Tool Geometry

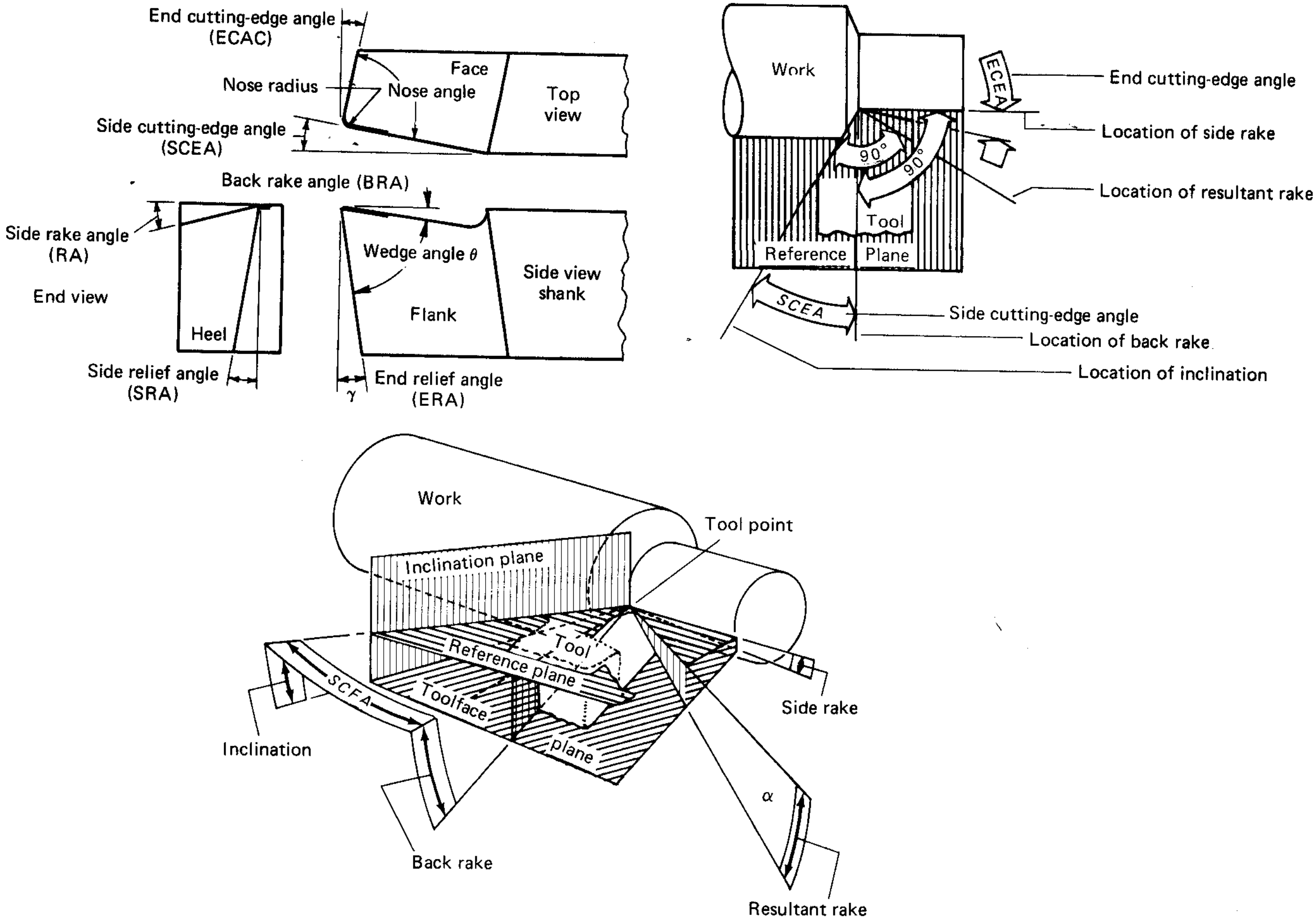
For cutting tools, geometry depends mainly on the properties of the tool material and the work material. The standard terminology is shown in Figure 22-11 for single-point tools. The most important angles are the rake angles and the end and side relief angles.

The *back rake angle* affects the ability of the tool to shear the work material and form the chip. It can be positive or negative. Positive rake angles reduce the cutting forces resulting in smaller deflections of the workpiece, toolholder, and machine.

If the back rake angle is too large, the strength of the tool is reduced as well as its capacity to conduct heat. In machining hard work materials, the back rake angle must be small, even negative for carbide and diamond tools. The higher the hardness, the smaller the back rake angle. For high-speed steels, back rake angle is normally chosen in the positive range, depending on the type of tool (turning, planing, end milling, face milling, drilling, and so on), and the work material.

