Chapter 1

Material Properties and Characterization

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Abstract:

As the name indicates, rapid prototyping (RP) has traditionally been used to provide a physical representation of a product in a relatively short time. RP is performed by either material removal or material addition. In material-removal type RP processes, the part is produce by machining it is out of a block of material; mainly using computer numeric controlled (CNC) machining centers. In material-addition type RP, the prototype is made by adding layers of materials using one of the available RP technologies.

Earlier prototyping materials and technologies were used to provide product designers with the ability to visualize the product, but with limited ability to assess the functional performance of the product. Nonetheless, prototyped parts also need to allow for design validation (assessment of the mechanical and physical behaviors); which indicates that the prototyping material should have the same characteristics as the production material. This was only available in limited situations where the prototyped parts were made using removal processes, casting processes, or metal spray deposition. However, recent advances in rapid prototyping technologies have

allowed the use of production type polymers that can be used to assess the functional behavior of these materials.
One of the shortcomings of testing prototyped products made of production type materials is that the material structure and the mechanical response of the prototyped part may not match those resulting from conventional processing (forming, molding, etc.) that is used to fabricate the actual product. This is caused by differences in processing conditions between RP and conventional processing. For example, if metal spray deposition is used for rapid prototyping purposes, the microstructure and level of porosity in the prototyped part are likely to be different from those of a cast or stamped product of the same size and shape.
Therefore, the goal of this chapter is to provide an introduction to structure and properties of engineering materials, testing methods used to determine mechanical properties, and techniques that can be used to select materials for material-addition type rapid prototyping.

Key words:
Mechanical Properties, Mechanical Testing, Material Selection, Polymers

1.1 Structural Properties of Materials

The structure of materials affects their properties and service behavior. Based on their structure, materials can be classified as either crystalline or non-crystalline (or amorphous)[1]. **Crystalline structures** are organized structures in which atoms and molecules of solids arrange themselves in a regular and repeating manner that is called ***lattice***. On the other hand, **amorphous structures** have some level of local order relative to their neighbors, but globally, they do not have an ordered structure like crystalline materials. Another difference between the two types of materials is related to their different thermal expansion behavior; this will be explained in more detail in sections 1.2.1 and 1.2.2.

1.1.1 Crystalline Structures

The lattice structure in a crystalline material is made up of a repeating order of atoms that is known as the ***unit cell***. Common types of unit cells that are observed in metals include body-centered cubic (BCC), face-centered cubic (FCC), and hexagonal close packed (HCP). Figure 1-1 shows a schematic of the atom arrangement in each of these three aforementioned