

Drill diameter *D*, mm	Steel				Gray and malleable cast iron, copper and aluminium alloys	
	HB <160	*HB* 160-240	*HB* 240-300	*HB*> 300	*HB* ≤ 170	*HB*> 170
2 - 4	0.09 - 0.13	0.08 - 0.10	0.06 - 0.07	0.04 - 0.06	0.12 - 0.18	0.09 - 0.12
4 - 6	0.13 - 0.19	0.10 - 0.15	0.07 - 0.11	0.06 - 0.09	0.18 - 0.27	0.12 - 0.18
6 - 8	0.19 - 0.26	0.15 - 0.20	0.11 - 0.14	0.09 - 0.12	0.27 - 0.36	0.18 - 0.24
8 - 10	0.26 - 0.32	0.20 - 0.25	0.14 - 0.17	0.12 - 0.15	0.36 - 0.45	0.24 - 0.31
10 - 12	0.32 - 0.36	0.25 - 0.28	0.17 - 0.20	0.15 - 0.17	0.45 - 0.55	0.31 - 0.35
12 - 16	0.36 - 0.43	0.28 - 0.33	0.20 - 0.23	0.17 - 0.20	0.55 - 0.66	0.35 - 0.41
16 - 20	0.43 - 0.49	0.33 - 0.38	0.23 - 0.27	0.20 - 0.23	0.66 - 0.76	0.41 - 0.47
20 - 25	0.49 - 0.58	0.38 - 0.43	0.27 - 0.32	0.23 - 0.26	0.76 - 0.89	0.47 - 0.54
25 - 30	0.58 - 0.62	0.43 - 0.48	0.32 - 0.35	0.26 - 0.29	0.89 - 0.96	0.54 - 0.60
30 - 40	0.62 - 0.78	0.48 - 0.58	0.35 - 0.42	0.29 - 0.35	0.96 - 1.19	0.60 - 0.71
40 - 50	0.78 - 0.89	0.58 - 0.66	0.06 - 0.07	0.35 - 0.40	1.19 - 1.36	0.71 - 0.81

Niotes: rated feeds is applied at drilling with depth *l* <3D with grade of tolerance not higher 12th in the conditions of rigid technological system. Otherwise use correction factors:

1) on hole depth – $K_{ls} = 0.9$ at $l \le 5D$; $K_{ls} = 0.8$ at $l \le 7D$; $K_{ls} = 0.75$ at $l \le 10D$;

2) for reaching more quality of a hole in connection with the subsequent machining by reamer or a tap – $K_{qs} = 0.5$;

3) at insufficient rigidness of MATP system: at average rigidness K_{rs} = 0.75; at small rigidness K_{rs} = 0.5;
4) on cutting tool material – K_{ts} = 0.6 for CC drills.

26. Feeds, mm/rev, for cor-drills and reamers from HSS and CC

Worked stock	Diameter of end reamer *D*, mm								
	To 15	15 … 20	20 … 25	25 … 30	30 … 35	35 … 40	40 … 50	50 … 60	60 … 80
Steel	0.5 – 0.6	0.6 – 0.7	0.7 – 0.9	0.8 – 1.0	0.9 – 1.1	0.9 – 1.2	1.0 – 1.3	1.1 – 1.3	1.2 – 1
Cast iron *HB* ≤200 and copper alloys	0.7 – 0.9	0.9 – 1.1	1.0 – 1.2	1.1 – 1.3	1.2 – 1.5	1.4 – 1.7	1.6 – 2.0	1.8 – 2.2	2.0 – 2
Cast iron, *HB*>200	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8 – 0.9	0.9 – 1.1	1.0 – 1.2	1.2 – 1.4	1.3 – 1.5	1.4 – 1

Notes: 1. Values of feeds are applied for holes machining with grade of tolerance not higher 12th. For reaching more high accuracy (9-11th grade of tolerance) and also at holes preparing for the subsequent machining by one reamer or by a tap use correction factor K_{qs} = 0.7.
2. At a core-drilling of blind holes feed should not exceed 0.3 – 0.6 mm/rev.

27. Feeds, mm/rev, at preliminary (rough) reaming by HSS reamers

Worked stock	Diameter of a reamer *D*, mm									
	To 10	10 … 15	15 … 20	20 … 25	25 … 30	30 … 35	35 … 40	40 … 50	50 … 60	60 … 80
Steel	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.7	2.0
Cast iron *HB* ≤200 and copper alloys	2.2	2.4	2.6	2.7	3.1	3.2	3.4	3.8	4.3	5.0
Cast iron, *HB*>200	1.7	1.9	2.0	2.2	2.4	2.6	2.7	3.1	3.4	3.8

Notes: 1. Feed should be diminished: at finish reaming for one stroke with accuracy of 9-11 grade of tolerance and surface roughness *Ra* = 3.2 – 6.3 microns or at reaming for the subsequent burnishing and a honing, multiplying by factor K_{qs} = 0.8; at finish reaming after rough for reaching accuracy of 7 grade of tolerance and surface roughness *Ra* = 0.4 – 0.8 microns multiplying by factor K_{qs} = 0.1; for CC reamers multiplying by factor K_{ts} = 0.7.
2. At reaming of blind holes feed should not exceed 0.2 – 0.5 mm/rev.

28. Values of factor C_v and power exponents in the formula of cutting speed at drilling

Worked stock	Material of a cutting part of the tool	Feeding s, mm/about	Factor and power exponents				Cutting fluids
			C_v	*q*	*y*	*m*	
Carbon steel σ_u = 750 МПа	Р6М5	≤ 0,2 > 0,2	7,0 9,8	0,40 0,40	0,70 0,50	0,20 0,20	Yes
Heat- resistance steel 12Х18Н9Т, *HB* 141		—	3,5	0,50	0,45	0,12	Yes
Gray cast iron, *HB* 190		≤ 0,3 > 0,3	14,7 17,1	0,25 0,25	0,55 0,40	0,125 0,125	No
	ВК8	—	34,2	0,45	0,30	0,20	No
Malleable cast iron, *HB* 150	Р6М5	≤ 0,3 > 0,3	21,8 25,3	0,25 0,25	0,55 0,40	0,125 0,125	Yes
	ВК8	—	40,4	0,45	0,3	0,20	No
Copper heterogeneous alloys of average hardness (*HB* 100-140)	Р6М5	≤ 0,3 > 0,3	28,1 32,6	0,25 0,25	0,55 0,40	0,125 0,125	Yes
Silumin and foundry aluminium alloys, σ_u = 100 - 200 MPa, *HB* <65; duralumin, *HB* <100		≤ 0,3 > 0,3	36,3 40,7	0,25 0,25	0,55 0,40	0,125 0,125	Yes

Notes: rated data are actual for HSS drills with double sharpening and undegrinded web. At single sharpening of HSS drills the calculated cutting speed should be diminished multiplying by factor $K_{sh\ v}$ = 0.75.

