Advances in 3D Printing for Education and Research

November 2009

Zehavit B Reisin, Product Marketing Manager, Objet Geometries Ltd., Israel

ABSTRACT

Digital Materials™—the latest major development in 3D printing—make it possible to fabricate models from a wide range of composite materials. This development enables the printing of models, and even specific parts of models, with physical and mechanical properties previously unobtainable with 3D printing systems. This paper explores the potential impact of advanced 3D technology on education, training and research.

INTRODUCTION

Models have always been used in research for demonstrating theory and examining feasibility. Often, researchers and educators use physical, three-dimensional models to facilitate the communication of design concepts and intent. If one picture is worth the proverbial thousand words, one model can have the communicative value of 1,000 pictures.

When Objet introduced PolyJet™ technology in early 2000, it became practical, for the first time, for educational institutes and research facilities to quickly and inexpensively produce complex, high-quality 3D models. The models produced were made from one modeling material, in the Objet FullCure® family of acrylic-based photopolymers. These materials yield models with different mechanical and physical properties, depending on the material used.

Objet's new PolyJet Matrix™ technology, takes 3D printing to a higher level. First announced in November 2007, this technology makes possible the simultaneous jetting of two different types of modeling materials while printing models. Objet demonstrated this at EuroMold, in December 2007, and was awarded first prize for innovation. The following are some of the benefits of using this technology for printing models.

Mixed Tray Printing. With this option, different parts are printed with different materials in a single build, eliminating the need for material replacement, and expanding simultaneous printing possibilities for multiple users. This has the potential for dramatically reducing operating costs, and allows a great degree of flexibility, necessary in educational and research settings.

Mixed Parts. This option enables printing a complete model whose parts are made from different materials. The printed model is realistic *as-is*, in that its individual parts have the required color and/or mechanical properties. Eliminated is the need for designing, printing, and then gluing separate parts to make a finished model. This approach also offers dramatic savings in printing and post-production processing.

Digital Materials. These are composites of two FullCure model materials. Specific material combinations yield models with varying physical and mechanical properties. Laboratory tests can be performed on models with the required properties, and models can be made that communicate not only the look, but also the texture, feel and strength of the design.

COMPOSITE MATERIALS

A *composite* is a three-dimensional combination of at least two chemically distinct materials: a *reinforcing* material is embedded in the *matrix* material. The result is a material that has mechanical properties that cannot be obtained with either of the component materials alone.

Composite materials have been used since ancient times: adding straw to mud for stronger walls. In more recent times, composites were created by adding carbon black to rubber, steel rods to concrete, sand to cement and asphalt, fiberglass to resin, etc.

Today, composites are found in hundreds of common and specialized applications, from golf clubs and tennis rackets to aircraft and spacecraft. Composite materials are used when there is a need for strength in a light-weight product. By carefully engineering these materials, their properties can be tailored to meet specific applications.

Digital Materials

PolyJet Matrix technology brings the advantages of composite materials to 3D printing. This is the technology behind Digital Materials—each specially fabricated from two substances to produce parts and models with attributes not available by printing them with any single material or with a simple mix of materials.

Digital Materials are fabricated on the fly, automatically, during printing, from two modeling materials—each with distinct properties. Software determines the range of Digital Materials that can be obtained from the basic materials installed, and controls the jetting parameters for printing them.

The wide range of materials made possible by this technology offers improved mechanical and physical properties in printed parts. For rigid items, this means varying degrees of tensile strength, flexibility and impact resistance. Rubber-like parts can have a range of Shore A values, previously unavailable with 3D printing. All of this is achieved by fabricating specific combinations of rigid and rubber-like modeling materials.

For example, model materials in the Vero family are rigid. If a Digital Material is fabricated from one of these together with a rubber-like secondary material, the result is a material that is tougher than the primary material. If the primary material is flexible (from the Tango family) and the secondary material is rigid, the resulting digital material is stronger (higher tensile strength), harder (increased Shore Scale A value) and more resistant to tear.

