# Prototyping

## 6.6.1. Traditional

        The traditional method of making a prototype is by machining, joining, simple molding, or some other labor-intensive method. These methods, almost always slow, are not used for large production quantities, but are acceptable to make a few items for proveout. Ideally, these prototypes are made from the same material that will be used for the final product, but that is not always possible. When it is not possible, the major purpose of the prototype is to verify the part dimensional characteristics. When the prototype can be made from the same material as the final product, a full range of tests can be carried out to verify all the part-design parameters. The standard against which the prototype should be compared is the functional specification.

        The process design must be compatible with the part design for the prototype to have any real meaning. If the part design does not satisfy all of the criteria or design rules for the manufacturing process that is envisioned, neither the part-design dimensions nor the performance characteristics can be verified.

## 6.6.2. Rapid Prototyping

        Several systems have been developed to make prototypes much more quickly than could be done using traditional prototyping methods. These systems use the CAD drawing of the part and then, by various methods, manufacture a part that duplicates the CAD drawing. The prototype may be of the same material or may be of some different material, depending on the rapid prototyping system. Rapid prototyping systems are very valuable in shortening the time required to create a prototype, sometimes reducing the time by a factor of 10. Such time saving allows several different prototypes to be compared and evaluated, thus improving the efficiency of the entire product-realization process.

        All of the major rapid prototyping methods begin with a CAD representation of the part. This CAD representation is loaded into a special software processing system that divides the CAD representation into many thin cross-sectional slices (about 0.004 to 0.02 inch or to 0.5 mm), thus creating a sliced CAD representation. (The sliced part is like a stack of pancakes.) Each slice becomes a path for the rapid prototyping machine to follow in making the physical representation of the CAD drawing. Various manufacturers have invented different methods to create a thin slice of real material. The most prominent of those systems are discussed in the following sections. The most important of these systems are stereolithography, laminated object manufacturing, selective laser sintering, fused deposition modeling, and ballistic particle manufacturing.

        Fused Deposition Modeling (FDM). As with the other rapid prototyping methods, the FDM process begins with a CAD representation of the part that is cross-sectionally sliced. The part is built up by depositing a thin layer of hot thermoplastic resin, which is applied by using an application head. The thermoplastic is fed into the head as a ribbon, which is heated inside the head and then laid onto the surface of the platform to form each slice layer. The platform is then lowered and, after the previous slice has cooled and solidified, the next slice layer is laid down. The FDM process is capable of making a prototype out of the same material as the final part, although some post-forming consolidation (by heating) may be necessary to obtain properties that are comparable to the molded part. This process and some parts made by the FDM process are shown in Figure 6.4.

        Stereolithography (SLA). The term **stereolithography** means "three-dimensional printing." In this process each slice is a path for a laser to trace on the top of a table located inside a vat of **photopolymer**, a polymer that polymerizes when a light is shined on it. The first slice is polymerized on the thin film of photopolymer that covers the platform. After this slice has polymerized (it takes only a few seconds). the platform is lowered the thickness of a slice. This lowering allows a thin film of photopolymer to cover the polymerized slice al- ready on the platform. The laser then follows the path of the second slice as dictated by the sectioned CAD drawing, thus causing the resin covering the platform to be polymerized in the shape of the second slice. The process is repeated for all of the slices of the sectioned CAD drawing. The finished prototype rests on the platform andis surrounded by the photopolymer. The prototype is extracted simply by raising the platform and allowing the photopolymer to run off.

**Figure 6.4Diagram of the fused deposition modeling (FDM) method.**

        Because the prototype is made by building up many slices of cured polymer, it generally is not strong. However, considerable strength can be achieved by post-curing it under a UV light. Because the prototype is not constructed out of the same material as the finished part, only dimensional and conceptual proveout are possible. The prototype can, however, be used as a model for shell casting so that a cast metal or cast plastic part could be produced in a production mode.

        Selective Laser Sintering (SLS). The sliced CAD representation method used in other processes also is used in SLS. In SLS a laser is used to fuse a thermoplastic powder that is spread across the top of the platform. After the fusion of each layer, the platform is lowered and a new, thin layer of thermoplastic powder is spread across the top. The laser then fuses the powder in a new pattern and, by fusing slightly deeper than one layer, fuses the top layer to the one below it. Thus, if the final part is to be made of thermoplastic, the prototype can be of the same material. Mechanical properties are not quite comparable to the molded part, but are very close.

        Ballistic Particle Manufacturing (BPM). The BPM process also relies on a sliced CAD representation to initiate the process. In BPM, each layer is applied by spraying a very fine thermoplastic powder onto the surface of the platform. This is a technology much like that used in ink-jet systems for printing. Each layer is sprayed onto the previous layer with a binder to hold the layers together. Although highly porous, the prototype can sometimes be made of the same material as the final part. Sintering is required to obtain properties similar to those of a molded part.

        Laminated Object Manufacturing (LOM). The LOM process also uses a CAD representation of the part that is sliced to create a multilayered object. In the LOM process, a sheet of paper is placed on the top of a platform and the slice pattern is cut into the paper by a laser. Areas of the paper that are to be removed are cut with crosshatching so that they will easily separate from the final prototype. A second layer of adhesive-coated paper is then placed on top of the first and bonded to it. The laser then cuts the next slice pattern into the paper. This system of bonding a layer of paper to those already on the platform and cut ting subsequent slices in each layer continues until the entire structure has been created. The prototype is then removed from the platform and the crosshatched areas are removed, leaving just the prototype, which is made of laminated paper. As with stereolithography, the prototype is not made from the same material as the final part, so it can be used only for concept, shape, and size considerations.

        All the rapid prototyping methods can be used to make models for soft molds. Many can also be used in investment casting in the same way that wax traditionally is. In fact, some of the processes allow wax as the prototype material so that traditional investment casting methods can be used.

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