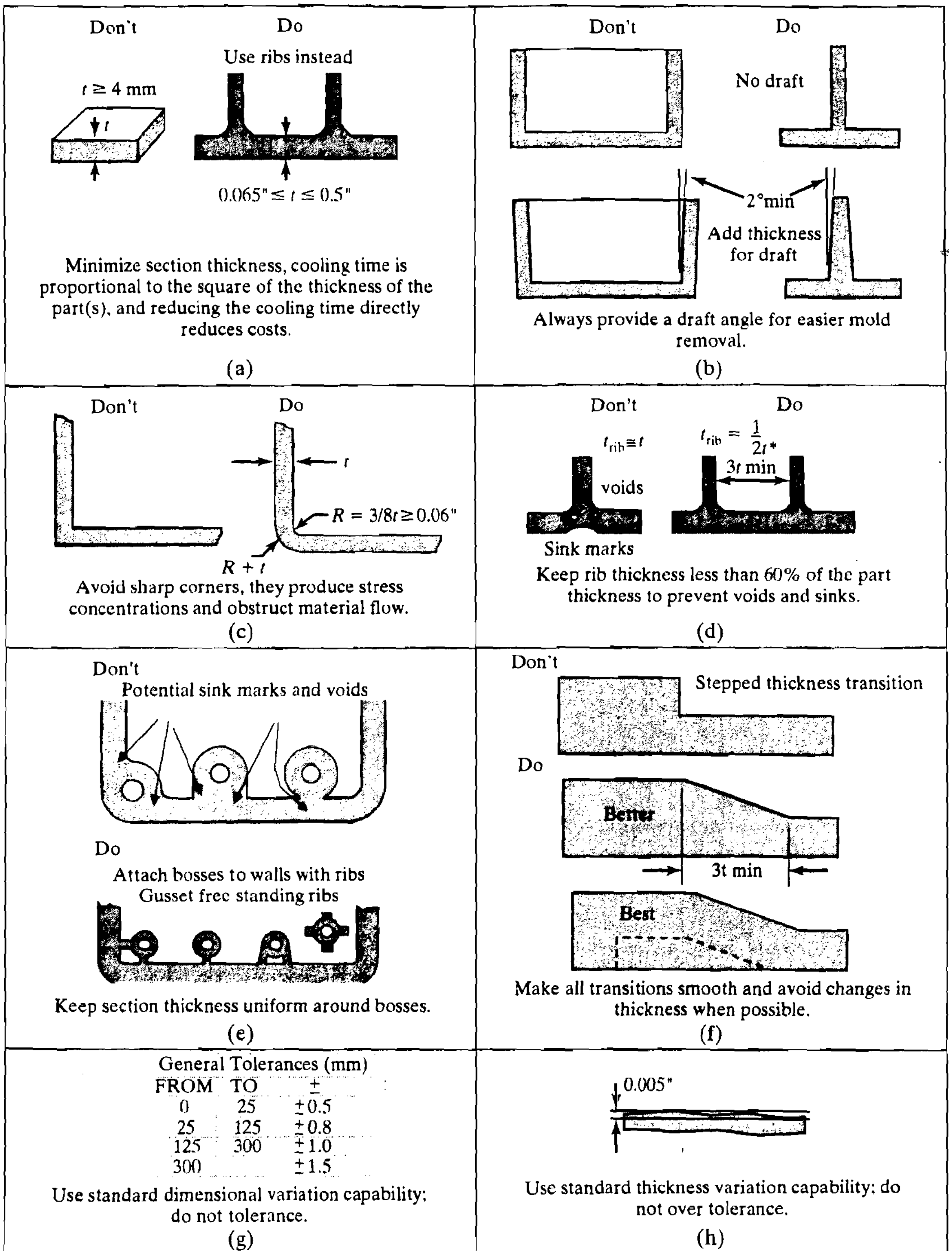


FIGURE 7.8

Design for manufacture of injection-molded parts. (*Product Design: Techniques in Reverse Engineering and New Product Development*, by Otto/Wood, © 2001, Prentice-Hall. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, NJ.)

5.5 FORGING

The term *forging* is used to define the plastic deformation of metals at elevated temperatures into predetermined shapes using compressive forces that are exerted through dies by means of a hammer, a press, or an upsetting machine. Like other metal forming processes, forging refines the microstructure of the metal, eliminates the hidden defects such as hair cracks and voids, and rearranges the fibrous macrostructure to conform with the metal flow. It is mainly the latter factor that gives forging its merits and advantages over casting and machining. By successful design of the dies, the metal flow during the process can be employed to promote the alignment of the fibers with the anticipated direction of maximum stress. A typical example is shown in Figure 5.41, which illustrates the fibrous macrostructure in two different crankshafts produced by machining from a bar stock and by forging. As can be seen, the direction of the fibers in the second case is more favorable because the stresses in the webs when the crankshaft is in service coincide with the direction of fibers where the strength is maximum.

