In addition, many of the reinforcing fibers are extremely abrasive and quickly dull most conventional cutting tools. Diamond or polycrystalline diamond tooling may be required to achieve realistic tool life. Abrasive slurries can be used in conjunction with rigid tooling to assure the production of smooth surfaces. Lasers and water jets are alternative cutting tools. Lasers, however, can burn or carbonize the material or produce undesirable heat-affected zones. Water jets can create moisture problems with some plastic resins, and pressurized water can cause delaminations, but the low heat and light cutting force are attractive characteristics. Elastic deflections are minimized during the cut. Parts can often be held in place by simple vacuum cups, and water jets also minimize the generation of dust, which may be toxic.

When fiber-reinforced materials must be joined, the major concern is the lack of continuity of the fibers in the joint area. Thermoplastics can be softened and welded by applying pressure with heated tools, combining pressure and ultrasonic vibration, or using pressure and induction heating. Thermoset materials generally require the use of mechanical joints or adhesives, with each method having its characteristic advantages and limitations. Metal-matrix composites are often brazed.

### Key Words

- adhesive bonding
- annealing
- autoclave
- blow molding
- braiding
- bulk molding compound
- compression molding
- calendering
- casting
- cementation
- ceramics
- ceramic-matrix composites
- clay products
- cold molding
- composites
- compression molding
- crystalline ceramics
- devitrification
- dipping
- dry pressing
- elastomer
- explosive bonding
- extrusion
- fibers
- filament winding
- firing
- foam molding
- glass
- glass ceramic
- hand lay-up
- hot-isostatic pressing
- injection molding
- inserts
- isostatic pressing
- lamination
- laser sintering
- matrix
- mats
- metal-matrix composites
- open-mold processing
- parison
- plastics
- prepregs
- pressure-bag molding
- pultrusion
- reaction injection molding
- resin-transfer molding
- roll bonding
- rotational molding
- rovings
- sandwich structures
- sheet-molding compound
- sintering
- slip casting
- snap-fit
- sol-gel processing
- spinning
- spray molding
- tape casting
- tapes
- tempered glass
- thermoforming
- thermoplastic polymer
- thermosetting polymer
- tows
- transfer molding
- vacuum-bag molding
- viscous flow
- vitrification
- wet processing
- yarns

