RAPID PROTYPING IN THE JEWELRY INDUSTRY. THE BASICS AS THEY RELATE TO THE JEWELRY INDUSTRY.

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ABSTRACT

This paper will cover the basic types of Rapid Prototyping processes and equipment available to the Jewelry Industry. Reviewing the Pros and Cons of each basic system and their configuration.

KEY WORDS

Stereolithography, Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Laser Sinterings, Laminated Objects, Desk Top Manufacturing, Fused Deposition Modeling, Polymers, Cycle Time, Modeling.

In last year's Symposium Dr. Corti of The World Gold Council in London released data from a worldwide survey that listed technology development needs in the jewelry industry. They were ranked according to importance to the Industry. This survey identified CAD/CAM and rapid prototyping as an emerging technology with a high priority ranking. That gave me the idea for this paper, which is to explain the various ways and means of creating a 3 dimensional part by means of rapid prototyping.

Let's begin by defining some of the terminology. Rapid prototyping is the physical modeling of a design using a special class of machine technology. Rapid prototyping systems quickly produce models and prototype parts from 3-D CAD model data. These processes include:

- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Laminated Object Manufacturing (LOM)
- Fused Deposition Models (FDM)
- Solid Ground Curing (SGC)
- Direct Shell Production Casting Process (DSPC)

I will discuss only four of these systems because of their applications. "Desk Top Manufacturing" terminology originated because of the small footprint of the apparatus, taking input from a personal computer, running unattended overnight, no toxic fumes or hazardous materials of major safety concerns, and all <u>capable</u> of <u>fitting</u> on a <u>desk</u>. These systems use lasers or light, photo sensitive polymer or metal and can create 3-dimensional parts in a short time, lower cost, without the need of a shrinking and skilled work force. The great advantage of these systems is that design changes require nothing more than changes to an image on a personal computer.

Imagine if you were a tool maker and mold making were this easy: first, your part concept takes shape on a CAD/CAM systems 3-D solid modeler. Then the CAD program employs a software module to automatically create the resulting model's negative – essentially a digital version of the mold cavity. This computer bound "mould" is then downloaded to a rapid prototyping system, which builds a metal casting pattern for the mold cavity insert, in a matter of hours. Then a casting of the prototype is cast in sand or investment casting, with some cleanup and modeling, and you have a functional mold that can do thousands of shots. From beginning to end, the injection mold takes less than 8 weeks versus the 20 you might expect at half the cost you would pay to cut in steel the old way. This may sound farfetched, but in '94 Ford Motor Co. was using this technology to create an injection mold and continues to use this technology today.

HISTORY

Stereolithography began in the mid '80's and has evolved into a thriving industry. In 1996 the rapid prototyping market grew by 42.6% to an estimated $421 million up from '95's $295 million with estimates of $1.1 billion in '99. At first, only the big players (Ford, GM, IBM, McDonald-Douglas', etc.) were willing to invest in this technology, but they were immediately rewarded with the benefits of this technology, which is responding to engineering and market changes, with the least expense in prototyping. Over the years the software for CAD drawings has become more advanced and lower in price. The resin and materials have become more varied and the types of apparatus all have evolved. Today there are many companies that use this technology to maintain their competitiveness in the market place. Some examples are:

- GM – engine manifold
- AT&T – phones and cases
- Cobra – gold clubs

- Tupperware – plastic bowls

As you can see, the possibilities are endless in what you can create in a material that can be cast, molded, or used as is, to represent a first run prototype.

<u>BASIC EQUIPMENT SET-UPS</u>

The concept and processes for rapid prototyping are numerous, but they all basically follow the same steps. That is that you begin with a computer generated model in a file that is compatible with the equipment (IGEAS, STL., XFT, etc.). That file is down loaded to a piece of equipment that will build the part in slices that ultimately, and through some post process, gives you a 3 dimensional exact replica of that CAD drawing. Detail and dimensional tolerances are dependent on the process, but a functional part can then be molded, cast or exhibited within a very short time, making this functional from a design and marketing standpoint.

