Chapter 16: Sheet-Metal Forming Processes

1. Text 16.27 Note the roughness of the periphery of the flanged hole in Fig. 16.25c, and comment on its possible effects when the part is used in a product.

   **Answer**
   
   The quality of the sheared edge (see Fig. 16.5a on p. 387) is important in subsequent forming operations, especially in subsequent operations such as stretch flanging (see, for example, Fig. 16.25a on p. 403). Depending on the notch sensitivity of the sheet material, a rough periphery can cause cracks to initiate. In service, this can cause additional problems such as decreased fatigue life of the part, as well as crevice corrosion.

2. Text 16.29 Give several specific examples from this chapter in which friction is desirable and several in which it is not desirable.

   **Answer**
   
   By the student. For example, high friction in sheet-metal forming can result in high localized strain and thus lowers formability. In ironing, high friction increases press forces. Friction is desirable, for example, with draw beads to improve their effectiveness and in clamps to secure blanks.

3. Text 16.33 Calculate for a metal where the R values for the 0\(^\circ\), 45\(^\circ\), and 90\(^\circ\) directions are 0.8, 1.7, and 1.8, respectively. What is the limiting drawing ratio (LDR) for this material?

   **Answer**
   
   From Eq. (16.12) on p. 409 we have
   
   \[ R_{\text{avg}} = \frac{R_0 + 2R_{45} + R_{90}}{4} = \frac{0.8 + 3.4 + 1.8}{4} = 1.50 \]
   
   The limiting drawing ratio (LDR) is defined as the maximum ratio of blank diameter to punch diameter that can be drawn without failure, i.e., \( D_0/D_p \). From Fig. 16.33 on p. 410, we estimate the LDR for this steel to be approximately 2.5.

Chapter 17: Processing of Metal Powders

4. Text 17.11 Why is there density variation in the compacting of powders? How is it reduced?

   **Answer**
   
   The main reason for density variation in compacting of powders (Section 17.3 on p. 444) is associated with mechanical locking and friction among the particles; this leads to variations in pressure depending on distance from the punch and from the container walls (see Fig. 17.11 on p. 493). The variation can be reduced by having double-acting presses, lowering the frictional resistance of the punch and die surfaces, or by adding lubricants that reduce inter-particle friction among the powders.

5. Text 17.17 Describe the relative advantages and limitations of cold and hot isostatic pressing.

   **Answer**
   
   Cold isostatic pressing (CIP) and hot isostatic pressing (HIP) both have the advantages of producing compacts with effectively uniform grain structure and density, thereby making shapes with uniform strength and toughness (see Section 17.3.2 on p. 447). The main advantage of HIP is its ability to produce compacts with essentially 100% density, good metallurgical bonding of
powders, and very good mechanical properties; however, the process is relatively expensive and is therefore used mainly for aerospace applications.

6 Text 17.26 Refer to Fig. 17.10a. What should be the volume of loose, fine iron powder in order to make a solid cylindrical compact 25 mm in diameter and 20 mm high?

Answer
The volume of the cylindrical compact is
\[ V = \pi \left( \frac{25}{2} \right)^2 \times 20 = 9817 \text{ mm}^3 \]
Loose, fine iron powder has a density of 1.40 g/cm\(^3\) (see Fig. 17.10a on p. 446). Density of iron is 7.86 g/cm\(^3\) (see Table 3.1 on p. 89). Therefore, the weight of iron used is
\[ W = \rho V = (7.86 \text{ g/cm}^3)(9817 \text{ mm}^3)(10^{-3} \text{ cm}^3/\text{mm}^3) = 77.2 \text{ g} \]
Therefore, the initial volume is
\[ V = \frac{W}{\rho} = \frac{77.2}{1.40} = 55.1 \text{ cm}^3 \]

Chapter 18: Processing of Ceramics, Glass, and Superconductors

7. Text 18.14 Describe the differences and similarities in processing metal powders vs. ceramics.

Answer
Some of the similarities are:
- Both involve an initial powder form.
- Both involve sintering or firing.
- Both can produce porous parts.
- Both can be injection molded.

Some of the differences include:
- Ceramics are commonly glazed in a second firing operation, whereas this is rare for metals except when enameling.
- Ceramic processing involves water-based slurries, while this does not occur with metals.

8. Text 18.19 Are any of the processes used for making discrete glass products similar to ones described in preceding chapters? Describe them.