### Review Questions

1. Why are the fabrication processes applied to plastics, ceramics, and composites often different from those applied to metals? What are some of the key differences?
2. How does the fabrication of a thermoplastic polymer differ from the processing of a thermosetting polymer?
3. What are some of the ways that plastic sheet, plate, and tubing can be cast?
4. Why do cast plastic resins typically have a lustrous appearance?
5. What types of polymers are most commonly blow molded?
6. Why do blow molding molds typically contain a cooling system?
7. For what types of parts and production volumes would compression molding be an appropriate process?
8. What are typical mold temperatures for compression molding? What is the most common mold material?
9. What are some of the attractive features of the transfer molding process?
10. Cold molding is faster and more economical than other types of molding. What limits its use?
11. What is the most widely used process for the fabrication of thermoplastic materials (in terms of number of parts produced)?
12. In what ways is injection molding of plastic similar to the die casting of metal?
13. What is the benefit of a hot-runner distribution system in plastic injection molding?
14. Why is the cycle time for the injection molding of thermosetting polymers significantly longer than that for the thermoplastics?
15. How are the individual components mixed in the reaction injection molding process?
16. What are some of the attractive consequences of the low temperatures and low pressures of the reaction injection molding process?
17. What are some of the typical production shapes that are produced by the extrusion of plastics?
18. For what types of materials and products might thermoforming be considered attractive?
19. What types of products are produced by rotational molding?
20. What is the difference between open-cell and closed-cell foamed plastics?
21. What are some typical applications for rigid-type foamed plastics?
22. What type of products are produced by the spinning process?
23. What are some of the general properties of plastics that affect their machinability?
24. What are some of the attractive features of laser machining plastic?
25. What property of plastics is responsible for making snap-fit assembly a popular alternative for plastic products?
26. What are some of the attractive properties of plastics that favor their selection? What are some of the common limitations?
27. What are some of the design concerns when specifying and setting up a plastic molding process?
28. Why should adequate fillets be included between adjacent sections of a mold? What is a major benefit of rounding exterior corners?
29. Why is it most desirable to have uniform wall thickness in plastic products?
30. Why are product dimensions less precise when they cross a mold parting line?
31. Why might threaded inserts be preferred over other means of producing threaded holes in a plastic component?
32. What are some of the ways in which metal inserts are held in place in a plastic part?
33. When designing a decorative surface (design or lettering) on a plastic product, why is it desirable that the details be raised on the product rather than depressed?
34. Why does locating a parting line on a sharp corner make that feature less noticeable?
35. What is the benefit of countersinking holes that are to be threaded or used for self-tapping screws?
36. What types of products can be produced from elastomeric materials using the dipping process?
37. What process or equipment is used to form rubber compounds into sheets?
38. What method is generally used to bond elastomers to other materials?
39. What are the two basic classes of ceramic materials, and how do their processing differ?
40. What are some of the most common processes used to shape glass?
41. What are some of the special heat-treatment operations performed on glass products?
42. What are glass-ceramics? How are they produced?
43. What are some of the techniques that can be used to impart some degree of plasticity to crystalline ceramic materials?
44. Describe the differences between the injection molding of plastics and the injection molding of ceramics.
45. What is the difference between slip casting and tape casting?
46. What is the purpose of the firing or sintering operations in the processing of crystalline ceramic products?
47. How does cementation differ from sintering?
48. What are the benefits and limitations of machining ceramic materials before firing versus after firing?
49. What are some of the nonconventional methods used to machine ceramics?
50. Why are joining operations usually avoided when fabricating products from ceramic materials?
51. Discuss some of the design guidelines that relate to the production of parts from ceramic material.
52. Why are the processes used to fabricate particulate composites essentially the same as those used for conventional material?
53. What are some of the processes that can be used to produce a high-quality bond between the layers of a laminar composite?
54. List several fabrication processes for fiber-reinforced products that are essentially the same as for unreinforced plastics. List several that are unique to reinforced materials.
55. What types of materials are used as reinforcing fibers in fiber-reinforced composites?
56. What are some of the forms in which reinforcement fibers appear in composite materials?
57. What is a prepreg?
58. What are sheet-molding compounds (SMCs)? Bulk-molding compounds (BMCs)?
59. In what way is pultrusion similar to wire drawing?
60. What are some typical products that are made by filament winding?
61. What are some of the various molding processes that can be used to shape products from laminated sheets of woven fibers?
62. What are the benefits of using an autoclave instead of room-temperature and low-pressure curing?
63. What form of reinforcing fibers can be incorporated in the spray-molding process? Injection molding?
64. What is the major benefit of three-dimensional fiber reinforcement?
65. Describe some of the ways in which a metal matrix can be introduced into a fiber-reinforced composite.
66. Why might it be desirable to have a weak bond between a reinforcing fiber and a ceramic-matrix material?
67. Discuss some of the techniques used to cut fiber-reinforced composites.
68. What is the major concern when considering the joining of fiber-reinforced composites?

### Problems

1. Consider some of the more prominent sporting goods that are fabricated from composite materials, such as skis, snowboards, tennis rackets, golf club shafts, bicycle frames, and body panels for racing cars. For two specific products, identify composite materials that are currently being used and the companion shape-producing fabrication methods.

2. Figure 14-A depicts the handles of two large wrenches, a ratchet wrench and a pipe wrench. These components are traditionally forged from ferrous alloy or made from a cast steel or cast iron. For various reasons, alternative materials may be desired. The ratchet wrench is quite long, and reduced weight may be a reasonable desire. Both of these tools could