29. Values of factor C_v and power exponents in the formula of cutting speed at redrilling, coredrilling and reaming

Worked stock	Kind of machining	Cutting tool material	Factor C_v and power exponents					Cutting fluids
			C_v	*q*	*x*	*y*	*m*	
Carbon steel σ_u = 750 MPa	Redrilling	Р6М5 ВК8	16.2 10.8	0.4 0.6	0.2 0.2	0.5 0.3	0.2 0.25	Yes
	Core-drilling	Р6М5 Т15К6	16.3 18.0	0.3 0.6	0.2 0.2	0.5 0.3	0.3 0.25	Yes
	Reaming	Р6М5 Т15К6	10.5 100.6	0.3 0.3	0.2 0	0.65 0.65	0.4 0.4	Yes

Qenched carbon steel, σ_u = 1600 – 1800 MPa, *HRC* 49 – 54	Core-drilling	T15K6	10.0	0.6	0.3	0.6	0.45	Yes
	Development		14.0	0.4	0.75	1.05	0.85	Yes
Gray cast iron, *HB* 190	Redrilling	P6M5	23.4	0.25	0.1	0.4	0.125	No
		BK8	56.9	0.5	0.15	0.45	0.4	
	Core-drilling	P6M5	18.8	0.2	0.1	0.4	0.125	No
		BK8	105.0	0.4	0.15	0.45	0.4	
	Reaming	P6M5	15.6	0.2	0.1	0.5	0.3	No
		BK8	109.0	0.2	0	0.5	0.45	
Malleable cast iron, *HB* 150	Redrilling	P6M5	34.7	0.25	0.1	0.4	0.125	Yes
		BK8	77.4	0.5	0.15	0.45	0.4	
	Core-drilling	P6M5	27.9	0.2	0.1	0.4	0.125	Yes
		BK8	143.0	0.4	0.15	0.45	0.4	
	Reaming	P6M5	23.2	0.2	0.1	0.5	0.3	Yes
		BK8	148.0	0.2	0	0.5	0.45	No

30. Average values of cutting tool life *T* of drills, core-drills and reamers

Cutting tool (process)	Worked stock	Cutting tool material	Firmness *T*, mines, at diameter of the instrument, mm							
			To 5	6-10	11-20	21-30	31-40	41-50	51-60	61-80
Drills (drilling and redrilling)	Carbon and alloy steel	HSS	15	25	45	50	70	90	110	-
		CC	8	15	20	25	35	45	-	-
	Corrosion resistance steel	HSS	6	8	15	25	-	-	-	-
	Gray and malleable cast iron, copper and aluminium alloys	HSS	20	35	60	75	105	140	170	-
		CC	15	25	45	50	70	90	-	-
Core-drills (coredrilling)	Carbon and alloy steel, gray and malleable cast iron	HSS and CC	-	-	30	40	50	60	80	100
Reamers (reaming)	Carbon and alloy steel	HSS	-	25	40	80	80	120	120	120
		CC	-	20	30	50	70	90	110	140
	Gray and malleable cast iron	HSS	-	-	60	120	120	180	180	180
		CC	-	-	45	75	105	135	165	210

31. Correction factor K_{lv} for cutting speed at drilling, considering a hole depth

Parametre	Drilling					Redrilling, core-drilling, reaming
Depth of machined hole	3*D*	4*D*	5*D*	6*D*	8*D*	—
Factor K_{lv}	1.0	0.85	0.75	0.7	0.6	1.0

Torque *M*, N·m, and **axial force** P_o, N, are calculated under formulas:
at drilling

$$M = 10C_M D^q s^y K_p; \qquad (10)$$

$$P_o = 10C_p D^q s^y K_p; \qquad (11)$$

at drilling and a core-drilling

$$M_{кр} = 10C_M D^q t^x s^y K_p; \qquad (12)$$

$$P_o = 10C_p D^q t^x s^y K_p; \qquad (13)$$

Values of factors C_M and C_p, and power exponents are shown in tab. 32.

The factor considering actual conditions of machining, in this case depends only on a workpiece material and is defined by expression $K_p = K_{mp}$.

Values of factor K_{mp} are shown for a steels and cast irons in tab. 9, and for copper and aluminium alloys – in tab. 10.

For torque definition at reaming each tooth of the cutting tool can be considered as a boring tool. Then at diameter of tool *D* a torque, N·m,

$$M_{кр} = \frac{C_p \times t^x \times s_z^y \times D \times z}{2 \times 100} \qquad (14)$$

Here s_z – feed, mm per one tooth of the reamer, equal to *s/z*, where *s* – feed, mm/rev, *z* – quantity of reamer teeth. Values of factors C_p and power exponents see in tab. 32.

Power of cutting, kW, is calculated by the formula

$$N_e = M_{кр} \times n / 9750, \qquad (15)$$

where an cutting tool or workpiece rotational speed (frequency of rotation), rpm (revolution per minute), $n = 1000 \cdot v / \pi \cdot D$.

