Processes and Process Selection

Die casting. Image courtesy of Thomas Publishing, New York.

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Materials Selection in Mechanical Design. DOI: 10.1016/B978-1-85617-663-7.00013-8

13.1 INTRODUCTION AND SYNOPSIS

A *process* is a method of shaping, joining, or finishing a material. *Sand casting*, *injection molding*, *fusion welding*, and *electro-polishing* are all processes; there are hundreds of them. The choice, for a given component, depends on the material of which it is to be made; on its size, shape, and required precision; and on how many are to be made—in short, on the *design requirements*.

To select processes we must first classify them. Section 13.2 develops the classification. It is used to structure Section 13.3, in which process *families* and their *attributes* are described: the materials they can handle, the shapes they can make, and the precision with which they can do it.

Processing has dual functions. The obvious one is that of shaping, joining, and finishing. The less obvious one is that of property control. Metals are strengthened by rolling and forging; steels are heat-treated to enhance hardness and toughness; polymers are drawn to increase modulus and strength; and ceramics are hot-pressed, again to increase strength. Process-property relationships are explored more closely in Section 13.4.

Process selection—finding the best match between process attributes and design requirements—is the subject of Sections 13.5 and 13.6. In using the methods developed there, one should not forget that material, shape and processing interact (Figure 13.1). Material properties and shape limit the choice of

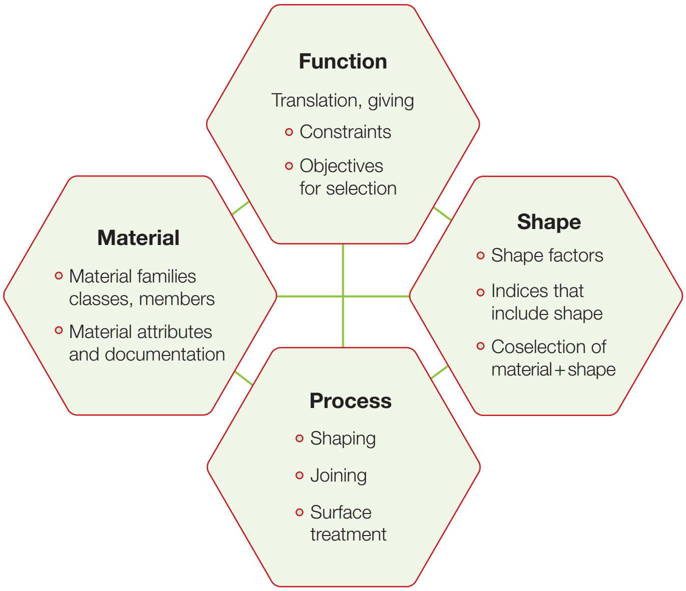

FIGURE 13.1
Processing selection depends on material and shape. The “process attributes” are used as criteria for selection.

process: Ductile materials can be forged, rolled, and drawn; those that are brittle may have to be shaped using powder methods. Materials that melt at modest temperatures to low-viscosity liquids can be cast; those that do not have to be processed by other routes. Shape, too, can influence the choice of process. Slender shapes can be made easily by rolling or drawing but not by casting. Hollow shapes cannot be made by forging, but they can by casting or molding. Conversely, processing affects properties. Rolling and forging change the hardness and texture of metals and align the inclusions they contain, enhancing strength and ductility. Heat treatment allows manipulation of strength, ductility, and toughness. Composites do not exist until they are processed; before processing, they are just a soup of polymer and a sheaf of fibers.

Like the other aspects of design, process selection is an iterative procedure. The first iteration gives one or more possible process routes. The design must then be rethought to adapt it, as far as possible, to ease manufacture by the most promising route. The final choice is based on a comparison of *process cost*, requiring the use of cost models developed in Section 13.6, and on *documentation*: guidelines, case histories, and examples of process routes used for related products. Documentation also helps in dealing with the coupling between process and material properties.

The chapter ends, as always, with a summary and annotated recommendations for further reading.

13.2 CLASSIFYING PROCESSES

Manufacturing processes can be classified under the headings shown in Figure 13.2. *Primary shaping* create shapes. The first row lists six classes of primary forming processes: casting, molding, deformation, powder methods, methods for forming composites, and special methods such as rapid prototyping. *Secondary processes* modify shapes or properties; here they are shown as "machining," which adds features to an already shaped body, and "heat treatment," which enhances surface or bulk properties. Below these come *joining* an, *surface treatment* or *finishing.*

Figure 13.2 has merit as a flow chart; it shows a progression through the manufacturing route. It should not be treated too literally, however; the order of the steps can be varied to suit the needs of the design. The point it makes is that there are three broad process families: shaping, joining, and finishing. The attributes of one family differ so greatly from those of another that, in assembling and structuring data for them, they must be treated separately.