USE IN ARTS & INDUSTRIAL DESIGN

The first commercial implementation of Digital Materials released consisted of 21 materials. The enthusiasm with which these Digital Materials were received encouraged Objet to release nine additional Digital Materials, which together formed *Digital Materials Pack 1*. These materials offer design students the ability to print model parts having different degrees of translucence—used, for example, to highlight parts of a model. Also possible with these materials is the ability to print parts with a built-in pattern, and to achieve polypropylene simulation with improved dimensional stability. Examples of the material properties achieved and their uses are shown in table 1.

Figure 1: Printed patterns

Primary: FullCure720	**Secondary:** TangoBlack
Digital Material feature	**Applications**
distinct translucent shades to highlight model parts	• medical applications • mechanical assemblies • electronic assemblies

Primary: FullCure720	**Secondary:** VeroBlack
Digital Material feature	**Applications**
pattern visualization—dots, grid	• telecom • automotive • consumer goods • architecture

Primary: DurusWhite	**Secondary:** Vero family / FullCure720
Digital Material feature	**Applications**
polypropylene simulation, with dimensional stability	• automotive • packaging • gardening • irrigation & piping • containers • laboratory equipment • loudspeakers

Table 1: Digital Materials Pack 1—applications

USE IN MECHANICAL ENGINEERING

For prototype models to be suitable for mechanical engineering, design testing, and other educational and research projects, they must look, feel and function like “the real thing,” in terms of physical appearance, tactile qualities and operational performance. To meet this challenge, Digital Materials simulate elastomers and commodity plastics.

Elastomer Simulation

Digital Materials can simulate elastomer products, in hardness (Shore scale A), flexibility (elongation-at-break) and tear resistance. These features are available in Objet Digital Materials Pack 2, which consists of 18 new model materials, 12 of them rubber-like.

Primary: TangoBlackPlus/TangoPlus **Secondary:** VeroWhite	
Digital Materials feature	**Applications**
elastomer simulation	• wires & cables • grips & handles • plugs & connectors • shock absorbers • function buttons • gaskets & seals • living hinges

Table 2: Digital Materials Pack 2—elastomer applications

Figure 2: Printed model with soft function buttons

Figure 3: Printed gasket

Commodity Plastics Simulation

Digital Materials can simulate a variety of commodity (standard) plastics. These Digital Materials are also available in Objet Digital Materials Pack 2.

Primary: VeroWhite **Secondary:** TangoBlackPlus/TangoPlus	
Commodity-plastics simulation	**Applications**
polyethylene	• toys • pipes • wire • cable insulation • shampoo bottles
polypropylene	• food containers • lab equipment • loudspeakers • automotive (bumpers) • packaging
polystyrene	• CD/cassette boxes • food packaging • domestic appliances • electronic products • toys
PVC	• window frames • wire insulation • pipes • packaging • household appliances
shades, textures	• labels, imprints

Table 3: Digital Materials Pack 2—plastics simulation

Figure 4: Printed shading

At present, a total of 48 unique Digital Materials are available, realistically simulating a vast range of industrial materials. With Objet's Connex line of 3D printers, up to 11 *different* materials can be applied to a single model.

CONCLUSION

New advances in 3D printing technologies improve the realism of printed parts and entire working models, making them more suitable than ever for design demonstration and testing, an important aspect of education, training, and research. In addition, 3D models tangibly communicate size, shape, feel, function, and movement, even over distance. A design file can be sent anywhere in the world, where it can be printed—instantly communicating this information. This facilitates the sharing of knowledge, distance learning, and cooperation between researchers.

With 3D printing, specialized parts can be made, on site, with innovative materials, replacing those produced with traditional methods. This is especially useful for making custom research tools.

Objet contributes to making all of this possible by developing Digital Materials and 3D-printing technologies that can be applied in an ever-growing range of educational and scientific settings.