32. Values of factors and power exponents in formulas of a torque and axial force at drilling, redrilling and a core-drilling

Worked stock	The process name	Cutting tool material	Factor and power exponents in formulas							
			Torque				Axial force			
			C_M	*q*	*x*	*y*	C_p	*q*	*x*	*y*
Carbon steel, σ_u = 750 MPa	Drilling	HSS	0.0345	2.0	-	0.8	68	1.0	-	0.7
	Redrilling and core-drilling		0.09	1.0	0.9	0.8	67	-	1.2	0.65
Heat-resistence steel 12X18H9T, *HB* 141	Drilling	HSS	0.041	2.0	-	0.7	143	1.0	-	0.7
	Redrilling and core-drilling		0.106	1.0	0.9	0.8	140	-	1.2	0.65
Gray cast iron, *HB* 190	Drilling	CC	0.012	2.2	-	0.8	42	1.2	-	0.75
	Redrilling and core-drilling		0.196	0.85	0.8	0.7	46	-	1.0	0.4
	Drilling	HSS	0.021	2.0	-	0.8	42.7	1.0	-	0.8
	Redrilling and core-drilling		0.085	-	0.75	0.8	23.5	-	1.2	0.4
Malleable cast iron, *HB* 150	Drilling	HSS	0.021	2.0	-	0.8	43.3	1.0	-	0.8
		CC	0.01	2.2	-	0.8	32.8	1.2	-	0.75
	Redrilling and core-drilling		0.17	0.85	0.8	0.7	38	-	1.0	0.4
Heterogeneous copper alloys of average hardness, *HB* 120	Drilling	HSS	0.012	2.0	-	0.8	31.5	1.0	-	0.8
	Redrilling and core-drilling		0.031	0.85	-	0.8	17.2	-	1.0	0.4
Silumin and duralumin	Drilling	HSS	0.005	2.0	-	0.8	9.8	1.0	-	0.7

Note. The axial force calculated by the formula at drilling are actual for drills with undegrinded web; with not undegrinded web axial force at drilling is increased in 1.33 times.

MILLING

The configuration of a processed surface and equipment kind define type of an applied milling cutter (mill) (fig. 3). Its sizes are defined by the sizes of a processed surface and depth of a cut off layer (or depth of cut). Diameter of a mill for reduction of cost and the expense of the cutting tool gets out whenever possible the least size, considering thus rigidity of technological system, the cutting scheme, the shape and the sizes of processed blank (workpiece). For reduction of basic technological time diameter of a mill gets out such whenever possible to process a surface for one stroke or with the least quantity of strokes.

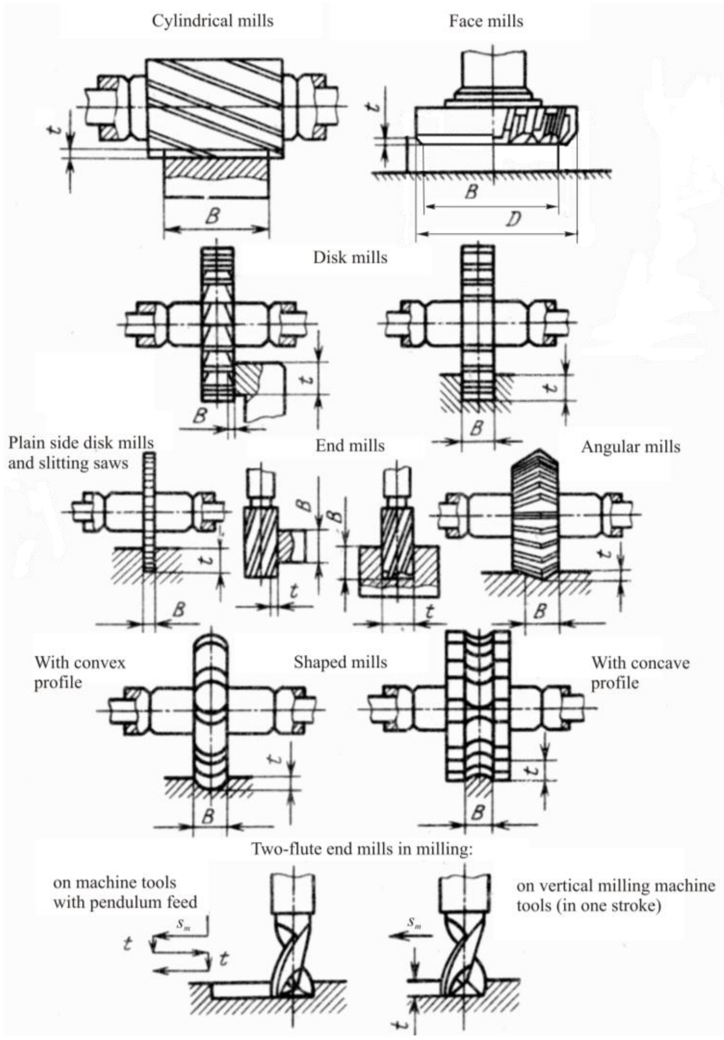
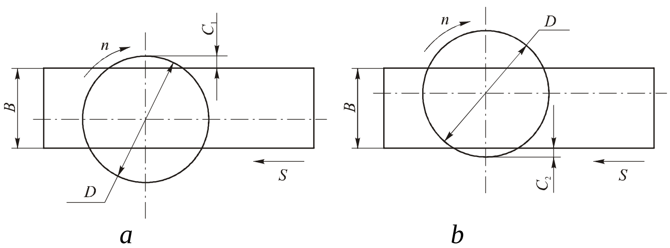


Fig. 3. Types of milling cutters (mills)

At face milling for achievement of productive cutting modes the diameter of mill *D* should be more width of milling *B*, i.e. $D = (1.25…1.5) \times B$, and at machining of blanks their asymmetrical arrangement concerning a mill is obligatory: for carbon steel and alloyed steel blanks – their shift (displacement) in a direction of **incision** (start of cutting) of a mill tooth (fig. 4, *a*), than a small thickness of a cut off layer is provided in the cutting beginning; for heat-résistance and corrosion-résistance steel blanks – shift of blank towards an exit of a mill tooth from cutting (fig. 4, *b)*, than minimum possible thickness of a cut off layer is provided at exiting of tooth from cutting. Non-observance of the specified rules leads to considerable decreasing of cutting tool life.



a *b*

Fig. 4. An arrangement of steel blank at face milling concerning a mill: *a* – incision of a mill tooth at $c_1 = (0.03 … 0.05)\ D$; *b* – an exit of a mill tooth at $c_2 = 0$.

Depth of milling *t* and width of milling *B* – the concepts connected with the sizes of a blank layer, removed at milling (fig. 3). In all kinds of milling, except for face milling, *t* defines duration of a mill tooth contact with blank; *t* is measured in the direction, perpendicular to a mill axis. The width of milling *B* defines length of mill tooth edge, participating in cutting; *B* is measured in the direction parallel to an axis of a mill. At face milling these concepts are interchanged the position.

