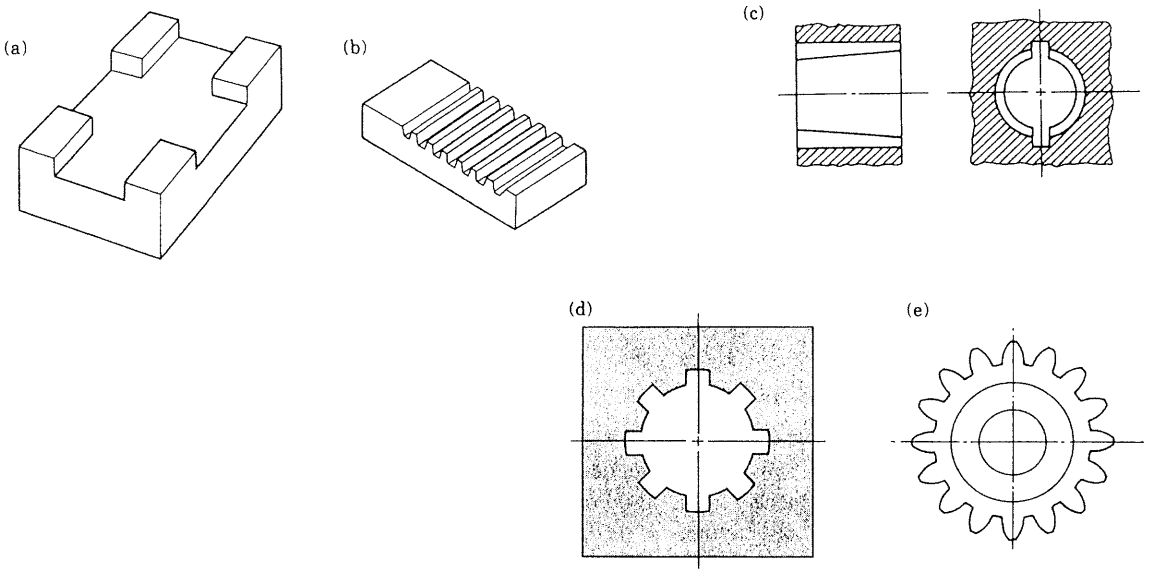
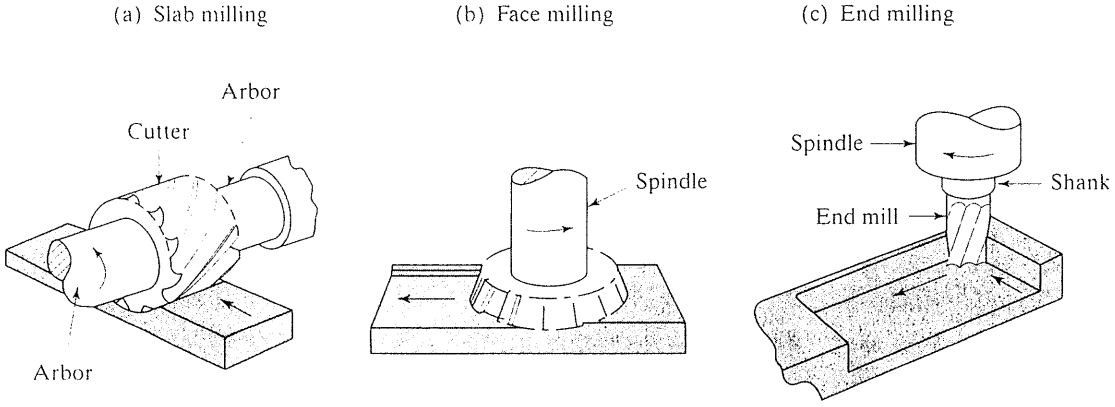


FIGURE 23.1 Typical parts and shapes produced with the machining processes described in this chapter.

23.2 MILLING OPERATIONS

Milling includes a number of highly versatile machining operations capable of producing a variety of configurations (Fig. 23.2) with the use of a **milling cutter**, a multitooth tool that produces a number of chips in one revolution. Parts such as the one shown in Fig. 23.3 can be machined efficiently with various types of milling cutters.

FIGURE 23.2 Some of the basic types of milling cutters and milling operations.



Basic types of milling cutters and operations Figure 23.2 (page 718)

