Custom Manufacturing Grabs More of the Rapid Prototyping and Manufacturing Market

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Customized manufacturing — it seems like an oxymoron, since manufacturing usually generates thousands of identical parts, yet it perfectly describes a growing approach to creating just what the market demands today.

Back in the early 1900s, when Henry Ford offered his cars in any color as long as it was black, he did so with good reason. His assembly lines ran quickly and smoothly working with just one set of auto-body parts. However, today's customer has raised the expectations bar on products ranging from surgical implants to custom shoe inserts. Rapid manufacturing technologies offer very attractive solutions to optimize the economics of such challenges.

In this article *DE* explores a range of applications well under way in both customized manufacturing and mass customization. The former term refers to a cost-effective approach to generating a family of very similar products. Each one is based on a common design, which is then produced in hundreds or thousands, e.g., artificial hip joints in a dozen sizes. Mass customization describes the newer business model of creating many parts simultaneously or in quick succession, where each unit is completely unique but is defined by a sequence of consumer-tailored choices, e.g., online ordering of custom game figurines.

The Right Fits for Medical Uses

One very successful custom manufacturing application is the direct-metal production of fully certified dental copings, i.e., the metal base of an actual tooth crown subsequently coated for final use. Rapid Quality Manufacturing (RQM) creates such parts from cobalt chrome metal powders on EOS' laser-sintering equipment. Manufactured in batches of several hundred, the copings are customized to suit individual patients — no two pieces are exactly alike.

Production of each dental coping starts with a scan of either a dental impression of the teeth or, more recently, a scan of the patient's actual teeth (this newer process is called Chair Side Oral Scanning; *see August 2007* DE). This electronic data is sent to a dental lab where technicians review and clean the models and make any necessary adjustments. The lab then sends the revised file to a supplier such as RQM, which laser-sinters the metal substructure.

The cobalt chrome material, medically certified for actual end use, serves as a base on which the dental lab applies a final porcelain coating prior to its being cemented in the patient's mouth. The result is a fast, cost-effective, high-quality crown. As anyone who has had one done will agree, a great fit without lots of in-chair rework is a welcome achievement. Each EOS machine can produce 200-300 copings a day. RQM is currently producing crowns and bridges for its partner, Quantum Technologies of Windsor Canada, and has targeted full-scale production with a second customer for late 2008.

Servicing both the dental and hearing-aid industries is In'Tech Industries of Ramsey, MN, operators of a fleet of high-end 3D Systems' SLA Viper equipment. The company produces such high-resolution parts as fully custom earmolds for hearing aids and patterns for a range of dental end-applications.

In'Tech regularly manufactures anywhere from a hundred to a thousand parts per day just for its hearing-aid clients alone. They have the capability to work from clients' scan data, or do their own laser scanning of silicon impressions, then build the actual parts from biocompatible medical materials in clear, skin, and other colors.

As large as the hearing-aid market seems (a few million per year in the U.S.), it is still dwarfed by business in the dental industry for the simple reason that the latter involves greater insurance coverage. Hence, In'Tech's customers also include a large network of dental labs. Traditionally, after dentists took impressions of teeth, those labs cast the molds with plaster. The heavy physical models became the patterns for fitting various dental parts. Now, In'Tech scans the original impressions or receives direct scan data of teeth, then uses the data to drive its larger SLA Viper Pro machines. The large build volume accommodates rapid production of high-resolution epoxy-based models that include individual teeth, arch sections, and full arches, all on a high-volume basis. These models replace the traditional plaster versions for the actual dental lab work.

Moving from head to toe, consider that few people would buy a pair of generic one-size-fits-all shoes; even flip-flops come in small, medium, and large. You definitely want the right fit when you need extra support to slip inside those shoes — known as a medically prescribed orthotic. Soletec Systems of Leicestershire, England, offers a full range of services for producing custom footwear and orthotics, and they have turned to rapid manufacturing to efficiently create the best fit.

From Orthotics to Implants

The company installs MicroScribe scanning equipment from Immersion at the offices of medical professionals and trains them on its use. For an orthotic, first a simple procedure automatically captures seven different data points on a patient's foot. Soletec's custom software then takes this information and creates a CAD model of the desired corrective orthotic form (a slim, removable insert that sits on the insole of a shoe). Lastly, the CAD geometry file is sent electronically to a service bureau where the unique orthotic is produced on a CNC machine from medical-grade polypropylene or nylon acetate.

This direct approach eliminates the traditional need for making a rather messy plaster cast of a patient's foot. The cast had to be delivered to a service bureau to be used as a mold for forming the actual part. Soletec Systems' solution does away with the

molding step, saves up to two weeks over the traditional shipping and manufacturing time, and produces finished pieces that rarely require any modifications.

When it comes to delicate surgeries, even more is at stake to do the best possible job the first time. Arcam's Electron Beam Melting (EBM) systems are the source behind the production of just-right CE-certified joint-replacement products from Adler Ortho Group, an Italian manufacturer of orthopaedic implants.

Several years ago, Adler Ortho developed a new design for a titanium acetabular cup as part of a hip-replacement surgical configuration. The product name comes from acetabulum, the cup-shaped socket of the hip joint which is a key feature of the pelvis. The head (upper end) of a femur (thigh bone) fits into the acetabulum and articulates with it, forming a ball-and-socket joint.

Key to a successful surgery, termed "fit and forget," is the implant's ability to attach itself to the hosting bone. Adler Ortho chose EBM technology to produce implants with full material properties formed in a lattice structure for improved osteointegration (bone growth into the part). The choice of material was Ti6A14V, and the final design is a lattice with spaces of about 700 microns throughout the outer surface. Bone growth occurs by attaching itself directly to the metal without any fiber tissue involved. During its first year on the market, more than 1,000 cups of various sizes were successfully implanted, and production is ramping up.