Feed. In milling feed can be (**it distinguish**??): feed per one tooth s_z (mmpt), feed per one revolution of a mill *s* (mmpr) and feed per minute s_m, (mmpm) which are calculated in the ratio:

$$s_m = s \times n = s_z \times z \times n$$

where n – frequency of a mill rotation (the rotational speed), rpm; z – teeth quantity of a mill.

Initial value of feed at rough milling is its feed per one tooth s_z, at finish milling – on one feed per minute s_m which is used for the further calculation of feed per one tooth $s_z = s/z$. Recommended feeds for various mills and cutting conditions are specified in tab. 33 – 38.

Cutting speed v in milling is the peripheral speed of the cutter (a mill), m/minute (mpm),

$$v = \frac{C_v D^q}{T^m t^x s_z^y B^u z^p} K_v \qquad (1)$$

Values of factor C_v and power exponents are specified in tab. 39, and cutting tool life T – in tab. 40.

The general correction factor for cutting speed, considering actual conditions of cutting,

$$K_v = K_{Mv} \times K_{sv} \times K_{tv}, \qquad (2)$$

where K_{Mv} – the factor considering quality of the processed material (tab. 1 - 4); K_{sv} – the factor considering a condition of blank surface (tab. 5); K_{tv} - the factor considering a material of the tool (tab. 6).

33. Feeds in rough milling by face, cylindrical and disk mills with cemented carbide (CC) inserts

Power of the machine tool, kW	Steels		Cast irons and copper alloys	
	Feed per mill tooth s_z, mm (mm/tooth), for CC mills			
	T15K6	T5K10	BK6	BK8
5 - 10	0.09 – 0.18	0.12 – 0.18	0.14 – 0.24	0.20 – 0.29
Over 10	0.12 – 0.18	0.16 – 0.24	0.18 – 0.28	0.25 – 0.38

Notes: 1. The specified values of feeds for cylindrical mills are valid at width of milling B < 30 mm; at B > 30 mm tabular values of feeds should be reduced by 30 %.
2. The specified values of feeds for disk mills are valid at milling of a plane and shoulders; at milling of grooves tabular values of feeds should be reduced in 2 times.
3. In milling with the feeds specified in the table the surface roughness Ra = 0.8 … 1.6 microns is reached.

34. Feeds in rough milling by face, cylindrical and disk mills from high-speed steel (HSS)

Capacity of the machine tool or milling head, kW	Rigidity (stiffness) of blank – attachment system	Mills			
		Face and disk		Cylindrical	
		Feed per one tooth s_z, mm (mm/tooth), in machining			
		Carbon steel	Cast iron and copper alloys	Carbon steel	Cast iron and copper alloys
		Mills with large tooth and mills with plug-in knifes (blades)			
Over 10	Higher	0.20 - 0.30	0.40 – 0.60	0.40 – 0.60	0.60 – 0.80
	Medium	0.15 - 0.25	0.30 – 0.50	0.30 – 0.40	0.40 – 0.60
	Lowered	0.10 - 0.15	0.20 – 0.30	0.20 – 0.30	0.25 – 0.40
5 - 10	Higher	0.12 - 0.20	0.30 – 0.50	0.25 – 0.40	0.30 – 0.50
	Medium	0.08 - 0.15	0.20 – 0.40	0.12 – 0.20	0.20 – 0.30
	Lowered	0.06 - 0.10	0.15 – 0.25	0.10 – 0.15	0.12 – 0.20
To 5	Medium	0.06 - 0.07	0.15 – 0.30	0.08 – 0.12	0.10 – 0.18
	Lowered	0.04 - 0.06	0.10 – 0.20	0.06 – 0.10	0.08 – 0.15
		Mills with small tooth			
5 - 10	Higher	0.08 - 0.12	0.20 – 0.35	0.10 – 0.15	0.12 – 0.20
	Medium	0.06 - 0.10	0.15 – 0.30	0.06 – 0.10	0.10 – 0.15
	Lowered	0.04 - 0.08	0.10 – 0.20	0.06 – 0.08	0.08 – 0.12
To 5	Medium	0.04 - 0.06	0.12 – 0.20	0.05 – 0.08	0.06 – 0.12
	Lowered	0.03 - 0.05	0.08 – 0.15	0.03 – 0.06	0.05 – 0.10

Notes: 1. Great values of feeds take for smaller depth and width of milling, smaller – for great values of depth and width.
2. In milling of heat-resistance and a corrosion-resistance steels the feeds are used the same as for a carbon steels, but not above 0.3 mm/tooth.

35. Feeds in milling of steel blanks by various mills from high-speed steel

Diameter of a mill D, mm	Milling cutter type	Feed per tooth s_z, mm, at depth of milling t, mm						
		3	5	6	8	10	12	15
16	End	0.08 – 0.05	0.06 – 0.05	—	—	—	—	—
20		0.10 – 0.06	0.07 – 0.04	—	—	—	—	—
25		0.12 – 0.07	0.09 – 0.05	0.08 – 0.04	—	—	—	—
35		0.16 – 0.10	0.12 – 0.07	0.10 – 0.05	—	—	—	—
35	Angular and shaped	0.08 – 0.04	0.07 – 0.05	0.06 – 0.04	—	—	—	—
40	End	0.20 – 0.12	0.14 – 0.08	0.12 – 0.07	0.08 – 0.05	—	—	—
	Angular and shaped	0.09 – 0.05	0.07 – 0.05	0.06 – 0.03	0.06 – 0.03			
	Plain side	0.009-0.005	0.007 – 0.003	0.01-0.007	—			
50	End	0.25 – 0.15	0.15 – 0.10	0.13 – 0.08	0.10 – 0.07	—	—	—
	Angular and shaped	0.10 – 0.06	0.08 – 0.05	0.07 – 0.04	0.06 – 0.03			
	Plain side	0.01 – 0.006	0.008 – 0.004	0.012 – 0.008	0.012 – 0.008			
60	Angular and shaped	0.10 – 0.06	0.08 – 0.05	0.07 – 0.04	0.06 – 0.04	0.05 – 0.03	—	—
	Plain side	0.013-0.008	0.010 – 0.005	0.015 – 0.01	0.015-0.022	0.015 – 0.01		
	Slitting saws	—	—	0.025 – 0.015	0.01 – 0.012	0.02 – 0.01		
75	Angular and shaped	0.12 – 0.08	0.10 – 0.06	0.09 – 0.05	0.07 – 0.05	0.06 – 0.04	0.06 – 0.03	—
	Plain side	—	0.015 – 0.005	0.025 – 0.01	0.022 – 0.01	0.02 – 0.01	0.017 – 0.008	0.015 – 0.007
	Slitting saws	—	—	0.03 – 0.015	0.027 – 0.012	0.025 – 0.01	0.022 – 0.01	0.02 – 0.01
90	Angular and shaped	0.12 – 0.08	0.12 – 0.05	0.11 – 0.05	0.10 – 0.05	0.09 – 0.04	0.08 – 0.04	0.07 – 0.03
	Slitting saws	—	—	0.03 – 0.02	0.028 – 0.016	0.027 – 0.015	0.023 – 0.015	0.022 – 0.012
110	Slitting saws	—	—	0.03 – 0.025	0.03 – 0.02	0.03 – 0.02	0.025 – 0.02	0.025 – 0.02
150-200		—	—	—	—	—	—	0.03 – 0.02

