SELECTIVE LASER SINTERING AS A RAPID PROTOTYPING AND MANUFACTURING TECHNIQUE

By Kent Nutt

Introduction

With accelerating growth and competition in today's global marketplace, manufacturers face the daunting tasks of meeting changing market needs, maintaining market share, and reasserting a technological edge. Now, more than ever, adopting new technologies is a key component in ensuring the successful outcome of new projects--and in producing long-term market success.

Over the last decade, great strides have been made in the advancement of conceptual design technologies, including the development and maturity of three-dimensional (3-D) CAD and CAE software tools. Additionally, the development and implementation of CAM and CIM technologies have streamlined mass production processes.

Design for manufacturing (DFM), design for assembly (DFA), and concurrent engineering are additional techniques developed to enhance communications and interaction among design, marketing, and manufacturing personnel. The collaborative efforts cultivated by these techniques provide ongoing reality checks as products evolve from conceptual design to final form.

Amidst all this technology and innovation, remaining bottlenecks between conceptual design and mass production occur:

1.) in the rapid creation of three-dimensional models and prototypes; and
2.) in the cost-effective production of patterns, molds, and tools.

These bottlenecks are especially prevalent where complex shapes or geometries are involved and occur primarily because traditional techniques, including manual methods, often require weeks--or even months.

Although product designers and manufacturing engineers must be able to visualize and assess designs for form, function, fit, and other factors before designs can be finalized for production, there is only so much time that companies can afford to spend on the creation of models, prototypes, patterns, and tools. This is especially true in industries where declining volumes and increasing varieties of parts and products must be produced.

What's more, lengthy delays can prevent designers and engineers from going through the reiterations and fine-tuning necessary to create a design with superior qualities, functionality, manufacturability, and market potential.

During recent years, several new technologies for quickly creating three-dimensional representations have emerged to address these needs and challenges. They are known under a variety of names, including rapid three-dimensional prototyping, desktop manufacturing, solid free-form fabrication, and conceptual modeling, among others.

These technologies offer the capability to rapidly produce three-dimensional solid objects directly from designs created by CAD, CAE, or CAM systems. Instead of waiting several weeks for a model, prototype, or pattern to be completed, these technologies can finish the job in a few days--or even a few hours.

Testing for Form, Fit, and Functionality

As evidenced throughout the manufacturing industry, one of today's most critical requirements is the ability to quickly fabricate prototypes that allow both a review of the product's proposed form and the testing and verification of fit, function, and other specifications. To provide accurate results, however, these prototypes must employ materials with characteristics similar to those used in the final product.

Unfortunately, early rapid prototyping technologies like stereolithography, which use only photo-sensitive liquid polymers, have limited applications here.

Another technology, however, the Selective Laser SinteringTM (SLS) process developed by DTM Corporation provides greater potential and a wide range of applications. In contrast to stereolithography, the SLS process offers a multiple-materials approach to rapid prototyping technology, addressing the need for functional, comprehensive design evaluations, while at the same time offering the ability to generate patterns and tools--and the future potential for direct fabrication of parts using metals and other materials.

How the Selective Laser Sintering (SLS) Process Works

As the SLS process begins, a very thin later of heat-fusible powder is deposited into a work space container and heated to just below its melting point. An initial cross-section of the object under fabrication is traced on the layer of powder by a laser. The temperature of the powder impacted by the laser beam is raised to the point of "sintering," forming a solid mass. As the process is repeated, each layer fuses to the underlying layer, and successive layers of powder are deposited and sintered until the object is complete.

The laser beam intensity is modulated to sinter the powder only in areas defined by the object's design geometry. In areas not sintered, powder remains loose and serves as a natural support for the next layer of powder and the object under fabrication.

CAD and CAE: Conceptual Design Requirements for the SLS Process

The SLS process requires the use of CAD and CAE software, with designs created preferably in three-dimensional surface or solid form. Designs created in 2-D CAD or CAE require modification prior to SLS acceptance and processing.