To organize processes in more detail, we need a hierarchical classification like that used for materials in Chapter 5. Figure 13.3 shows part of it. The process universe has three families: shaping, joining, and finishing. In this figure, the shaping family is expanded to show classes: casting, deformation,

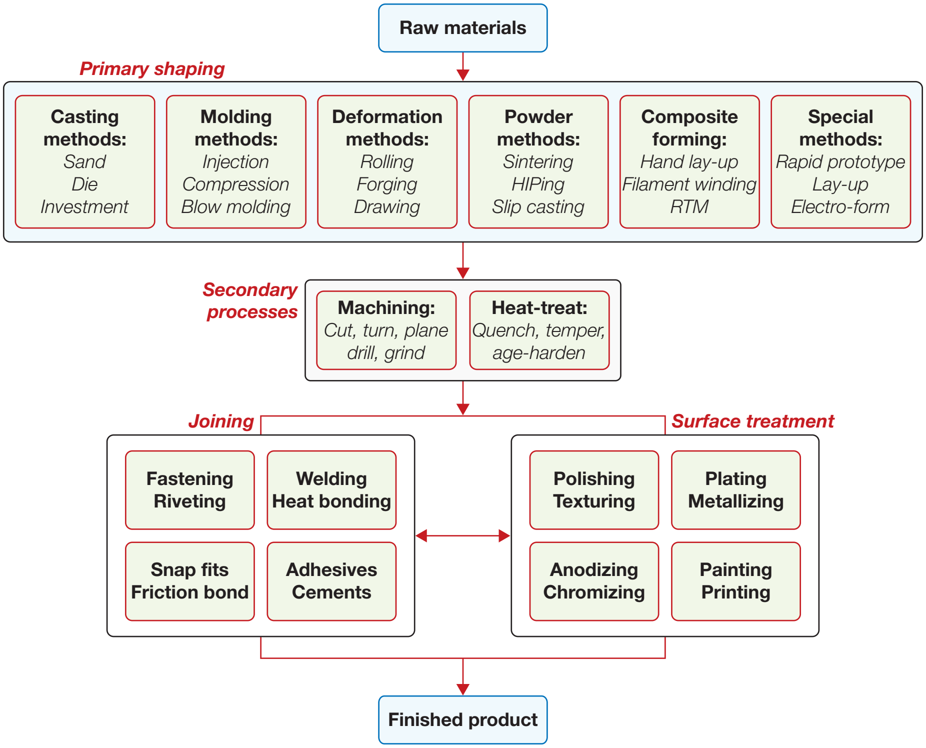

FIGURE 13.2
The classes of process. The first row contains the family of shaping processes; below lie the secondary processes of machining and heat treatment, followed by the families of joining and finishing (surface treatment) processes.

molding, and so on. One of these—molding—is again expanded to show its members: rotation molding, blow molding, injection molding, and so forth. Each of these has certain attributes: the materials it can handle, the shapes it can makes, their size, precision, and an optimum batch size (the number of units that molding can make economically).

Expanding members of the shaping family

Expanding the casting family at about the same level of detail as that used for molding in the figure gives the result:

1. Sand casting
2. Shaping–casting
3. Die casting
4. Investment casting

The other two families are partly expanded in Figure 13.4. The joining family contains three broad classes: adhesives, welding, and fasteners. In this