Answer
For example:
- Pressing of glass is similar to closed-die forging.
- Blowing of glass is similar to bulging or hydroforming.
- Production of glass fibers is similar to extrusion and drawing.
- Flat glass sheet or plate production is similar to drawing or rolling, depending on the particular method used.

9. Text 18.21 Explain the phenomenon of static fatigue and how it affects the service life of a ceramic or glass component.

Answer
Static fatigue occurs under a constant load and in environments where water vapor is present. Typical examples of applications that are susceptible to static fatigue include load-bearing members (such as a glass rod under tension) and glass shelving (supporting various objects, including books).

Chapter 19: Forming and Shaping Plastics and Composite Materials

10. Text 19.17 Describe the features of a screw extruder and its functions.

Answer
A typical extruder is shown in Fig. 19.2 on p. 487. The three principal features of the screw shown are:
• Feed section: In this region, the screw is intended to entrain powder or pellets from the hopper; as a result, the flight spacing and depth is larger than elsewhere on the screw.
• Melt section: In the melt section, the flight depth is very low and the plastic is melted against the hot barrel; also, gases that are entrained in the feed section are vented.
• Metering section: This region produced the pressure and flow rate needed for the extrusion operation.

Note that screws are designed for particular polymers, so the feed, melt, and metering sections are polymer-specific. Also, some extruders use two screws to increase the internal shearing and mixing of the polymer.

11. Text 19.21 Describe the problems involved in recycling products made from reinforced plastics.

**Answer**
The main problems are that recycling usually requires the use of a single type of material, and that some plastics (mainly hard and brittle polymers) are more difficult to chop into small pieces for further processing than others. With reinforced plastics, this requires that the reinforcement be separated from the matrix, a very difficult task and uneconomical task. Note that matrices are often thermosets, so it is not practical to melt the matrix and separate the fibers from a molten phase.

12. Text 19.44 It is well known that plastic forks, spoons, and knives are not particularly rigid. What suggestions would you have to make them better? Describe processes that could be used for producing them.

**Answer**
Plastic spoons, forks, and knives are not particularly strong or rigid, but they are inexpensive because they are mass produced typically by injection molding. Stiffening ribs can, for example, be designed into them to increase their stiffness, or they can be made larger and thicker. If strength is a key issue, then stronger plastics can be used (see Table 7.1 on p. 172).

Chapter 20: Rapid-Prototyping Operations

13. Text 20.13 List the processes described in this chapter that are best suited for the production of ceramic parts. Explain.

**Answer**
For direct production of ceramic parts, three-dimensional printing is likely the best option. With the proper binder, this can also be accomplished by fused-deposition modeling, and is also possible by selective laser sintering. However, the ceramic particles will abrade the tooling in FDM and require much heat to fuse in SLS. The 3D printing approach, where a binder is sprayed onto the ceramic particles, is the best approach for making green parts, which are then fired in a furnace to fuse the powder.

14. Text 20.14 Few parts in commercial products today are directly manufactured through rapid prototyping operations. Explain.

**Answer**
The two main reasons why so few parts are produced by rapid-prototyping operations are production cost and production time. Note that the materials used in rapid prototyping are very expensive; also, although they can be produced quickly as compared to conventional forming operations (and machining unless very expensive CNC equipment is used) mass production is not realistic. There is a quip that the production of a first forging takes six months and a million dollars, but the second forging is then almost free and takes only seconds for manufacture. With rapid prototyping, the first part takes a few hours. The second part takes a few hours, and so on, with no economies of scale. These processes are ideally suited for making single examples of products, but are not intended for mass production.
15. Text 20.25 One of the major advantages of stereolithography is that it can use semitransparent polymers, so that internal details of parts can readily be discerned. List and describe several parts in which this feature is valuable.

**Answer**
The transparent feature is especially useful for (a) flow visualization, such as with a new heat-exchanger design; (b) investigating mating parts to make sure the interface is as intended; and (c) implantable medical devices, where the body part is made from stereolithography for visualization of how the devices function.

Chapter 30: Fusion-Welding Processes


**Answer**
In oxyfuel-gas cutting, it is desirable to melt as small a width (kerf) as possible. If the workpiece has high thermal conductivity (see Table 3.1 on p. 89), the heat will be dissipated throughout the workpiece more rapidly, resulting in a wider kerf. Low thermal conductivity results in a more localized heating and, hence, a smaller kerf. For this reason, processes that involve a highly localized application of heat, such as laser-beam or electron-beam welding, can be used with much smaller kerfs than other processes. (See, for example, Fig. 30.16 on p. 883.)