Design models created in CAD, CAE, or CAM software are entered into the rapid prototyping system through a compatible interface known as the ".STL file." This file format is currently the industry de facto standard and is a method used to convert CAD databases into a form usable by rapid prototyping systems.

The .STL file is transferred to the SLS machine for computer-based processing. The modulated laser beam selectively describes the object's geometry based on the coordinate points. The design information is thus transferred from a computer representation to a real world, physical object through a unified, completely digital process.

The SLS process: A tangible reality

The SLS process has several inherent advantages that address the basic requirements for fast modeling, prototyping, and pattern-making within industry. These include:

1.) Speed;
2.) The additive-layer nature of the part building process; and
3.) The ability to employ a variety of heat-fusible powdered materials.

Speed: Using the SLS process a model or prototype can be produced at the rate of one-half to one-inch per hour, depending on the complexity of its geometry. A four-inch part can conceivably be finished in four to eight hours.

The SLS process software also allows concurrent slicing of the part geometry files while processing of the object is taking place. Non-SLS technologies currently require time-consuming, crosshatching scans of various types of lasers interspersed with re-application of photopolymer resins. This must take place before the part can be removed for final curing.

Moreover, no post-production curing is necessary with the SLS process, except when ceramic materials are used. In contrast, current implementations of non-SLS processes require some degree of post-production curing to completely harden the liquid photopolymer resins.

An additive process: Based on an additive-layer process, SLS technology does not require traditional dies or part-specific tooling and is particularly applicable where fewer, more complex designs are to be prototyped or modeled.

The additive-layer nature of the SLS process also allows for the creation of very complex parts without the need for external support structures, clamping, or repositioning of specific portions of the design geometry. Designs with internal cavities, overhangs, notches within notches, and other intricate geometries, which are difficult to achieve through other processes, are easily produced using the SLS process.

Moreover, the unsintered powder that surrounds the fabricated part during the SLS process provides a customized support structure that is easily removed upon part completion.

Multiple materials: The SLS process can use a variety of materials. In fact, virtually any material that softens and has decreased viscosity upon heating can potentially be used. Materials currently available include: polycarbonate, investment casting wax, and PVC. Materials commercially available by the end of 1991 include ABS plastic and nylon.

Additionally, low-temperature ceramic parts can be fabricated with the SLS process using polymer-coated ceramic powder, with curing as a secondary process. While not yet released for commercial use, ceramic materials will be available in the near future.

The natural evolution of the SLS technology is also heading toward the use of powdered metals and alloys. Current market research indicates that this capability will have widespread application throughout manufacturing industries, primarily because more than percent of all design prototypes are currently made from various metals using conventional processes.

DTM is currently conducting tests using metal powdered with the SLS process. In fact, early laboratory research efforts in sintering brass, copper, aluminum, and cobalt at the University of Texas at Austin have proven very successful. These efforts are continuing with additional metal alloys and metal powder blends. Commercial use of metals is expected to be a reality in the near future.

Primary applications of SLS technology

Primary applications of the SLS process are occurring in three major areas:

1.) Visual representations (models);
2.) Functional, durable prototypes; and
3.) Production capabilities, including the creation of the molds, patterns, and tools required for limited production runs and on-demand batch manufacturing.

The advantages of the SLS process are significantly impacting product design capabilities in manufacturing organizations across many industries, resulting in shorter design cycles and superior design. In effect, the use of the SLS process serves as a time-saving, communications-enhancing bridge between design and manufacturing.

Specific industrial segments where the SLS process is in use include the automotive, aerospace, computer, consumer goods, electronics, foundry, and medical industries. SLS technology also serves as a front-end process to conventional machining, mold-making, and investment casting processes.

SLS Technology Applied to Investment Casting

In addition to its ability to rapidly transform CAD drawings into three-dimensional models and prototypes, the SLS process provides the ability to quickly create wax patterns directly from CAD drawings--without tooling. These patterns are then used with the lost wax method.