Notes: 1. In milling of cast iron, copper and aluminium alloys feed increase on 30 – 40 %.
2. Feeds are specified for shaped mills (formed-tooth milling cutters) with the convex smoothly outlined; for the same mills with sharply outlined or concave profile feeds should be reduced on 40 %.
3. Feeds for plain side milling cutters and slitting saws (mills) with small tooth are specified for depth of milling to 5 mm, with large tooth – for depth over 5 mm.

36. Feeds in milling of planes and shoulders of steel blanks by CC end mills

Kind of CC cutting elements	Diameter of mill D, mm	Rough milling						
		Feed per tooth s_z, mm, at depth of milling t, mm						
		1 - 3	5	8	12	20	30	40
Crown	10 - 12	0.01 – 0.03	—	—	—	—	—	—
	14 - 16	0.02 – 0.06	0.02 – 0.04	—	—	—	—	—
	18 - 22	0.04 – 0.07	0.03 – 0.05	0.02 – 0.04	—	—	—	—
Screw inserts	20	0.06 – 0.10	0.05 – 0.08	0.03 – 0.05	—	—	—	—
	25	0.08 – 0.12	0.06 – 0.10	0.05 – 0.10	0.05 – 0.08	—	—	—
	30	0.10 – 0.15	0.08 – 0.12	0.06 – 0.10	0.05 – 0.09	—	—	—
	40	0.10 – 0.18	0.08 – 0.13	0.06 – 0.11	0.05 – 0.10	0.04 – 0.07	—	—
	50	0.10 – 0.20	0.10 – 0.15	0.08 – 0.12	0.06 – 0.10	0.05 – 0.09	0.05 – 0.08	0.05 – 0.06
	60	0.12 – 0.20	0.10 – 0.16	0.10 – 0.12	0.08 – 0.12	0.06 – 0.10	0.06 – 0.10	0.06 – 0.08

	Finish milling			
Diameter of mill D, mm	10 - 16	20 - 22	25 - 35	40 - 60
Mill feed s, mm/rev	0.02 – 0.06	0.06 – 0.12	0.12 – 0.24	0.3 – 0.6

Notes: 1. In rough milling of cast iron the feeds for rough milling of steel should be increased on 30 – 40 %; in finish milling of cast iron the feed is the same as recommended for fair milling of a steel.
2. The upper limits of feeds are applied for rough milling at small width of milling on machine tools with high rigidity, the lower limits – for the large width of milling on machine tools with insufficient rigidity.
3. At work with feeds for finish milling the surface roughness Ra = 0.8 … 1.6 microns is reached.

37. Feeds s, mm/rev, in finish milling of planes and shoulders by face, disk and cylindrical mills

Surface roughness Ra, micron	Face and disk mills with plug-in knifes		HSS cylindrical mills at diameter of mill D, mm, depending on a processed material					
	For CC mills	For HSS mills	The carbon and alloyed steel			Cast iron, copper and aluminum alloys		
			40 - 75	90 - 130	150 - 200	40 - 75	90 - 130	150 - 200
6.3	—	1.2 – 2.7	—	—	—	—	—	—
3.2	0.5 – 1.0	0.5 – 1.2	1.0 – 2.7	1.7 – 3.8	2.3 – 5.0	1.0 – 2.3	1.4 – 3.0	1.9 – 3.7
1.6	0.4 – 0.6	0.23 – 0.5	0.6 – 1.5	1.0 – 2.1	1.3 – 2.8	0.6 – 1.3	0.8 – 1.7	1.1 – 2.1
0.8	0.2 – 0.3	—	—	—	—	—	—	—
0.4	0.15	—	—	—	—	—	—	—

31. Feeds in milling of steel blanks by two-flute mills (for milling of closed key slot) from high-speed steel

Diameter of mill D, mm	Milling on key slot milling machine tools with pendulum feed at depth of milling on one double stroke (component of a key slot depth)		Milling on the vertical milling machine tools in one stroke	
			Axial feed (for key slot depth achievement)	Longitudinal feed in key slot milling
	Depth of milling t, mm	Feed per one tooth s_z, mm,		
6	0.3	0.10	0.006	0.020
8		0.12	0.007	0.022
10		0.16	0.008	0.024
12		0.18	0.009	0.026
16	0.4	0.25	0.010	0.028
18		0.28	0.011	0.030
20		0.31	0.011	0.032
24		0.38	0.012	0.036
28	0.5	0.45	0.014	0.037
32		0.50	0.015	0.037
36		0.55	0.016	0.038
40		0.65	0.016	0.038

Note. Feeds are specified for a carbon steel with σ_u <750 MPa; in milling of steels with higher strength feeds should be reduced on 20 – 40 %.