I will now briefly describe each of the types of rapid prototyping methods:

- Stereolithography Apparatus (SLA) – In this system the machine receives design data from the CAD files and "slices" the data into thin horizontal cross sections. Then, a finely focused U.V. laser, guided by software on the X-Y axis, draws the first cross section of the CAD design on the surface of a vat of U.V. sensitive polymer (liquid plastic). An elevator table in the polymer vat rests just below the liquid surface. When the .015" diameter laser beam hits the liquid polymer surface, it solidifies a layer 0.005" to 0.030" thick only at the point of laser impingment. After a part slice at one depth has been made by scanning the laser beam back and forth in the shape of the model or pattern to be developed, the elevator platform, upon which the model is being constructed, drops the programmed amount. Another layer or slice is created on top of the first in the same manner. The process continues until the complete model has been constructed, thus the model is built from the bottom up. The process repeats until the part is complete, automatically and unattended. The part is stripped from the table and post cured in a U.V. oven for final curing. Speed is the main advantage of this process in that a CAD design is turned into a 3-D model that may be viewed, studied, tested, and compared. Average model takes from 4-12 hours to produce. This process has reduced some companies concept to market times by half with savings in the thousands. This type of apparatus is the most dominate in the industry with many job shops creating prototypes for relative low costs.

- Selective Laser Sintering (SLS) – This process is similar to SLA in that it builds a part layer by layer, but instead of using a photosensitive polymer it uses a variety of powdered materials, including polycarbonate, PVC, investment wax, and virtually any material that flows when heated. Beginning with a 3-D CAD data file download, the system deposits a very thin layer of powdered material on a flat platform in a cylindrical container. A laser beam traces across this layer, "sintering" (welding without melting) specific areas according to instructions from the object's CAD file. When the first layer is complete, the platform lowers very slightly, and another thin layer of powder is added. Selected areas of this layer are sintered by the laser to form the next cross-section; which bonds to the previous layer. The process continues, layer by layer, until the 3 dimensional object is complete. The unsintered powder stays in the container during the process, serving as a natural support for the object. This excess powder is removed and recycled upon completion of the object. This process can hold tolerances in a range of + or - .002 to + or - .010 and no post cure is necessary on some material.

- Laminated Object Manufacturing (LOM) – Models, prototypes, patterns for investment and sand casting, and other solids up to 15" x 10" x 15" can be producing in minutes from a CAD image using a laminated object manufacturing system. Performing like a 3-dimensional laser printer, laminated object manufacturing, manufactures an object by laminating and cutting its 2-dimensional cross section from film, foil, paper, composites, or other sheet material. A focused laser beam, positioned by the X-Y system, cuts around the peripheries of the cross section according to geometrical information provided by the computer producing a 15" x 10" x 15" high part. Therefore, cutting speed of the various materials are up to 15" per second. The entire process of cutting the layers can take just a few minutes. The laminated object manufacturing material are pre coated with heat activated adhesives. Materials .002 through .02" can be used with diameter of 17" x 11 ½" width. The laser cut pieces are stacked on a movable table and are then removed for post curing (cross hatching during cutting enables removal of unwanted areas).

- Fused Deposition Modeling (FDM) – This new CAD driven desktop modeling system uses a waxy, tough, non-toxic plastic filament that is heated and directed in place by an X-Y controller extruder nozzle (some units with 2 nozzles – one for the wax, another for the support material). Called fused deposition modeling, the process builds 3-dimensional objects without, expensive tooling or expensive lasers, by building parts layer by layer from material that is heated and then solidified. The system uses a filament material that is passed from a spool to a head, which heats the material to just above the solidification temperature. As the head moves across the part, the material is deposited on the previous layer, bonding onto it. The fused deposition modeling system uses four materials – investment casting wax, a machinable wax and two plastics. The investment casting wax can be used directly for small production runs, eliminating the need for manufacture tooling. The machinable wax can be used directly for spray metal mold tooling. The plastics have to be used to test fit, form, and function. The system has advantages over others in that it does not require special venting, no lasers or expensive polymers are required and post curing in not required and can even be driven from a FAX! The system maintains an overall tolerance of +or – 0.005 in the X, Y, and Z axis over a 1 cubic foot working envelope. Positioning and repeatability are held to within + or – 0.001". Another units precision is .0005"-.005" in the Z build layer, and dimensionaly .001" in X-Y axis.

