Design for Additive Manufacturing

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The burgeoning field of additive manufacturing—the use of additive technologies to fabricate objects, layer by layer—is having a profound impact on the way engineers realize custom parts, and it is democratizing product design and manufacturing in unprecedented ways. Additive manufacturing enables fabrication of customized and form-fitting parts directly from three-dimensional computer-aided design (CAD) models and from scanning or medical imaging data, resulting in customized products as varied as form-fitting prosthetics, athletic gear, and dental implants. Artists create sophisticated furniture, jewelry, and artistic structures that cannot be made in any other way. Manufacturers consolidate parts, enabling more efficient lightweight assemblies with fewer assembly steps. Economical small-lot production opens the door to more affordable customization and even co-design, in which customers are intimately involved in designing their own products.

Design opportunities extend across length scales, as well. Fabrication of complex lattice structures, internal channels, and multimaterial structures, on size scales ranging from microns to meters, enables lightweight structures, tissue scaffolds, conformal cooling channels, and embedded sensors and electronics. Selective deposition of material leads to functionally graded materials with different properties in different spatial locations.

In this talk, these design opportunities will be explored, along with the corresponding design challenges posed by additive manufacturing. Conventional computer-aided design (CAD) and computer-aided engineering (CAE) tools are poorly equipped to support additive manufacturing. For some additive manufacturing applications, CAD models may be required to support models with hundreds or thousands of features with hierarchical size ranges from microns to meters. These CAD tools also need to represent distributions of materials and material compositions, a task that is not easily accomplished with commercial CAD systems which are typically based on boundary representations and constructive solid geometry. Furthermore, CAE tools need to support Design for Additive Manufacturing (DfAM), including real-time feedback on the constraints and process-structure-property relationships relevant to a particular part and AM technology.

In much the same way that personal computers and 2D personal printers revolutionized print media over the past three decades, AM is poised to democratize design and manufacturing, enabling highly customized, personalized products that can be fabricated on-demand by retailers or personal desktop manufacturing systems. This democratization depends partially on the development of streamlined software tools that are accessible for a broad range of users, not just skilled engineers. While many CAD and CAE tools require significant engineering expertise, many user-friendly tools are being developed for creating digital 3D models. Online co-creation tools offer simple, intuitive ways to modify the appearance and geometry of an existing 3D model. Low-cost, easy-to-use 3D scanning technologies are being used to create digital models of physical objects, which can then be additively manufactured.

With AM, we can imagine a future in which customers *design* their own products on their own computers, rather than being forced to simply *select* an option from a catalog. Engineers can tailor every aspect of a product from its microstructure to its form, and complexity is nearly free. AM is poised to unleash a wave of innovation with profound implications for the way we design and build our engineered world.