39. Values of factor C_v and power exponents in the formula of cutting speed in milling

Kind of milling cutter	Material of a cutting part	Kind of machining	Parameters of cutting, mm			Factor and exponents in the formula of cutting speed						
			B	t	s_z	C_v	q	x	y	u	p	m
Milling of carbon steel, σ												
Face	T15K6*[1]	Milling of planes	—	—	—	332	0.2	0.1	0.4	0.2	0	0.2
	P6M5*[2]		—	—	≤ 0.1 > 0.1	64,7 41	0.25	0.1	0.2 0.4	0.15	0	0.2
Cylindrical	T15K6*[1]		≤35 > 35	≤2 > 2 ≤2 > 2	—	390 443 616 700	0.17 0.17 0.17 0.17	0.19 0.38 0.19 0.38	0.28 0.28 0.28 0.28	-0.05 0.08 0.08 0.08	0.1 0.1 0.1 0.1	0.33 0.33 0.33 0.33
	P6M5*[2]		—	—	≤ 0.1 > 0.1	55 35,4	0.45	0.3	0.2 0.4	0.1	0.1	0.33
Disk with plug-in knifes (blades)	T15K6*[1]	Milling of planes and shoulders	—	—	<0.12 ≥0.12	1340 740	0.2	0.4	0.12 0.4	0	0	0.35
	T15K6*[1]	Milling of slots	—	—	<0.06 ≥0.06	1825 690	0.2	0.3	0.12 0.4	0.1	0	0.35
Disk with plug-in knifes	P6M5*[2]	Milling of planes, shoulders and slots	—	—	≤ 0.1 > 0.1	75.5 48.5	0.25	0.3	0.2 0.4	0.1	0.1	0.2
Solid disk	P6M5*[2]		—	—	—	68.5	0.25	0.3	0.2	0.1	0.1	0.2
End with crown	T15K6*[1]		—	—	—	145	0.44	0.24	0.26	0.1	0.13	0.3
End with brazed CC inserts	T15K6*[1]		—	—	—	234	0.44	0.24	0.26	0.1	0.13	0.37
Solid end	P6M5*[2]		—	—	—	46.7	0.45	0.5	0.5	0.1	0.1	0.3
Plain side mills	P6M5*[2]	Plain side milling	—	—	—	53	0.25	0.3	0.2	0.2	0.1	0.2

and slitting saws		of slots and sawing										
Shaped with a convex profile	P6M5*[2]	Shaped milling	—	—	—	53	0.45	0.3	0.2	0.1	0.1	0.33
Angular and shaped with a concave profile	P6M5*[2]	Milling of angular flutes and shaped	—	—	—	44	0.45	0.3	0.2	0.1	0.1	0.33
Two-flute mills	P6M5*[2]	Key slot milling	—	—	—	12	0.3	0.3	0.25	0	0	0.2
Milling of a heat-resistance steel 12X18H9T with a delivery condition HB 141												
Face	BK8*[1]	Milling of planes	—	—	—	108	0.2	0.06	0.3	0.2	0	0.32
	P6M5*[2]		—	—	—	49.6	0.15	0.2	0.3	0.2	0.1	0.14
Cylindrical	P6M5*[2]		—	—	—	44	0.29	0.3	0.34	0.1	0.1	0.24
End	P6M5*[2]	Milling of planes and shoulders	—	—	—	22.5	0.35	0.21	0.48	0.03	0.1	0.27
Milling of gray cast iron, HB 190												
Face	BK6*[1]	Milling of planes	—	—	—	445	0.2	0.15	0.35	0.2	0	0.32
	P6M5*[2]		—	—	—	42	0.2	0.1	0.4	0.1	0.1	0.15
Cylindrical	BK6*[1]		—	< 2.5 < 2.5 ≥ 2.5 ≥ 2.5	≤ 0.2 > 0.2 ≤ 0.2 > 0.2	923 588 1180 750	0.37 0.37 0.37 0.37	0.13 0.13 0.40 0.40	0.19 0.47 0.19 0.47	0.23 0.23 0.23 0.23	0.14 0.14 0.14 0.14	0.42 0.42 0.42 0.42
	P6M5*[1]		—	—	≤0.15 >0.15	57.6 27	0.7 0.7	0.5 0.5	0.2 0.6	0.3 0.3	0.3 0.3	0.25 0.25
Disk with plug-in knifes	P6M5*[1]	Milling of planes, shoulders and slots	—	—	—	85	0.2	0.5	0.4	0.1	0.1	0.15
Solid disk	P6M5*[1]		—	—	—	72	0.2	0.5	0.4	0.1	0.1	0.15
End	P6M5*[1]	Milling of planes and shoulders	—	—	—	72	0.7	0.5	0.2	0.3	0.3	0.25
Plain side mills and slitting saws	P6M5*[1]	Plain side milling of slots and sawing	—	—	—	30	0.2	0.5	0.4	0.2	0.1	0.15
***Milling of malleable cast iron, HB* 150**												
Face	BK6*[1]	Milling of planes	—	—	≤0.18 >0.18	994 695	0.22 0.22	0.17 0.17	0.1 0.32	0.22 0.22	0 0	0.33 0.33
	P6M5*[2]		—	—	≤0.1 >0.1	90.5 57.4	0.25 0.25	0.1 0.1	0.2 0.4	0.15 0.15	0.1 0.1	0.2 0.2
Cylindrical	P6M5*[2]		—	—	≤0.1 >0.1	77 49.5	0.45 0.45	0.3 0.3	0.2 0.4	0.1 0.1	0.1 0.1	0.33 0.33
Disk with plug-in knifes	P6M5*[2]	Milling of planes, shoulders and slots	—	—	≤0.1 >0.1	105.8 68	0.25 0.25	0.3 0.3	0.2 0.4	0.1 0.1	0.1 0.1	0.2 0.2
Solid disk	P6M5*[2]		—	—	—	95.8	0.25	0.3	0.2	0.1	0.1	0.2
End	P6M5*[2]	Milling of planes and shoulders	—	—	—	68.5	0.45	0.3	0.2	0.1	0.1	0.33
Plain side mills and slitting saws	P6M5*[2]	Plain side milling of slots and sawing	—	—	—	74	0.25	0.3	0.2	0.2	0.1	0.2
***Milling of heterogeneous copper alloys of average hardness, HB* 100 – 140**												
Face	P6M5*[1]	Milling of planes	—	—	0.1 0.1	136 86.2	0.25 0.25	0.1 0.1	0.2 0.4	0.15 0.15	0.1 0.1	0.2 0.2
Cylindrical	P6M5*[1]		—	—	0.1 0.1	115.5 74.3	0.45 0.45	0.3 0.3	0.2 0.4	0.1 0.1	0.1 0.1	0.33 0.33
Disk with plug-in knifes	P6M5*[1]	Milling of planes, shoulders and slots	—	—	0.1 0.1	158.5 102	0.25 0.25	0.3 0.3	0.2 0.4	0.1 0.1	0.1 0.1	0.2 0.2
Solid disk	P6M5*[1]		—	—	—	144	0.25	0.3	0.2	0.1	0.1	0.2
End	P6M5*[1]	Milling of planes and shoulders	—	—	—	103	0.45	0.3	0.2	0.1	0.1	0.33
Plain side mills and slitting saws	P6M5*[1]	Plain side milling of slots and sawing	—	—	—	111.3	0.25	0.3	0.2	0.2	0.1	0.2
***Milling of silumin and foundry aluminum alloys,* σ_u = 100 - 200 MPa, *HB <65; and duralumin* σ_u = 300 … 400 MPa, *HB* <100**												