DESIGN STAGES

During the early steps of creating designs, you may have a sketch, complete design art, or a specific part to copy. If this is the case, then you must get it into a CAD system to make files that the rapid prototyping machines can understand. This can be accomplished two ways – scanning the artwork or digitizing the existing model. Once this is in your computer, some post clean up work may be necessary or a software program can create a clean 3-dimensional wire frame or J peg file. This should allow you to transfer to the rapid prototyping system and in a few hours have a representative model for the next step.

In the normal design process, a sketch or 2-dimensional drawing is approved and the part is hand cut in wax to create a prototype for making a mold. Then a master is cast and finished out, cycle time for 3-dimensional part is 4-6 weeks. Whereas the artwork to CAD to rapid prototyping is on the order of one week. Design teams can bring to meetings models that were "cocktail napkin concepts" just a few days before. Also, change iterations are swift, more products can be reviewed, casting molds can be made from the models, and some limited runs of tooling can be produced. These prototypes can be used to provide form, fit and function. By making patterns for silicon molds, investment casting or patterns for die cast prototypes. Successful use of rapid prototyping is the union between a process and a technology.

APPLICATIONS

Now that we have an idea of the systems available in the market, let's examine each system and their application in the jewelry industry. By far the stereolithography units dominate the market ranging in price from $95,000 - $300,000, with the lower price unit capable of producing 7x7x9.5" parts to the larger, more expensive system making a 20x20x24" part. The cost of the light sensitive polymer has dropped from $400/gal. to less than a hundred, and the tolerances have been refined as the polymer and techniques have changed. A major drawback to this process has been the ability to define small character and sharp edges with this system due to the material and support mechanisms. For jewelry with fine detail, intricate surfaces, or unusual geometries, these units may not yield the desired results. There are a lot of these units being used by job shops or services that charge per part and might be the best direction to take when evaluating this process for your application.

The process for laser sintering offers the advantage of making prototypes that will duplicate the production parts with reasonable accuracy. Using their investment wax, one can have a piece of jewelry cast in the desired metal within a relatively short time, and any iterations can be accomplished quickly by redoing the CAD drawings and repeating the process. Tolerances of + or - .002 are the limit of the system, which could create problems with fine, intricate shapes in some jewelry designs. As with any prototype made in a design sequence, the making of a rubber mold can also be accomplished using a plastic, nylon, or metal part created on most of these systems, and then multiple parts can be created using that rubber mold.

Probably the best system for use in the jewelry industry, because of part size, geometry and design, is the fused deposition method. Because of the relative low cost of the equipment, not requiring special materials, and accuracy of 0.0005" in Z axis and .001" in X-Y axis, it may be the best method of choice. Prototype can be produced in wax and cast or molded in a post process similar to what was described above.

CONCLUSION

When designing a new part for a market, one is normally facing a cycle time of 6 weeks before the artwork can be turned into a hard 3-dimensional object that can be seen, felt, and touched. The cost in manpower and time can sometimes limit your ability to change your product as the market changes. Today there are multiple methods to create a part from a CAD drawing and have a hard 3-dimensional part in a relatively short time and minimal labor cost. This timeliness can benefit you and your business in responding to a market change, redefine existing products, or provide you with cheap limited tooling runs. It would be my recommendations to you to investigate each method, depending on your needs, and then contact a job shop that has that equipment and allow them to create the parts for a one time charge. Then, if you are satisfied with the results and desire the capabilities of doing rapid prototyping in house, the payback can be in less than 2 years (depending on volume and present labor cost).

I hope that I have given you enough information so that you might try this new technology and experience the shorter cycle time that rapid prototyping can offer you and your organization.