For carbide tools, inserts for different work materials and toolholders can be supplied with several standard values of back rake angle: −6 degrees to + 6 degrees. The side rake angle and the back rake angle combine to form the effective rake angle. See Figure 22-11. This is also called the true rake angle or resultant rake angle of the tool.

True rake inclination of a cutting tool has a major effect in determining the amount of chip compression and the shear angle. A small rake angle causes high compression, tool forces, and friction, resulting in a thick, highly deformed, hot chip. Increased rake angle reduces the compression, the forces, and the friction, yielding a thinner, less-deformed and cooler chip. Unfortunately,



Back and side rake angles combine to produce a resultant or effective rake for cutting. Inclination is the angle between the cutting edge and its projection on the reference plane. All angles are positive.

FIGURE 22-11 Standard terminology to describe the geometry of single-point tools.

it is difficult to take advantage of these desirable effects of larger positive rake angles, since they are offset by the reduced strength of the cutting tool, due to the reduced tool section, and by its greatly reduced capacity to conduct heat away from the cutting edge.

In order to provide greater strength at the cutting edge and better heat conductivity, zero or negative rake angles commonly are employed on carbide, ceramic, polydiamond, and CBN cutting tools. These materials tend to be brittle, but their ability to hold their superior hardness at high temperatures results in their selection for high-speed and continuous machining operations. The negative rake angle increases tool forces, but this is necessary to provide the added support to the cutting edge. This is particularly important in making intermittent cuts and in absorbing the impact during the initial engagement of the tool and work.

In general, the power consumption is reduced by approximately 1% for each 1 degree in α. γ is the end relief angle. The wedge angle θ determines the strength of the tool and its capacity to conduct heat and depends on the values of α and γ.

The relief angles mainly affect the tool life and the surface quality of the workpiece. To reduce the deflections of the tool and the workpiece and to provide good surface quality, larger relief values are required. For high-speed steel, relief angles in the range of 5–10 degrees are normal, with smaller values being for the harder work materials. For carbides, the relief angles are lower to give added strength to the tool.

The side and end cutting-edge angles define the nose angle and characterize the tool design. The nose radius has a major influence on surface finish. Increasing the nose radius usually decreases tool wear and improves surface finish.

Tool nomenclature varies with different cutting tools, manufacturers, and users. Many terms are still not standard because of all this variety. The most common tool terms will be used in later chapters to describe specific cutting tools.

The introduction of coated tools has spurred the development of improved tool geometries. Specifically, *low-force groove* (LFG) geometries have been developed which reduce the total energy consumed and break up the chips into shorter segments (see Figure 22-5). The effect of these grooves is effectively to increase the rake angle, which increases the shear angle and lowers the cutting force and power. This means that higher cutting speeds or lower cutting temperatures (and better tool lives) are possible.

As a chip breaker, the groove deflects the chip at a sharp angle and causes it to break into short pieces that are easier to remove and are not so likely to become tangled in the machine and possibly cause damage to personnel. This is particularly important on high-speed, mass-production machines.

The shapes of cutting tools as used for various operations and materials are compromises, resulting from experience and research so as to provide good overall performance. Table 22.5 gives representative rake angles and suggested cutting speeds.

TABLE 22.5 Representative Machining Conditions for Various Work and Tool–Material Combinations

Work Material	Tool	Rake Angles (degrees)		Cutting Speed	
		Back	Side	m/min	fpm
B1112 steel	HSS	16	22	69	225
	WC	0	3	168	550
	Ceramic	− 5	− 5	427	1400
4140 steel	HSS	12	14	40	130
	WC	0	3	91	300
	Ceramic	− 5	− 5	274	900
8620 steel	HSS		uncoated		100
	WC		uncoated		400
	WC		coated with TiC		600
	WC		coated with AL_2O_3		1100
	WC, AL_2O_3 with LFG				1300
18–8 steel (stainless)	HSS	8	14	27	90
	WC	4	8	84	275
	Ceramic	− 5	− 5	152	500
Gray cast iron (medium)	HSS	5	12	34	110
	WC	0–4	2–4	69	225
	Ceramic	− 5	− 5	244	800
Brass (free-machining)	HSS	0	0	76	250
	WC	0	4	221	725
Aluminum alloys	HSS	35	15	91	300 plus
	WC	10–20	10–20	122	400 plus
Magnesium alloys	HSS	0	10	91	300 plus
	WC	10	10	213	700 plus
Titanium (turning)	WC	0	5	46	150

Table Valve Typical for
Lathe turning operation
Single-point tool

Feed: 0.38 mm/rev (0.015 ipr)
Depth: 3.18 mm (0.125 in.)