Face	P6M5*[1]	Milling of planes	—	—	≤0.1 >0.1	245 155	0.25	0.1	0.2 0.4	0.15	0.1	0.2
Cylindrical	P6M5*[1]		—	—	≤0.1 > 0.1	208 133.5	0.45	0.3	0.2 0.4	0.1	0.1	0.33
Disk with plug-in knifes	P6M5*[1]	Milling of planes, shoulders and slots	—	—	≤0.1 > 0.1	285 183.4	0.25	0.3	0.2 0.4	0.1	0.1	0.2
Solid disk	P6M5*[1]		—	—	—	259	0.25	0.3	0.2	0.1	0.1	0.2
End	P6M5*[1]	Milling of planes and shoulders	—	—	—	185.5	0.45	0.3	0.2	0.1	0.1	0.33
Plain side mills and slitting saws	P6M5*[1]	Plain side milling of slots and sawing	—	—	—	200	0.25	0.3	0.2	0.2	0.1	0.2

*[1] Without cooling (without cutting fluids). *[2] with cooling.

Note. Speed of cutting for the face mills, calculated under the tabular data, is valid at the main angle in the plan φ = 60°. At other values of this angle it is necessary tabular value of cutting speed to multiply by factors: at φ = 15 ° on 1.6; at φ = 30° – on 1.25; at φ = 45° – on 1.1; at φ = 75° – on 0.93: at φ = 90 ° – on 0.87.

40. Average cutting tool life *T* of milling cutters

Kind of milling cutter	Cutting tool life *T*, minutes, at a mill diameter, mm										
	20	25	40	60	75	90	110 150	200	250	300	400
Face	—		120	180				240		300	400
Cylindrical with plug-in knifes and solid with large tooth	—					180		240			
Solid cylindrical with small tooth	—		120	180			—				
Disk	—				120 150 180				240	—	
End	80	90 120 180			—						
Plain side mills and slitting saws	—				60	75	120	150	—		
Shaped and angular	—		120			180	—				

Cutting force. The main component of cutting force in milling – peripheral (tangential) force P_z, N

$$P_z = \frac{10 C_p t^x s_z^y B^u z}{D^q n^w} \times K_{Mp} \qquad (3)$$

where *z* – quantity of mill teeth; *n* – frequency of mill rotation (rotational speed of the cutter), rpm.

Values of factor *of* C_p and power exponents are specified in tab. 41, correction factor on quality of processed material K_{Mp} for steels and cast irons – in tab. 9, and for copper and aluminum alloys – in tab. 10. Values of other components of cutting force (fig. 5, 6): horizontal (force of feed) P_h, vertical P_u, radial P_y, axial R_h are calculated taking into account ratio with the main component P_z (tab. 42).

Component of cutting force which is forced on a milling arbor $P_{yz} = \sqrt{P_y^2 + P_z^2}$.

Twisting moment, N·m, on a spindle $M = \frac{P_z \times D}{2 \times 100}$, where *D* – diameter of a mill, mm.

Cutting power (effective), kW: $N_e = P_z \times v / (1020 \cdot 60)$.

41. Values of factor C_p and power exponents in the formula of peripheral force P_z in milling

Milling cutter	Material of a cutting part of the tool	Factor C_p and power exponents					
		C_p	*x*	*y*	*u*	*q*	*w*
Milling of a carbon steel, σ_u = 750 MПa							
Face	CC	825	1.0	0.75	1.1	1.3	0.2
	HSS	82.5	0.95	0.8	1.1	1.1	0
Cylindrical	CC	101	0.88	0.75	1.0	0.87	0
	HSS	68.2	0.86	0.72	1.0	0.86	0
Disk and plain side mills, slitting saws	CC	261	0.9	0.8	1.1	1.1	0.1
	HSS	68.2	0.86	0.72	1.0	0.86	0
End	CC	12.5	0.85	0.75	1.0	0.73	-0.13
	HSS	68.2	0.86	0.72	1.0	0.86	0
Shaped and angular	HSS	47	0.86	0.72	0.1	0.86	0
Milling of a heat-resistance steel 12X18H9T with a delivery condition HB 141							
Face	CC	218	0.92	0.78	1.0	1.15	0
End	HSS	82	0.75	0.6	1.0	0.86	0
Milling of gray cast iron, HB 190							
Face	CC	54.5	0.9	0.74	1.0	1.0	0
	HSS	50	0.9	0.72	1.14	1.14	0
Cylindrical	CC	58	0.9	0.8	1.0	0.9	0
	HSS	30	0.83	0.65	1.0	0.83	0
Disk and plain side mills, slitting saws	HSS	30	0.83	0.65	1.0	0.83	0
Milling of malleable cast iron, HB 150							
Face	CC	491	1.0	0.75	1.1	1.3	0.2
	HSS	50	0.95	0.8	1.1	1.1	0
Cylindrical, disk, end and plain side mills, slitting saws	HSS	30	0.86	0.72	1.0	0.86	0
***Processing of heterogeneous copper alloys of average hardness, HB* 100 – 140**							
Cylindrical, disk, end and plain side mills, slitting saws	HSS	22,6	0.86	0.72	1.0	0.86	0

Notes: 1. The peripheral force P_z in milling of aluminum alloys is calculated as for a steel with introduction of factor 0.25.