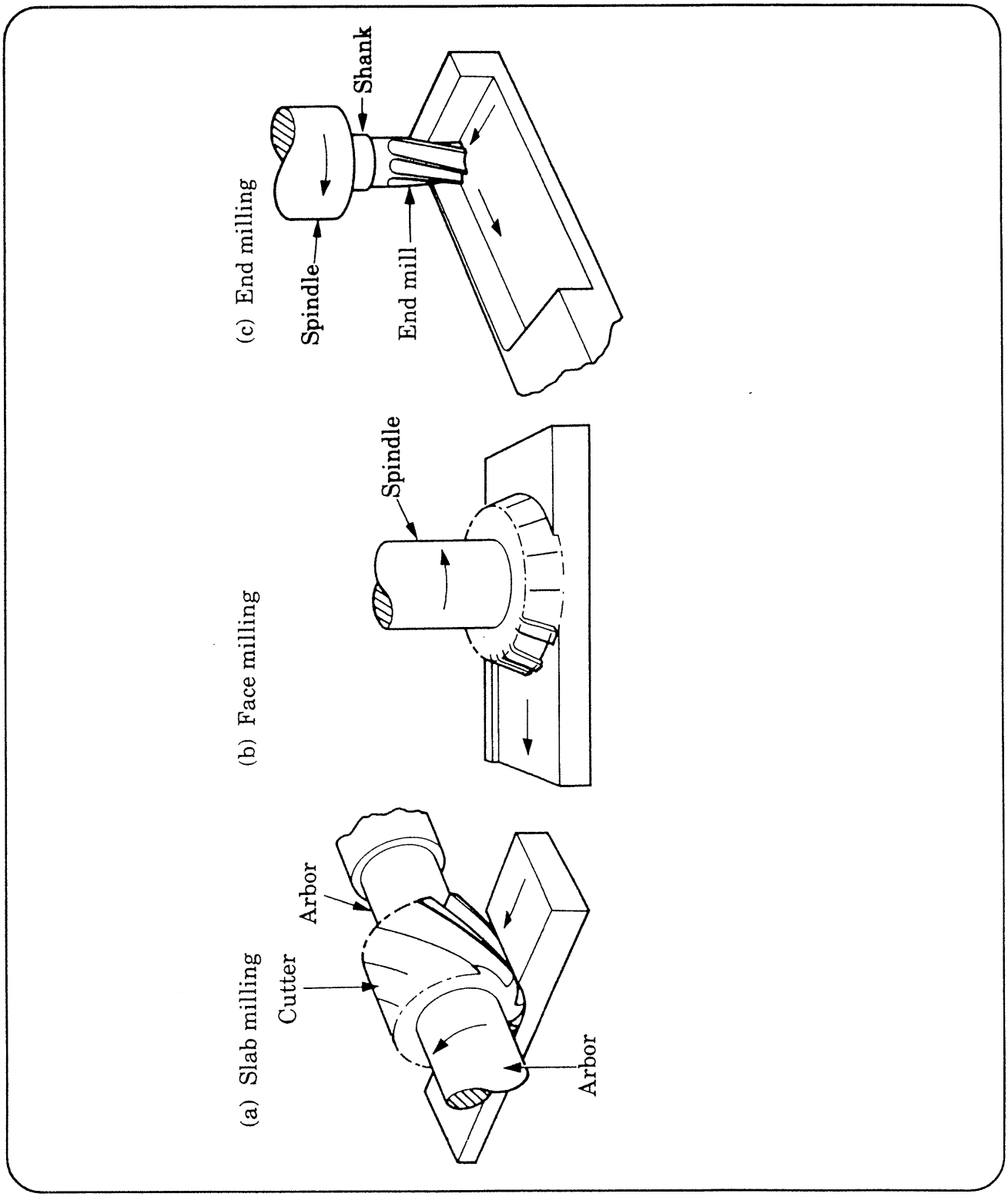
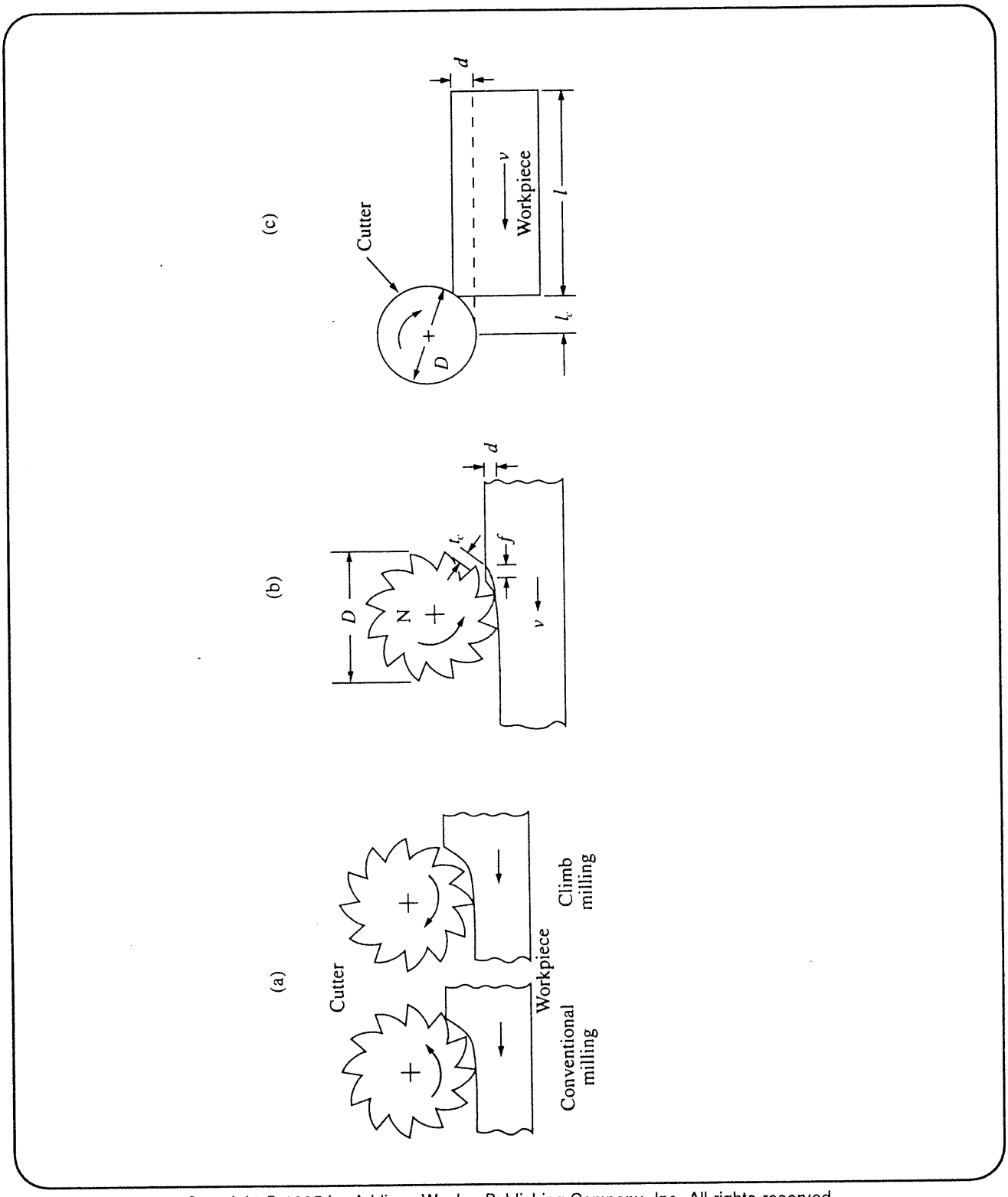