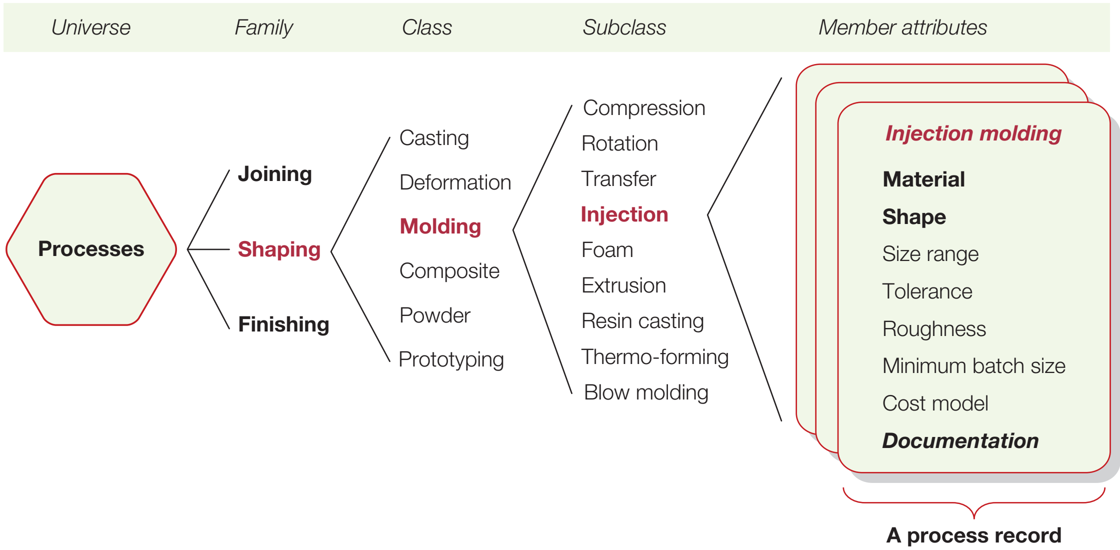

FIGURE 13.3
The taxonomy of the kingdom of process with part of the *shaping* family expanded. Each member is characterized by a set of attributes. Process selection involves matching these to the requirements of the design.

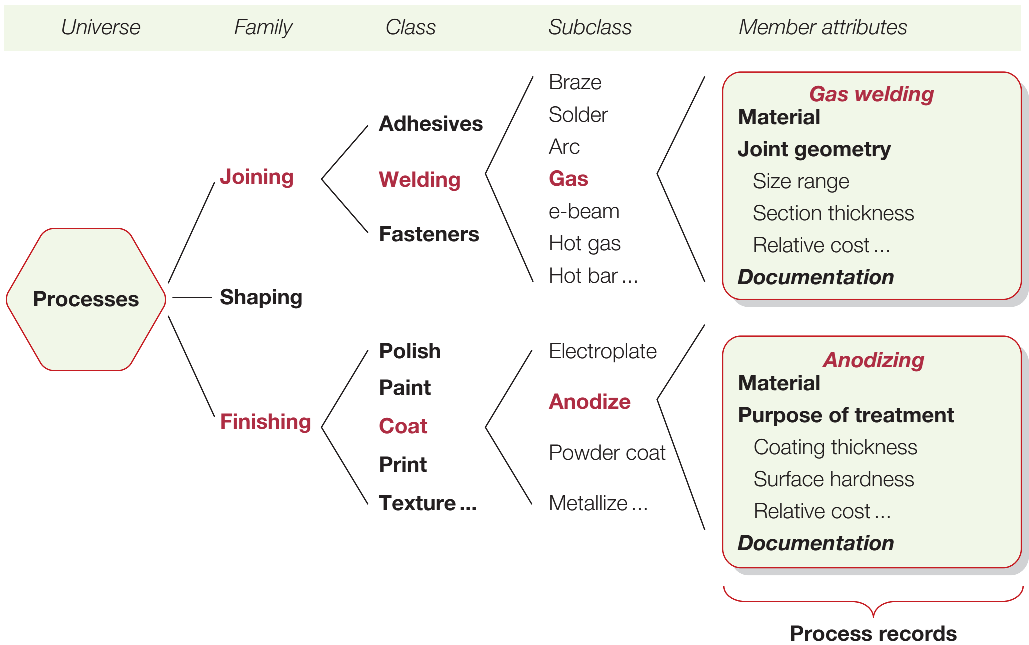

FIGURE 13.4
The taxonomy of the process kingdom again, with the families of *joining* and *finishing* partly expanded.

figure one of them—welding—is expanded to show its members. As before, each member has attributes. The first is the materials it can join. After that the attribute list differs from that for shaping. Here the geometry of the joint and the way it will be loaded are important, as are requirements that the joint can or cannot be disassembled, that it be watertight, that it be electrically conducting, and the like.

The lower part of the figure expands the family of finishing. Some of the classes it contains are shown; one—coating—is expanded to show some of its members. As with shaping and joining, the material to be coated is an important attribute but the others differ. Most important is the purpose of the treatment (protection, surface hardening, decoration, etc.), followed by properties of the coating itself.

Expanding the joining family

Expanding the fasteners family at about the same level of detail as that used for molding in the figure, gives the result:

1. Rivets and staples
2. Joining—fasteners
3. Threaded fasteners
4. Sewing
5. Snap fits

With this background we can embark on a lightning tour of processes. It will be kept as concise as possible; details can be found in the numerous books listed in "Further reading" (Section 13.9).