A large variety of materials can be worked by forging. These include low-carbon steels, aluminum, magnesium, and copper alloys, as well as many of the alloy steels and stainless steels. Each metal or alloy has its own plastic forging temperature range. Some alloys can be forged in a wide temperature range, whereas others have narrow ranges, depending upon the constituents and the chemical composition. Usually, the forging temperatures recommended for nonferrous alloys and metals are much lower than those required for ferrous materials. Table 5.2 indicates the range of forging temperatures for the commonly used alloys.

Forged parts vary widely in size ranging from a few pounds (less than a kilogram) up to 300 tons (3 MN) and can be classified into small, medium, and heavy forgings.

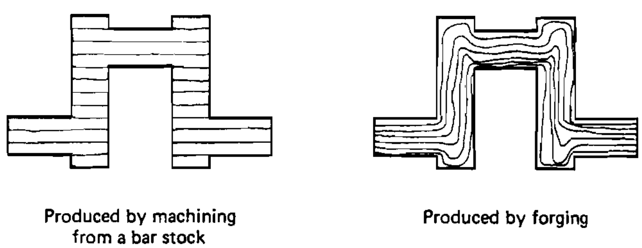
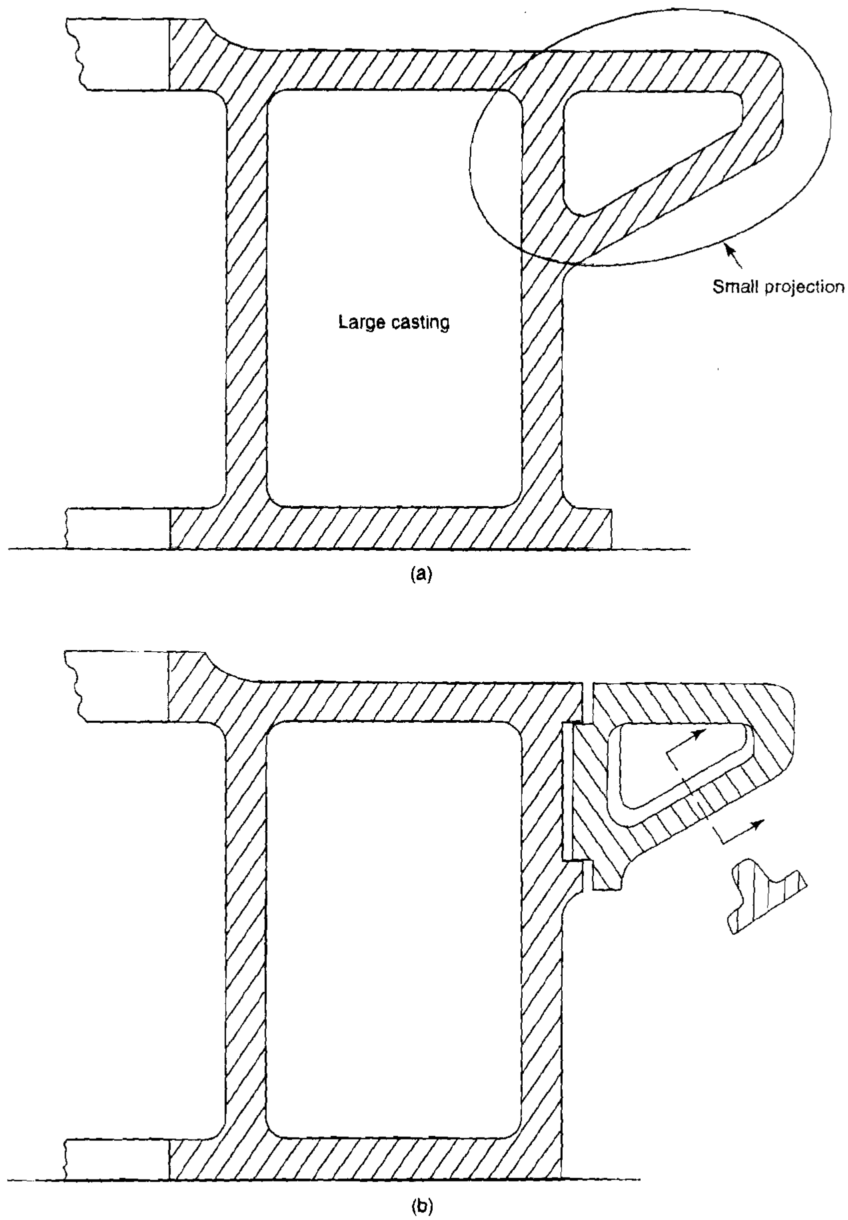