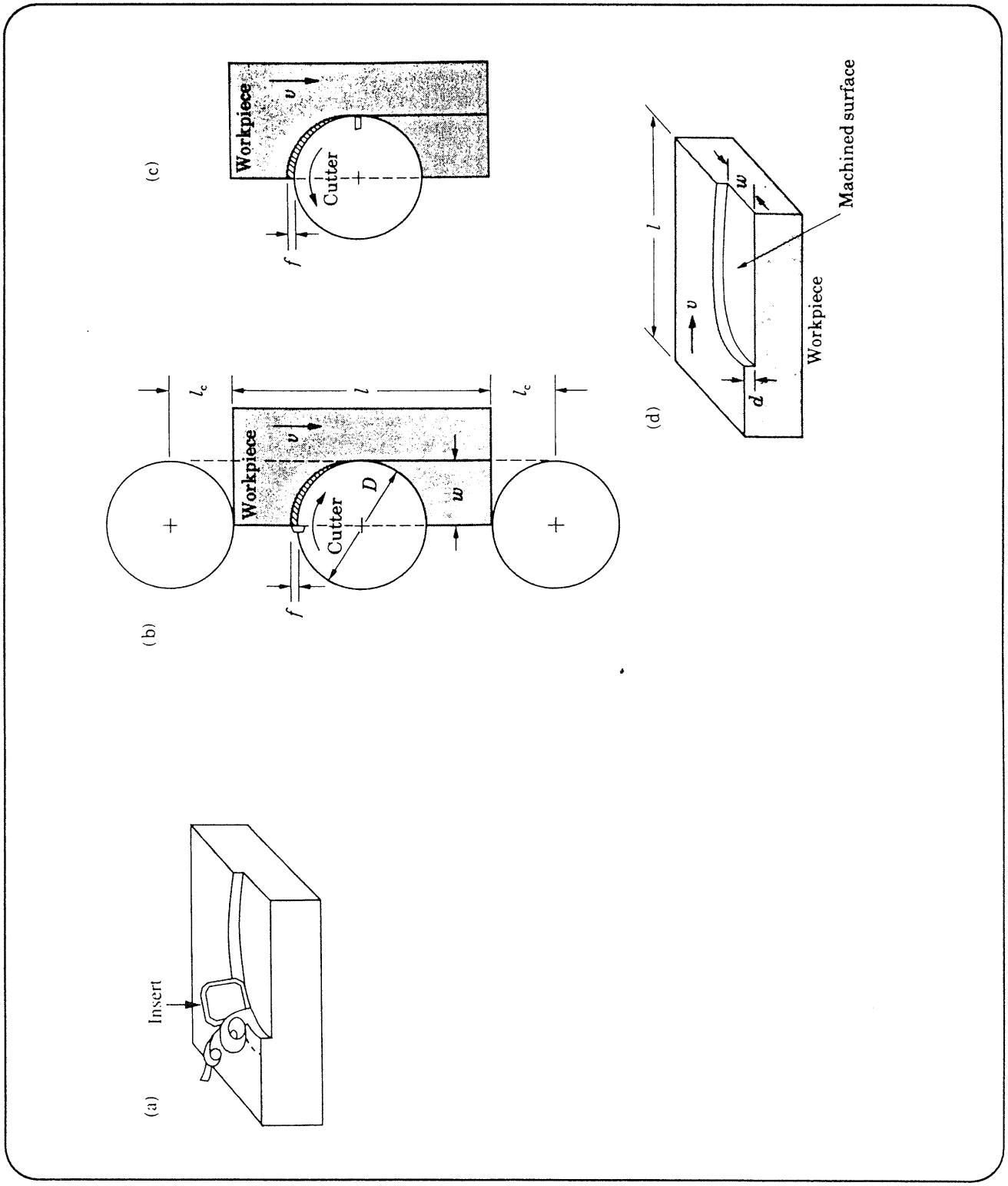
Figure 23.4 (page 719) (a) Schematic illustration of conventional milling and climb milling. (b) Slab milling operation. (c) Schematic illustration of cutter travel distance l_c to reach full depth of cut.



Master 92

Face-milling operation showing (a) action of an insert in face milling; (b) climb milling; (c) conventional milling; (d) dimensions in face milling.

Figure 23.5 (page 722)