Eliminating the tooling stage translates into numerous benefits for investment casters, including:

1.) Minimized upfront tooling costs;
2.) Significant time savings; and
3.) The ability to produce complex shapes that were previously too difficult to produce via tooling.

The SLS process and wax pattern-making are extremely well-matched for a number of reasons:

1.) The SLS process is the only process that can utilize investment casting wax.
2.) With average tolerances ranging from +/- .002 to +/- .010 inches, the SLS process offers the accuracy required by investment casting applications.
3.) The SLS process can easily create complex shapes and geometries that are difficult to produce via other methods.
4.) The problems, delays (as long as 100 hours for resin-based patterns), and complications sometimes associated with burnouts are virtually eliminated with the SLS process.
5.) Wax patterns created with the SLS process feature a surface finish that is suitable for most investment casting applications, typically 100 to 120 average micro inches RMS.

Specific applications where the SLS process can be useful to investment casters include:

1.) The creation of prototypes, short run parts, and marketing samples;
2.) Process development and refinement of gating and metal shrink requirements;
3.) Prototyping and creation of production tooling.

Additional Applications for the SLS Process--Present and Future

Because the SLS process utilizes an expanding and diverse variety of powdered materials and allows for the formation of complex geometries, a number of additional tooling and production applications become possible, including the following:

Short Run Tooling and Soft Tooling - Here, the SLS process can be used to create a master pattern from which various types of soft tools, including those made of silicon rubber and epoxy, can be made. These tools can then be used to generate short runs of parts for use in testing, marketing, and verification of fit and form. These short run parts also can be used, in some cases, to meet custom manufacturing requirements.

Spray Metal Tooling - An SLS-created pattern made of polycarbonate, is coated with thin a layer of protective material, followed by sprayed-on layers of liquid metal to further coat all surfaces. The metal-coated pattern is then put in a container filled with molten metal. The metal cools, and a tool for casting additional parts is created. Because the tool is made of metal, usually zinc with epoxy or aluminum backing, it is more durable than soft tools and can produce runs of up to several thousand parts, depending on the application.

Plaster Cast Tooling - As with other tooling methods, an SLS-generated pattern can be used to create a plaster cast tool, which is then used to make steel and other metal parts.

Vacuum Form Tooling - The SLS process can be used to create the master form, from which the vacuum-formed object will achieve its final shape. During the creation of the form in the SLS process, the form's porosity can be adjusted. This is an inherent advantage because a master form created with a suitable level of porosity eliminates the extra step of drilling the dozens of tiny holes needed to allow air to pass through during the vacuum process. With the SLS-generated form, air from the vacuum passes directly through the porous material.

Numerically-controlled (NC) tooling and path verification - An SLS-generated part can be used to trace and program the tooling paths that run numerically-controlled machines.

Electro Discharge Machining (EDM) - Upon availability of carbon materials for use with the SLS process, it will be possible to quickly and affordably generate the carbon or graphite electrodes used in electrode EDM. Currently, these electrodes are difficult and time-consuming to produce.

Forging Dies - Drop-forge dies are made of steel or steel castings at a grade of 0.60 percent carbon open hearth. Dies of this steel will forge mild steel, copper, and tool steel. SLS-generated wax patterns can be used to produce forging dies of steel castings. A pair of these dies can then be used to produce up to 20,000 pieces.

Service Bureaus: Bringing SLS Technology to the Marketplace

To fully understand customer requirements and how SLS technology and applications can meet these requirements, DTM has opened two SLS sales and service centers. These facilities provide a low-cost, low-risk way for customers to utilize the SLS technology and receive customized technical support as needed.

The DTM service bureaus offer a staff of technical support personnel, advanced CAD equipment, and multiple SLS 125 Systems. Customer designs are accepted as physical drawings and/or 2-D or 3-D CAD files in STL/IGES formats.

DTM's Sales and Service Centers are located in Austin, Texas at the company's headquarters and in Brecksville, Ohio. Direct sales of SLS Systems to end users will begin in late 1991.

For additional information on the SLS process and its applications, please contact DTM Corporation at 512/339-2922.

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