2. The peripheral force P_z calculated under the tabular data corresponds to machining by a sharp mill (without wear-out). At wear-out of mill to permissible value ($h_{flank} \leq 0.75$ mm for rough cutting) the peripheral force P_z is increased: at processing of a soft steel (σ_u <600 MPa) in 1.75 – 1.9 times; in all other cases — in 1.2 – 1.4 times.

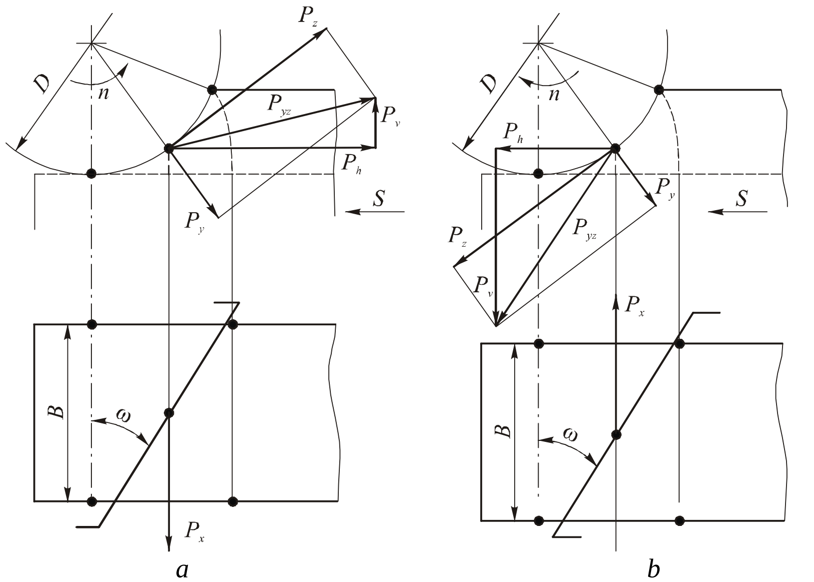


Fig. 5. Components of cutting force in milling by a cylindrical mill: *a* – in up milling (conventional milling) (cutting speed *v* is directed against the feed *s*); *b* – in down milling (climb milling) (cutting speed *v* is directed as the feed *s*)

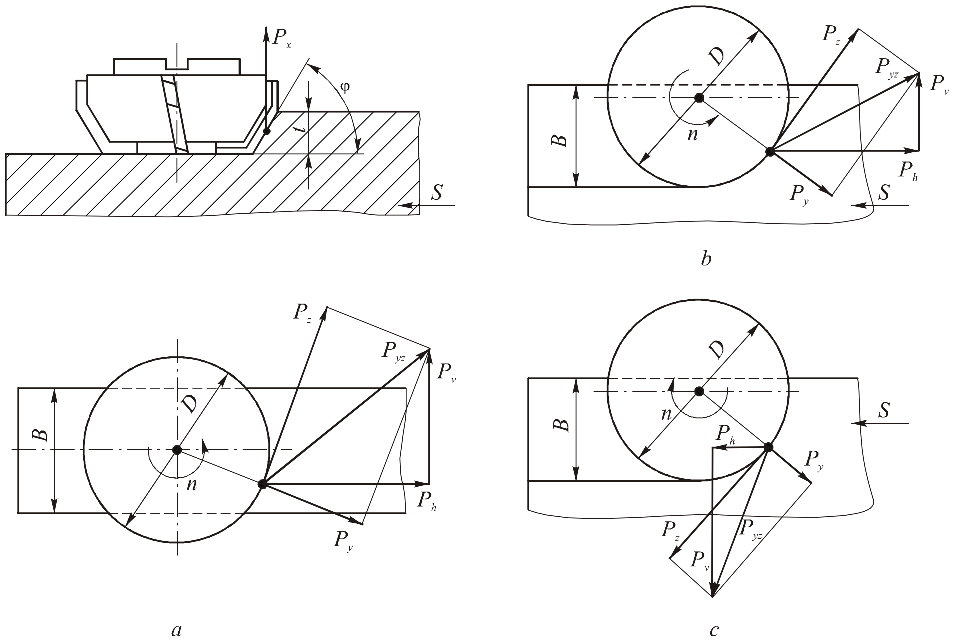


Fig. 6. Components of cutting force in face milling: *a* – in symmetrical milling; *b* – in asymmetrical up milling; *c* – in asymmetrical down milling

42. Relative values of cutting force components in milling

Scheme of milling	P_h/P_z	P_v/P_z	P_y/P_z	P_x/P_z
Cylindrical, disk, end[1], *angular and shaped mills* (fig. 5)				
Up milling (against feed)	1.1 – 1.2	0 – 0.25	0.4 – 0.6	(0.2 – 0.4) ·tg ω
Down milling (in a giving direction)	0.8 – 0.9	0.7 – 0.9	0.4 – 0.6	(0.2 – 0.4) ·tg ω
Face and end[2] *mills* (fig. 6)				
Symmetrical milling	0.3 – 0.4	0.85 – 0.95	0.3 – 0.4	0.5 – 0.55
Asymmetrical up milling	0.6 – 0.8	0.6 – 0.7	0.3 – 0.4	0.5 – 0.55
Asymmetrical down milling	0.2 – 0.3	0.9 – 1.0	0.3 – 0.4	0.5 – 0.55

*[1] Mills working under the scheme of cylindrical milling when face teeth do not participate in cutting.

*[2] Mills working under the scheme of face milling.

Note: Changing of making cutting forces P_y and P_x at face milling depending on the main angle in the plan φ see in tab. 23.

CUTTING-OFF

Stock cutoff machine operation

Cutting-off is produced by cut-off cutters, disk and tape saws, band saws, abrasive wheels.

Feed. For disk saws feed s_z , and for tape saws and abrasive wheels feed s_m are specified in tab. 43.

Cutting speed. For disk saws, mechanical band saws and tape saws cutting speed is fixed (rated) in m/minute, and for abrasive wheels – in m/s (tab. 44).