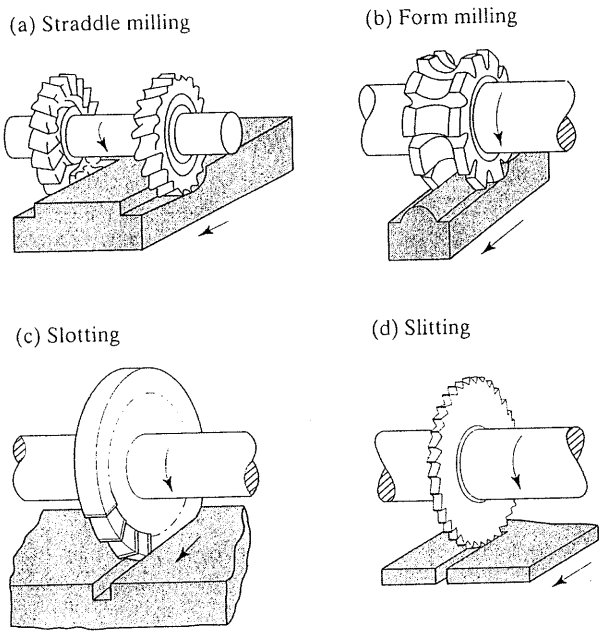


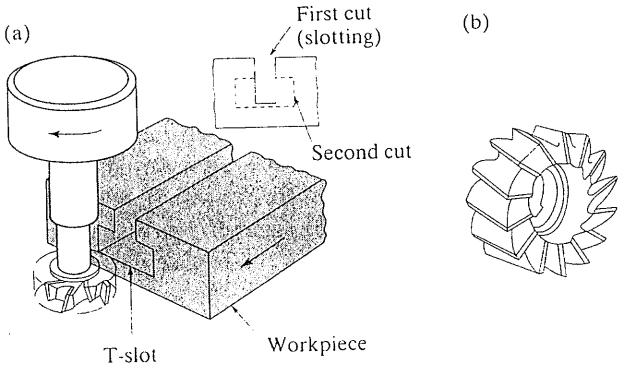
FIGURE 23.11 Cutters for (a) straddle milling, (b) form milling, (c) slotting, and (d) slitting with a milling cutter.

23.2.4 Other Milling Operations and Milling Cutters

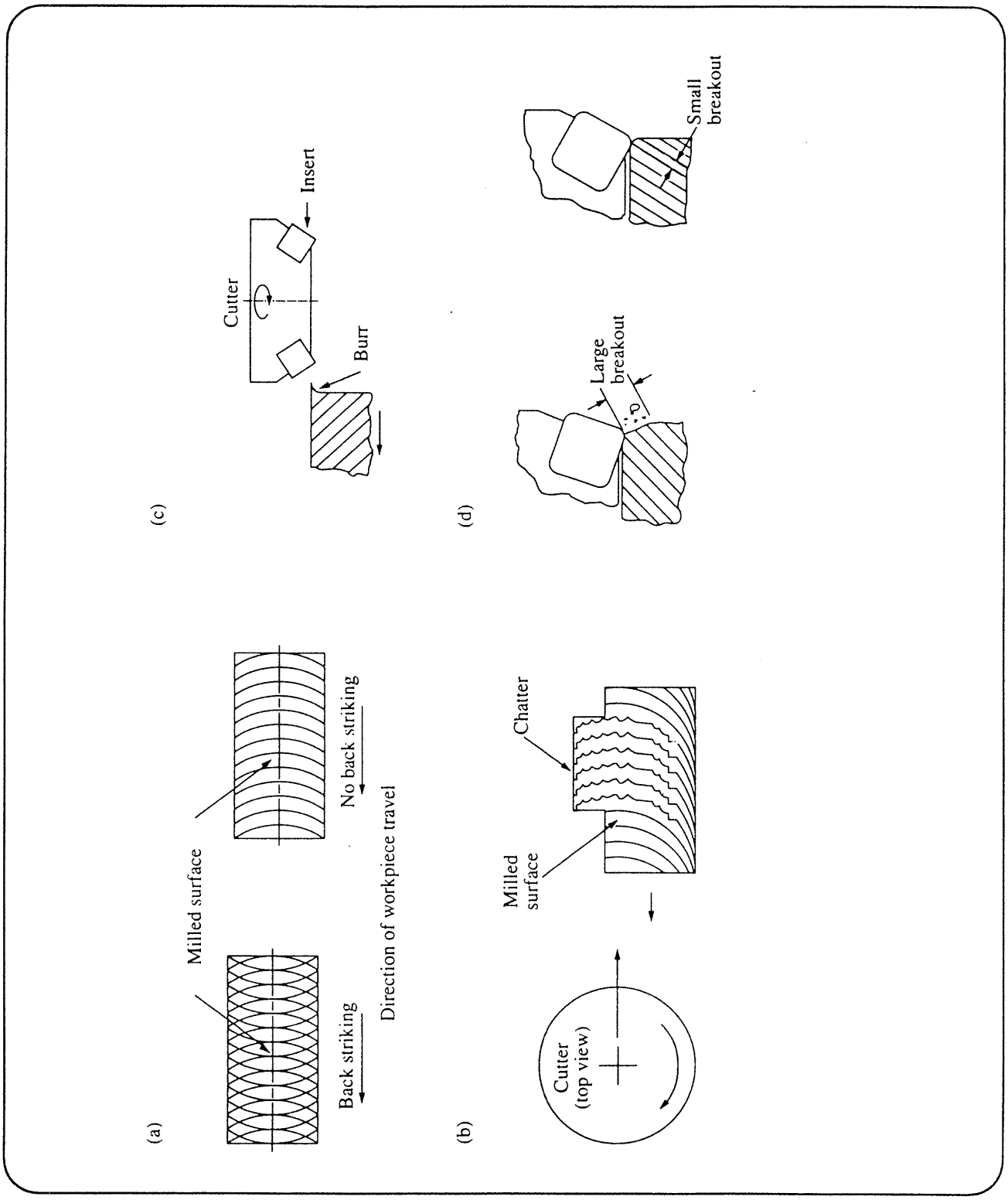
Several other milling operations and cutters are used to machine various surfaces. In **straddle milling**, two or more cutters are mounted on an arbor and are used to machine two parallel surfaces on the workpiece (Fig. 23.11a). **Form milling**, which produces curved profiles, uses cutters that have specially shaped teeth (Fig. 23.11b); such cutters are also used for cutting gear teeth (Section 23.8.1).