FIGURE 5.41 The fibrous macrostructure in two crankshafts produced by machining and by forging

TABLE 5.2 Forging temperature range for different metals

Metal	Forging Temperature
Low-carbon steel	1450–2550°F (800–1400°C)
Aluminum	645–900°F (340–480°C)
Magnesium	645–800°F (340–430°C)
Copper	800–1900°F (430–1040°C)
Brass	1100–1700°F (590–930°C)

FIGURE 3.32
Large casting with a small projection: (a) as an integral part; (b) two separate parts



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and/or metal-

lic shot-blasting machines. The latter two machines use sand particles or shots traveling at high velocities onto the surface of the casting to loosen and remove the adhering sand. As you may expect, these machines are particularly suitable when cleaning medium and heavy castings. On the other hand, rotary separators are advantageous for cleaning light castings. A separator is actually a long, large-diameter drum that rotates around its horizontal axis into which the castings are loaded together with jack

FIGURE 3.33
Restriction of surfaces to be machined

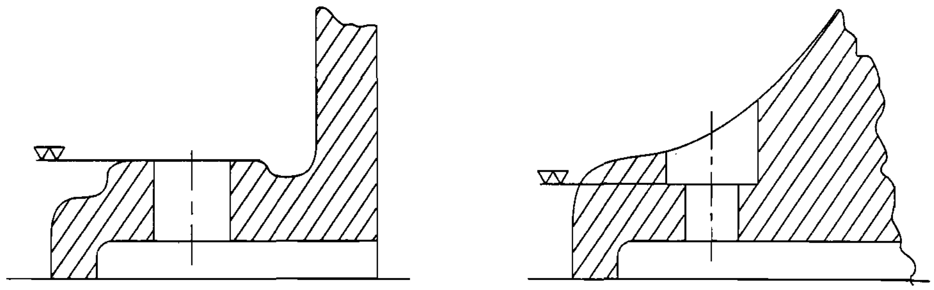


FIGURE 3.34
Use of reinforcement ribs

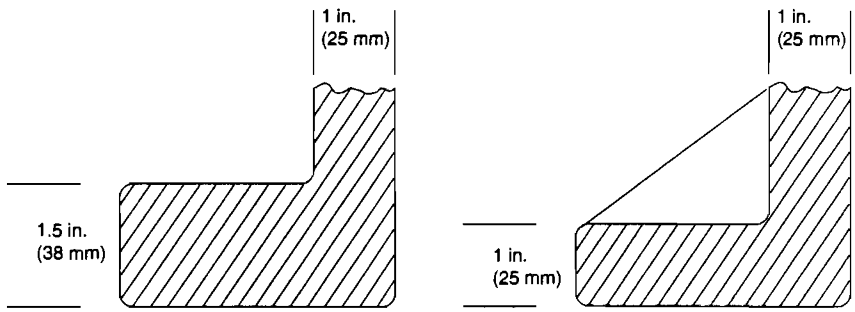
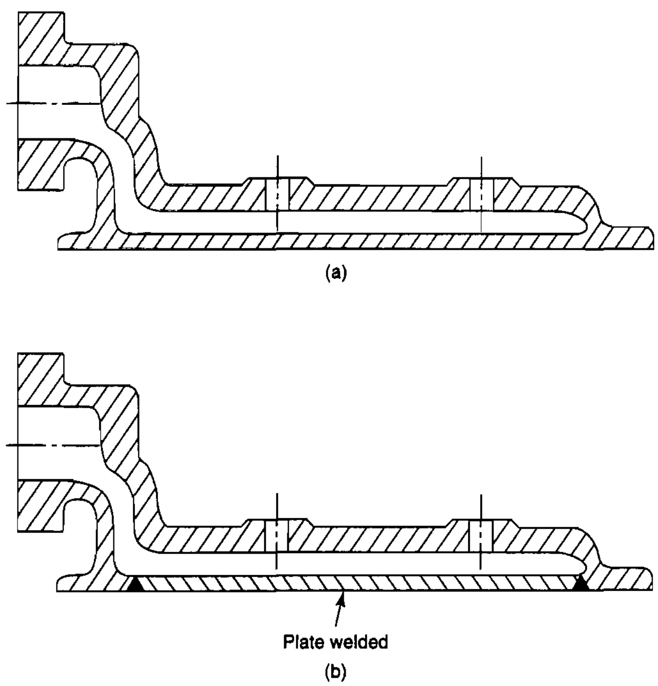


FIGURE 3.35
The design of a steam ring: (a) cast construction; (b) cast-weld construction



3.7 CAST