6 Cutting materials

(For further progress in cutting material development see Appendix)

Cutting tools are subjected to enormous strain. Their cutting characteristics depend on the cutting material selected. Due to the interaction between the material to be removed and the cutting material, the following materials are used depending on type of the metal removal procedure, cutting method, desired tool life, required temperature resistance etc.

6.1 Unalloyed tool steels

Since these steels have low heat resistance, which, in turn, results in low cutting speeds, they are only of minor importance in practice. The most essential data for unalloyed tool steels are given below.

Steel type:	Carbon steel
C content in %:	0.6 – 1.5
Heat resistance in °C:	Up to 300
Operating hardness in HRC:	62 – 66
Allowable cutting speed in m/min:	5 – 10

Table 6.1 Unalloyed tool steels

Denomination		Application
Material number	According to DIN	
1.1540	C 100 W 1	Thread cutting tools
1.1550	C 110 W 1	Twist drills, broaches
1.1560	C 125 W 1	Mills
1.1750	C 75 W 3	Saw-blade bodies for circular saws, collets

6.2 High speed steels

Thanks to alloying elements which form carbide, such as chromium, molybdenum, tungsten, vanadium, these have higher hot hardness, substantially better wear resistance and high retention of hardness. Consequently, high speed steels are much more efficient than tool steels.

It is possible to improve the performance of high speed steels by depositing hard chromium, or by nitriding or carburising. When depositing hard chromium, a thin (0.05 to 0.3 mm) but very hard chromium layer is deposited on the tool using electrolytes. By introducing nitrogen (nitrogenium), it is possible to greatly increase hardness in the marginal zone and to enhance wear resistance.

Carburising is the heat treatment (550 °C) of high speed steels in tanks containing cyanide.

Technical data for high speed steels:

Steel type:	Highly alloyed carbon steel				
C content in %:	0.6 – 1.6				
Most significant alloying elements m %:	Co	Cr	Mo	V	W
	2 – 16	4	0.7 – 10	1.4 – 5	1.2 – 19
Heat resistant in °C:	Up to 600				
Operating hardness in HRC:	62 – 65				
Allowable cutting speed for steel in m/min:	30 – 40				

Table 6.2 Denomination of high speed steels

Material - No.	Denomination	Explanation
3202	HS 12-1-4-5	
3207	HS 10-4-3-10	HS = high speed steel The numerals indicate the corresponding percentage of the alloying elements (W, Mo, V, Co). For example HS 12 – 1 – 4 – 5 5 % Co 4 % V 1% Mo 12 %W
3243	HS 6-5-2-5	
3255	HS 18-1-2-5	
3257	HS 18-1-2-15	
3265	HS 18-1-2-10	
3302	HS 12-1-4	
3316	HS 9-1-2	
3318	HS 12-1-2	
3343	HS 6-5-2	
3346	HS 2-9-1	

Table 6.3 High speed steels - ranges of application (data in material numbers without initial number 1.) [10 p.269]

Type of tool	Machining of		
	Light metal	Chilled cast iron, cast iron	Steel
Turning- and planing tools	3302	3202, 3207	3207, 3255, 3265
Cutter bits	3302	3302, 3202, 3207	3202, 3207 3255, 3257
Profile turning tools, gear-shaper cutters	3318	3302, 3343	3207, 3243 3255, 3302
High-quality twist drills with reinforced core	–	3302	3357, 3255
Twist drills (standard)	3318	3318, 3343 3346	3343, 3346
Thread taps	3316	3318, 3357	3318, 3343
Milling cutters, gear cutters	3302, 3318	3302, 3343	3255, 3302 3343
Saw-blade bodies for circular- and hacksaws	3318	3318, 3343	3318, 3343
Reamers	3318, 3302	3302	3318, 3302

6.3 Cemented carbides

Cemented carbides developed out of the so-called stellites (molten alloys of tungsten, chromium and cobalt). The basic substances in carbide-forming materials are oxides of tungsten, titanium and tantalate. A powder mixture of tungsten carbide (WC) or titanium carbide (TiC) and cobalt is first pressed into moldings and then sintered afterwards at 1300 to 1600 °C. In current practice, only sintered cemented carbides (cemented carbides, German abbbrev. HM, for short) are used.

Denomination of cemented carbides

Cemented carbides are identified by letters, colours and numbers.
The letters P, M and K specify the materials' major machining groups. They indicate what material or type of material is cut by P, M or K. The letters are also assigned specific identification colours.

- P – blue for long-chip materials
- M – yellow for multi-purpose materials
- K – red for short-chip materials.