Circular cutters for slotting and slitting are shown in Figs. 23.11c and d, respectively. The teeth may be staggered slightly, like those in a saw blade (Section 23.6), to provide clearance for the cutter when making deep slots. *Slitting saws* are relatively thin, usually less than 5 mm $\left(\frac{3}{16}\text{ in.}\right)$. *T-slot cutters* are used to mill T-slots (Fig. 23.12a), such as those found in machine-tool work tables for clamping workpieces. A slot is first milled with an end mill. The cutter then cuts the complete profile of the slot in one pass.

FIGURE 23.12 (a) T-slot cutting with a milling cutter. (b) A shell mill.



Surface features and corner defects in face milling operations **Figure 23.16 (page 732)**



Master 98

Terminology for a pull-type internal broach used for enlarging long holes

Figure 23.26 (page 740)

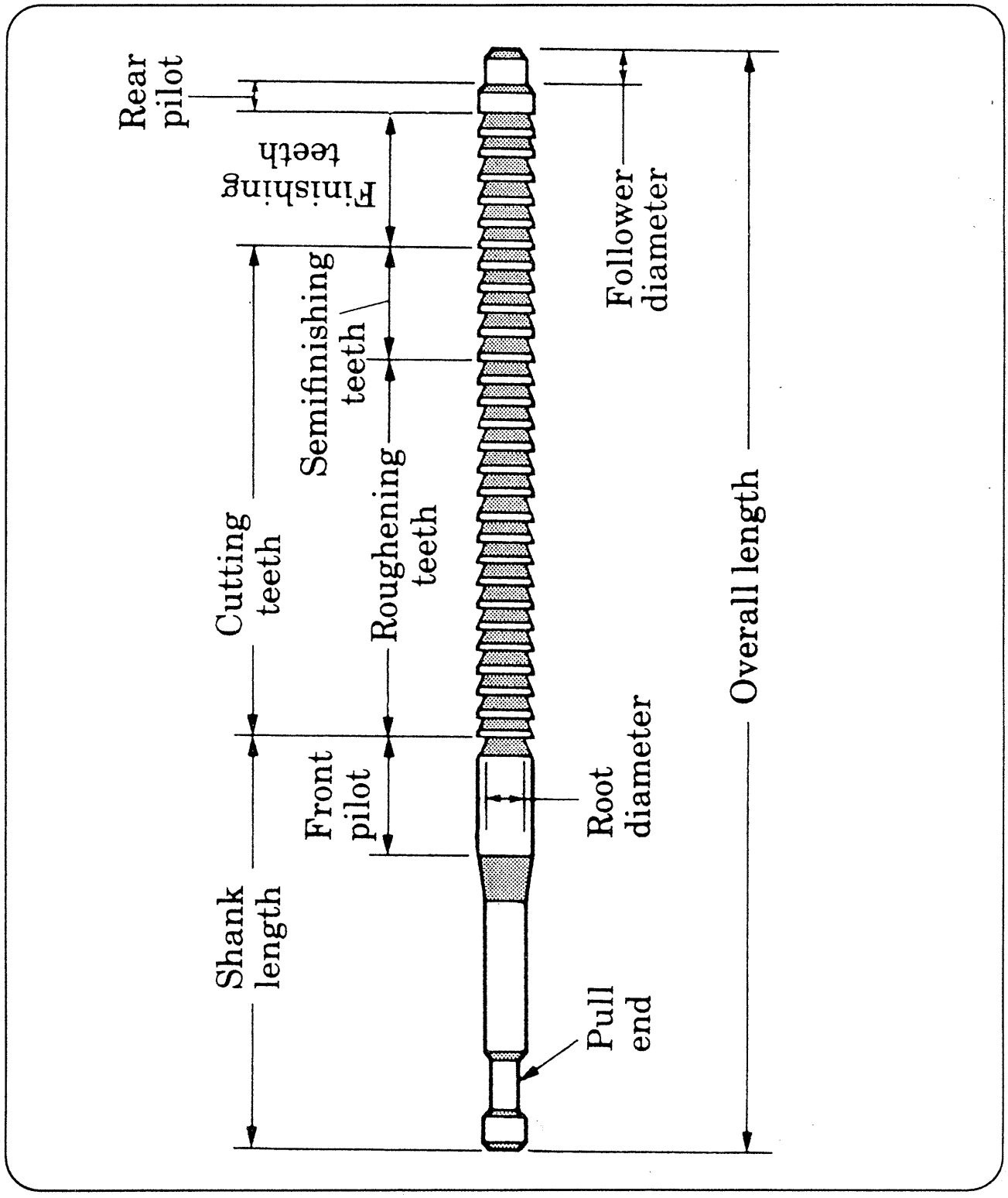
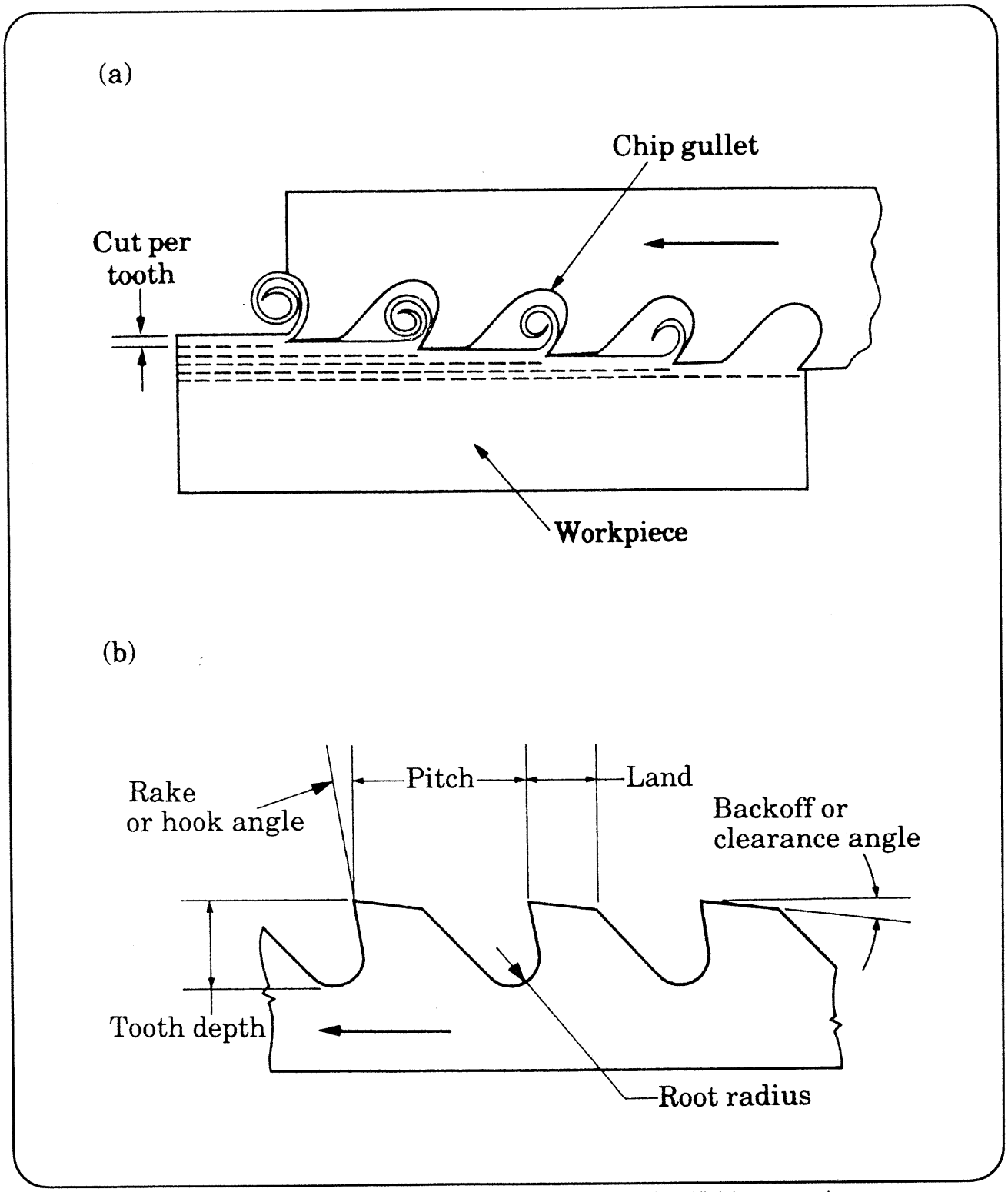