17. Text 30.20 What are the advantages of electron-beam and laser-beam welding compared with arc welding?

**Answer**
The main advantages of these processes are associated with the very small weld kerf, and the localized energy input and small heat-affected zone. Weld failures, especially by fatigue, occur in the heat-affected zone; thus, minimizing this volume reduces the likelihood of large flaws and rapid crack growth. Also, the low energy input means that thermal distortions and warping associated with these processes will be much lower than with arc welding (see also Figs. 30.23 and 30.25 on pp. 889-890).

18. Text 30.41 Discuss the need for, and the role of, work-holding devices in the welding operations described in this chapter.

**Answer**
The reasons for using fixtures are basically to assure proper alignment of the components to be joined, reduce warpage, and help develop good joint strength. The fixtures can also be a part of the electrical circuit in arc welding, where a high clamping force reduces the contact resistance.

Chapter 31: Solid-state Welding Processes

19. Text 31.12 Explain the similarities and differences between the joining processes described in this chapter and those described in Chapter 30.

**Answer**
The similarities between the processes described in the two chapters are that they all involve permanent joining by the application of heat and/or pressure. The differences are mainly in the power source and the workpiece shapes involved. Chapter 30 deals with chemical reactions and electrical energy sources (including high-energy beams), whereas Chapter 31 deals additionally predominantly mechanical energy sources, and no filler metal is required. The students are encouraged to make a comprehensive table regarding this topic.

20. Text 31.15 What advantages does friction welding have over other methods described in this and in the preceding chapter?
As described in Section 31.4 starting on p. 903, the main advantages of friction welding are that the entire cross-sectional area can be welded, instead of a mere bead along the periphery, and is suitable for a wide variety of materials. Also, with proper process control, the weld zone can be very small and thin, so that thermal distortions will be minimal. The heat input is controlled and heat-affected zones are small, so that friction welded joints are strong and give superior fatigue properties.

21. Text 31.33 Comment on workpiece size and shape limitations (if any) for each of the processes described in this chapter.

Answer
This is an open-ended question, and the students are encouraged to develop their own answers which deviate from the answer here. There are limitations that are often associated with fixturing requirements. Roll bonding is generally used with sheet metals, so parts that do not involve thin layers are difficult to roll bond. Ultrasonic welding is typically restricted to thin foils. Friction welding requires parts that can be mounted into chucks or similar fixtures. Explosion welding is restricted to thick plates, thus thin sheets would not be processed in this manner.

Chapter 32: Brazing, Soldering, Adhesive Bonding, and Mechanical-Fastening Processes

22. Text 32.13 Give examples of combination joints other than those shown in Fig. 32.12.

Answer
Combination joints merely combine methods of fastening in order to obtain a more structurally sound joint. This is often done when the size or access of the weld joint is limited. Any joining methods can be combined, such as:

• Adhesive bonding can be combined with the use of threaded fasteners.
• Threaded fasteners can be combined with welding.
• Crimping can be combined with adhesive bonding or spot welding.
• Snap fasteners can be combined with welding or adhesive bonding. This is a stretch of the definition of a combination joint, as the snap fasteners are often merely a form of clamping to hold components in place before welding or adhesive bonding, and aren’t expected to provide structural strength to the joint.

23. Text 32.18 If you are designing a joint that must be strong and also needs to be disassembled several times during the product’s life, what kind of joint would you recommend? Explain.

Answer
Disassembly is a difficult feature to assess when using joining methods (see also Section I.3 starting on p. 11 and Section 37.10.2 on p. 1087). If the part has to be disassembled often, bolted connections are likely the best solution, or else a quick disconnect clamp or similar devices should be used. If the number of disassemblies over the lifetime of the part is limited (such as automobile dashboards), integrated snap fasteners (see Fig. 32.19 on p. 942) and even soldering or brazing can be options. However, soldering and brazing are only suitable if the filler metal can be melted without damaging the joint, and if the joint can be resoldered.

24. Text 32.25 Suggest methods of attaching a round bar (made of a thermosetting plastic) perpendicularly to a flat metal plate. Discuss their advantages and limitations.

Answer
One can attach the plastic rod to the plate by a number of methods, including:

(a) Threading the end of the rod, drilling and tapping a hole into the plate, and screwing the rod in, using lock-tite R if necessary.
(b) Performing a shrink fit, where the metal is drilled, heated, and the plastic rod is inserted; as the metal cools, it contracts, binding against the rod.
(c) Fittings, such as those used in scaffolding, can be employed.
(d) The rod may be riveted in place.