Table 6.4 Major machining groups and major application groups for cemented carbides

Range of application (materials)	Cutting techniques, cutting conditions	Name	Typical properties
Long-chip materials for instance steel, cast steel long-chip malleable cast iron	Finishing methods *v* high, *s* low, as much as possible without vibrations	P 01	Wear resistance Toughness
		P 05	
	Turning, milling v_c high, *f* medium to low	P 10	
	Turning, milling v_c medium, *f* medium planing **s** low	P 20	
		25	
	Turning, planing, milling v_c medium to low, *f* medium to high	P 30	
	Turning, planing, slotting, milling machining on automata	P 40	
Multi-purpose-, long- and short-chip materials, steel, GS, austenitic manganese steel, alloyed cast iron, austenitic steels, free-machining steels	Turning v_c medium to high, *f* medium to low	M 10	↑ Wear resistance Toughness ↓
	Turning, milling v_c medium, *f* medium	M 20	
	Turning, planing, milling, v_c medium, *f* medium to high	M 30	
	Turning, form turning, cutting off – particularly on automata	M 40	
Short-chip materials grey cast iron, chilled cast iron, short-chip steel hardened, non-ferrous metals, plastics	Finishing	K 01	Wear resistance Toughness
		K 05	
	Turning, drilling, countersinking, reaming, milling, broaching, scraping	K 10	
	As K 10, stringent requirements in terms of cemented carbide's toughness	K 20	
	Turning, planing, slotting, milling, inadequate cutting conditions	K 30	
	As K 30, high rake angles, inadequate cutting conditions	K 40	

The numbers after the letters are an indicator of the wear characteristics and the toughness of the corresponding cemented carbide. These values constrain the application of individual types of cemented carbide. The higher the number is, the greater the toughness and the lower the wear resistance. The lower the number is, the higher the wear resistance, but the lower the toughness. The parameters are 01, 10, 20, 30, 40, 50.

Accordingly, the cemented carbide P10 is highly wear resistant, but very brittle. Consequently, it should never be used for planing, in which the cutting edge is subjected to sudden stress at each beginning of the cut. Under these circumstances, tool life would be shortened not by wear, but by early chipping of the cutting edge. However, this cemented carbide would be suitable to machine high-strength steels at high cutting speeds.

The parameters of cemented carbides

composition in %:	WC	TiC + TaC	Co
	30 – 92	1 – 60	5 – 17
Heat resistance in °C:	1000		
Operating hardness in HV 30:	1300 – 1800		
Allowable cutting speeds for steel in m/min:	on average 80 – 300		

Table 6.4 on page 36 outlines the denomination and the ranges of application for cemented carbide tools.

6.4 Ceramics

The main component of ceramic materials is aluminum oxide (Al_2O_3). We distinguish between two groups of sintered oxides: The pure aluminum oxides (Al_2O_3) with low alloyed contents of other metal oxides and those sintered oxides that contain not only Al_2O_3, but also greater amounts (40 to 60%) of metal carbides.

Ceramic tools are very hard and wear resistant. However, they are very brittle and sensitive to fracture.

Due to their great wear resistance, ceramic tools can withstand extremely high cutting speeds. Consequently, they are preferred to generate workpieces of high surface qualities in finishing and fine finishing.

However, their low toughness limits their range of applications. Ceramic tools are consequently used for turning, machining short-chip materials, such as grey cast iron, and cutting higher strength steels ($\sigma_B > 600$ N/mm^2).

The parameters of ceramic

Composition in %:

Al_2O_3	Mo_2C	WC
97	–	–
40	–	60
60	40	–

Heat resistance in °C:	1800 (but very sensitive to thermal stress)	
Operating hardness (hardness according to Vickers in kN/mm^2):		12 – 20 (30)
Allowable cutting speeds for steel and grey cast iron in m/min	100 – 300	roughing
	200 – 1000	finishing

6.5 Diamond tools

The hardest and densest of all materials known, diamond consists of pure carbon. Due to its great hardness, diamond is very brittle and thus very sensitive to impact and heat. These characteristics make it suitable for use in diamond tools. These are predominantly used for finishing- and superfinishing tools. With diamonds, surface roughness values to 0.1 mm can be achieved. Diamonds allow cutting speeds up to 3000 m/min, while the standard range of operation is from 100 to 500 m/min.

Diamonds are used primarily to machine the following carbon-free materials following:

Light metals:	aluminum and aluminum alloys
Heavy metals:	copper- and copper alloys, cathode copper, brass, bronze, argentan
Precious metals:	platinum, gold, silver
Plastics:	
Duroplastics:	glass fibre reinforced plastics, laminated paper, bakelites etc.
Thermoplastics:	plexiglass, vulcanised fibre, teflon etc.
Natural materials:	hard rubber, soft rubber.

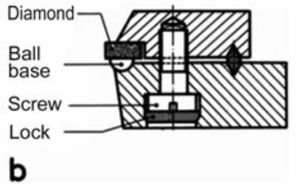
Diamond tools have cutting edges with defined geometry.

The most significant cutting edge forms of compact diamonds are shown in Figure 6.2. The bevelling cutting edge is the cutting edge that is most frequently in use.

In addition to compact industrial diamonds clamped in specific holders, as shown in Figure 6.1, so-called polycrystalline cutting bodies have also recently begun to be used. For polycrystalline cutting bodies, many very small diamonds are crystallized under high pressure and at high temperatures in the cutting edge area of a cemented carbide tool body. The cutting tips manufactured in this way can be soldered on or clamped.