Figure 23.24 (page 739) (a) Cutting action of a broach, showing various features (b) Terminology for a broach



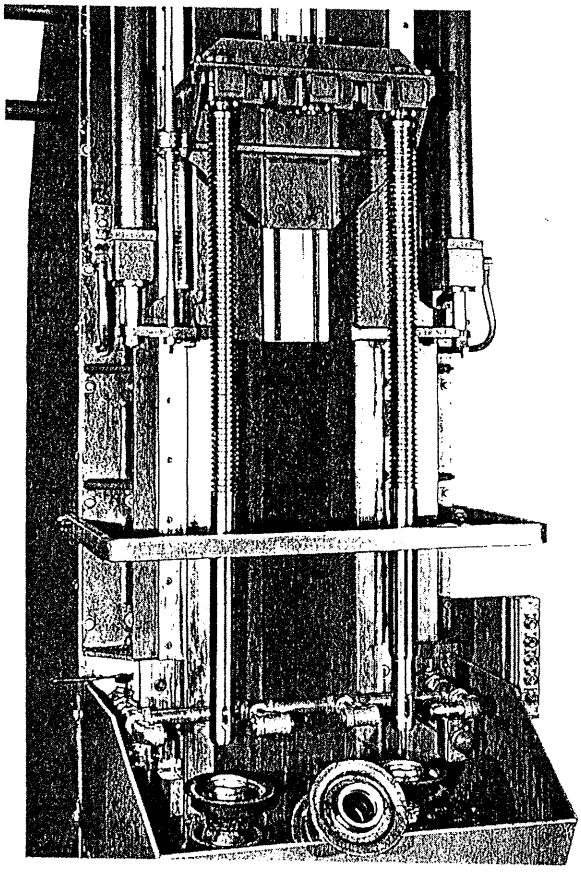


FIGURE 26-1 Vertical pull-down broaching machine shown with parts in position ready for the two broaches to be inserted. An extra part is shown lying at the front of the machine.

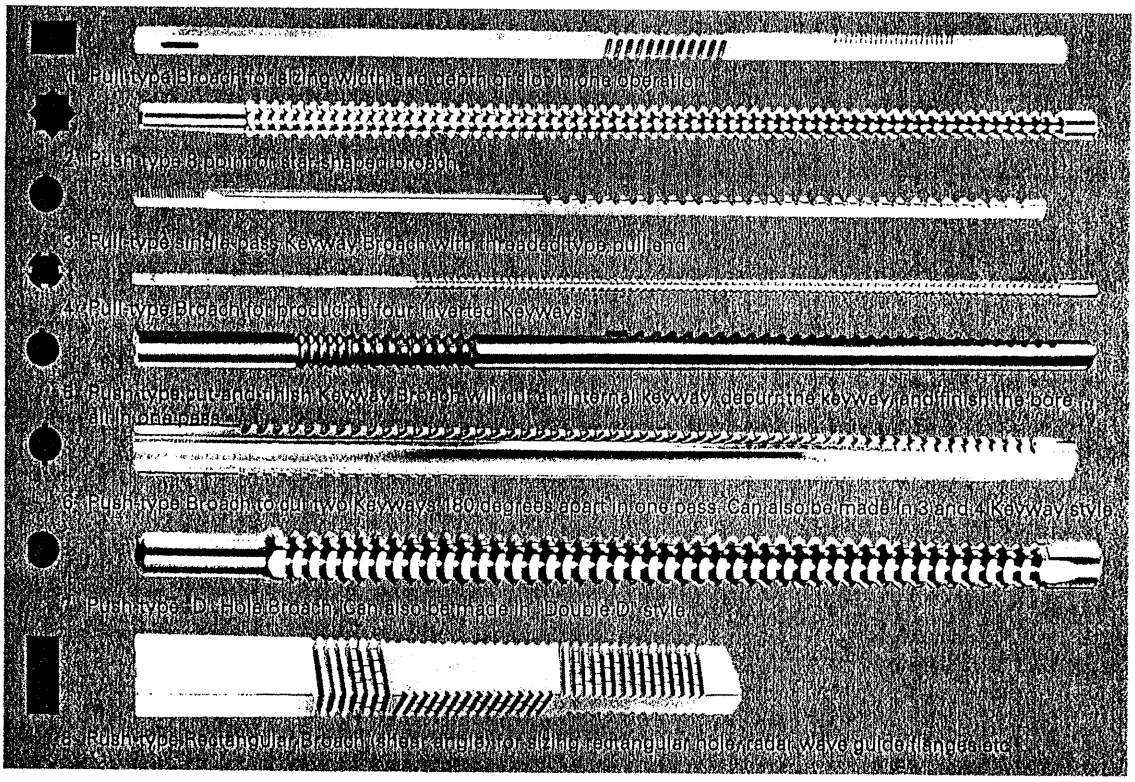
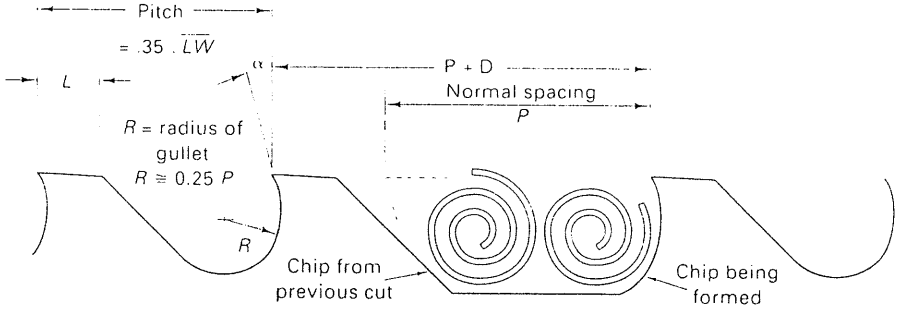


FIGURE 26-8 Examples of push-and-pull-type broaches. *(Courtesy of DuMont Corp.)*



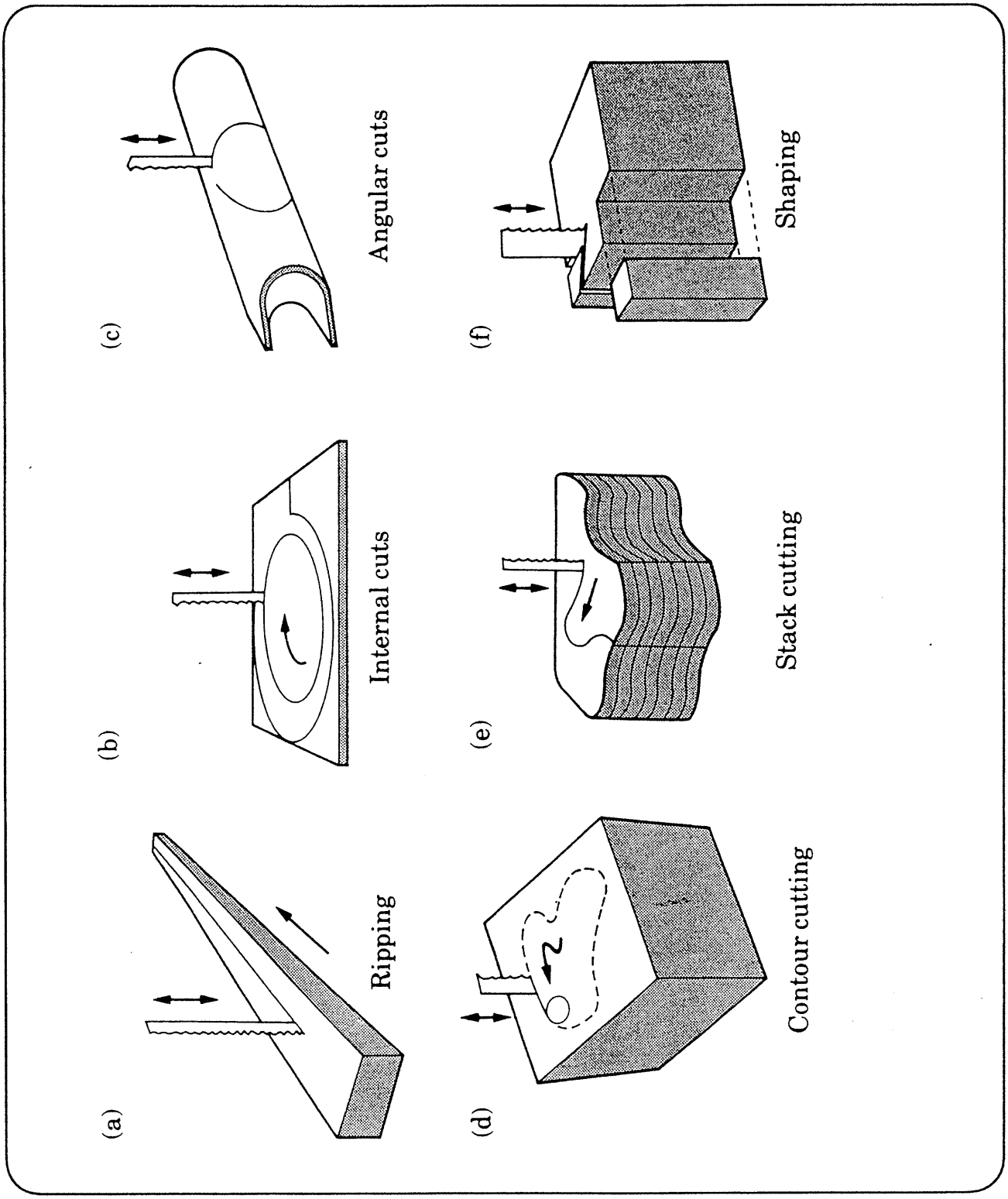
Extra-wide spacing may be used when chip disposal is a problem.
Chip adhering to broach tooth will be displaced by the next chip formed.