Some polycrystalline cutting tips used for cutting outer geometries are illustrated in Figure 6.3. The cutting tips can have the following angular values

Tool orthogonal clearance:	0°; + 6°; + 12°
Rake angle:	– 6°; 0°; + 6°



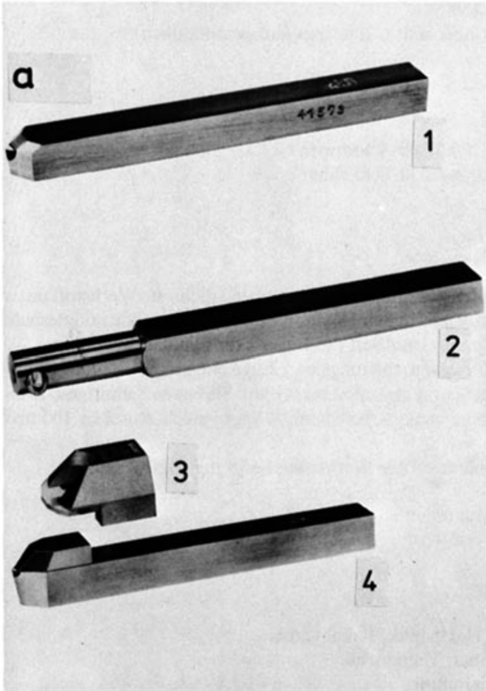


Figure 6.1a
Holders for diamond turning tools
1 for low tip heights,
2 holder for diamond drills,
3 sighting device by Winter, to align the bevelling cutting edges
4 holder with reinforced head (*photo by Winter & Sohn, Hamburg*)

Figure 6.1b
Holder with ball-based fit (*according to Winter & Sohn*)

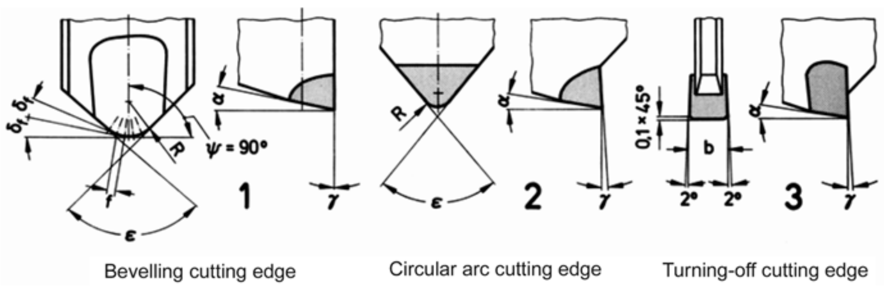


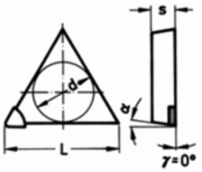
Figure 6.2
The most essential cutting edge forms of diamond turning tools
1 bevelling cutting edge, 2 circular arc cutting edge, 3 turning-off cutting edge
(*photo by E. Winter & Sohn, Hamburg*)

Cutting tips

Tool orthogonal clearance ∢ α: 12° or 0° — Rake angle γ: 0°

Spec. name	S	D	L
a	3,18	6,35	11,0
b	3,18	9,52	16,5
c	3,18	12,7	22,0
d*	4,76	9,52	16,5
e*	4,76	12,7	22,0

* only for wedge ∢ 90° (holder with negative rake angle)

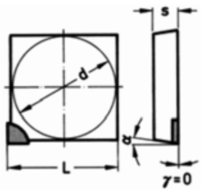


Cutting tips

Tool orthogonal clearance: 12° or 0° — Rake angle: 0°

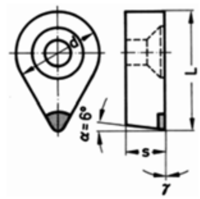
Spec. name	s	D	L
A	3,18	12,7	12,7
B*	4,76	12,7	12,7
C	3,18	15,88	15,88
D*	4,76	15,88	15,88
E*	3,18	19,05	19,05
F*	4,76	19,05	19,05

* only for wedge ∢ 90° (holder with negative rake angle)



Cutting tips, exchangeable
To be swivelled to max. 180°

Rake angle ∢ γ: + 6° or 0° or – 6°

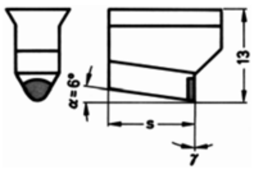


Spec. name.	s	d	L	Fitted to holder Cat.-No.
a	5	10	14,5	185a
b	6	12	17	185b
c	8	16	23	185c
d	10	20	28	185d

Ex. for ordering: Cat.-no. 85–b

Dovetail cutter inserts

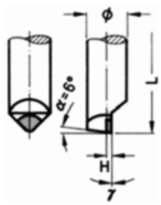
Rake angle: + 6° or 0° or – 6°



Specif. name.	S	Fitted to holder Cat.-No.
a	9	184a
b	12	184b
c	14	184c

Circular cutter inserts

Rake angle: + 6° or 0° or – 6°



Specif. name	○	L	H above centre
a	6	According to specifications	0,5
b	8		0,5
c	10		0,5
d	12		0,5

Figure 6.3
Diamond cutting tips and associated angles (*photo by E. Winter & Sohn, Hamburg*)