FIGURE 26-9 The gullet area provides room for the chips.

Summary of Troubleshooting Guide for Milling

Symptom	Improper Tool Material	Improper Cutting Parameters	Improper Tool Angles	Improper Cutting Fluid	Vibration & Chatter	Dull / Worn Tool	Poor system stiffness	Incorrect cutting geometry
Tool Breakage	X	X	X					
Excessive Tool Wear	X	X	X	X				
Rough finish		X			X	X		
Tolerances too broad						X	X	
Burnishes surface		X	X			X		
Back Striking			X			X		
Chatter Marks		X					X	
Burrs		X	X			X		X
Breakout		X						X

Figure 23.29 (page 743) Examples of sawing operations



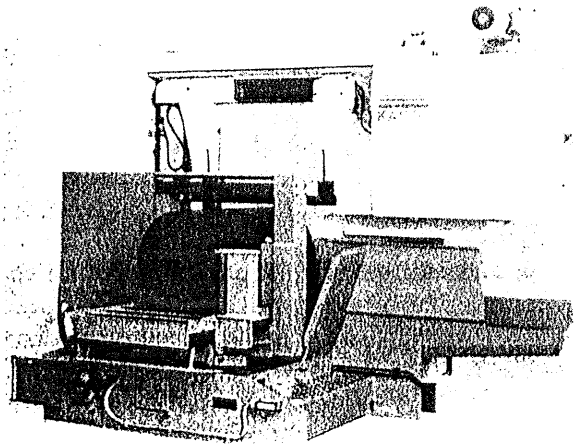


Figure 22-19. Horizontal band sawing machine. (Courtesy Kasto-Racine, Inc.)

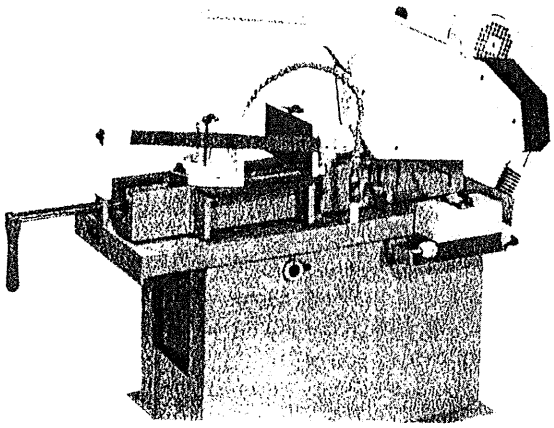


Figure 22-16. Power reciprocating saw with hydraulic saw feed. (Courtesy Kasto-Racine, Inc.)

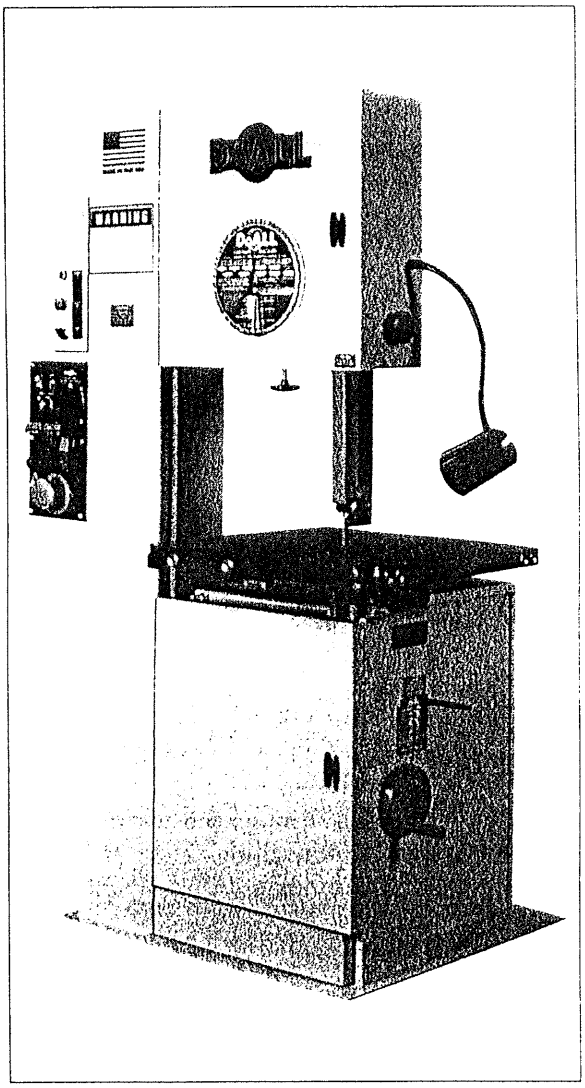


Figure 22-20. General-purpose contour band-sawing machine. (Courtesy ITS/DoAll Industrial Company)