For certain situations, surgical implants involving actual bone material can offer the best chances for success. AlloSource, one the nation's largest nonprofit bone and tissue providers, fills this need by shaping custom spinal implants from actual femur bone material. Their systems of choice are MDX-540 desktop milling machines from Roland DGA. The precision results are so good that the provider produces anywhere from several hundred to close to a thousand implants per week.

The implants, custom fit for each patient, are used in spine-fusion surgeries and look like flat, oval disks. To drive production, AlloSource creates the designs from a mix of physician-input, anatomical restrictions, and technician know-how. Lumbar grafts tend to be made in five or six sizes (heights) in 2mm increments; cervical grafts can have eight or nine heights usually 1mm apart.

Roland's Rapid Custom Manufacturing (RCM) technology makes fast work of milling exact shapes, producing spinal implants with an optimal cross-section for each patient. This approach offers a major improvement over traditional clinical processes for mass-producing one-size-fits-all parts, or tediously hand-sculpting unique versions.

Satisfying Niche Manufacturing Needs

One of the early adopters of direct digital manufacturing is ScriptPro of Mission, KS, a manufacturer of automated pill-dispensing systems for pharmacies. The company has been using Stratasys FDM systems for several years, manufacturing selected parts for end-use in their machines. A popular model, the SP200, is expected to fill from 60 to 80 percent of most prescriptions.

ScriptPro's dispensers can be the size of about four refrigerators side by side and include an electrical cabinet plus a control/monitor station. The system uses a robotic arm to pick up an empty pill vial, take it to a dispensing cell for filling, and place it on a conveyor. A label is applied, then the conveyor moves the vial into position in a collection station.

One of the challenges of designing and manufacturing these robotic dispensers is the need to accommodate the large variety of vial sizes (more than 50) available to pharmacies. Although most pharmacies use just a few sizes that vary in their sales demand, ScriptPro must be able to quickly assemble each customer's dispenser configuration.

ScriptPro builds unique holders or bezels designed so that the user cannot put the wrong vial into the

machine. Each SP200 dispenser has three vial receptacles and six bezels. The more basic styles are molded, but less common parts are produced on the Stratasys systems. The FDM process achieves such tight tolerances that little or no post-production work is required other than washing the parts before installation.

Being able to build the less common size bezels on an as-needed basis means savings on many levels. ScriptPro not only eliminates the need for custom-tooling (taking months each time) but keeps its inventory low, and can easily adapt to new styles.

Bringing Gamers' Worlds to Life

Rapid manufacturing plays a role in having fun, too. Z Corporation has sold its full-color 3D printing systems to at least two companies involved in video-game worlds, including the companies involved in the phenomenally popular *Rock Band 2* and *World of Warcraft*. For both situations, game enthusiasts create online characters (known as avatars) with unique feature combinations and order a 3D physical figurine that reflects the same design.

MTV Games and Harmonix produce Bandmate figurines based on avatars from the recently released *Rock Band 2* game. Players visit rockband.com, create a model that reflects their own colorful rock-star persona, style, and musical instrument, then select from a number of different options to create a unique final character. Choices include 25 combinations of height and body style, various hair styles, about ten different facial expressions, male or female character, and even the ability to create a custom tattoo or band logo.

Harmonix takes the information from these selections and uses a complex algorithm to convert the data into a Z Corp. format. The process is quite automated, with the files only being examined for any copyright violations in the logo design. Finished figures range from about 3 in. to 6 in. tall, with all designs priced $69 each. Current manufacturing time is a week to ten days, and 40 orders were placed within the first three weeks of the new game (version 2) coming online. Harmonix expects to produce close to a thousand a month by the end of 2008, and expand to other online game environments.

FigurePrints takes a somewhat different approach to the creation of 3D characters based on *World of Warcraft* avatars. Any character pose is possible, and the FigurePrints designers perform minute inspection and design work to ensure that all parts are thick enough to print, the angles and positions of weapons and armor are aesthetically pleasing, and all elements have proper support. Finished characters can be as large as 8 in. tall; considered customizable art pieces, they cost $129.95. The company's website states that the combination of overwhelming demand and hand craftsmanship currently limits them to taking orders on a monthly lottery basis.

Z Corporation says expanding the volume of this general concept depends on eventually simplifying the process for people who have intellectual property (IP). Companies are definitely recognizing the value of letting consumers interact with IP (think personalized M&Ms). Customized manufacturing is just an extension of this concept: the ability to take digital customized content, make it physical, and attach a monetary value to it.

Measuring Time Savings with RP&M

One real-world analysis of the cost-savings possible with rapid manufacturing technology comes from Linear Mold and Engineering, a Michigan manufacturer of precision mold and prototype tooling. Always on the lookout for savings in materials and energy, the company evaluated two-and- a-half years' worth of benchmark figures to compare project times for machining, CNC tooling, and EDM (electron discharge machining) versus Direct Metal Laser-Sintering (DMLS), the latter on EOS systems. Comparing total mold times for the first three traditional methods to times for molds made with DMLS inserts, the latter results included a decrease from five weeks to three weeks for a four-cavity mold-insert family and a reduction from 210 hours to 97 hours for single-cavity tool inserts.

Keep Up with Manufacturing Activity

• To understand the growing level of activity in the custom manufacturing world, check out the e-newsletter *The Additive Fabrication Spy* compiled by Castle Island's Ed Grenda. Known for his *Worldwide Guide to Rapid Prototyping* website and publications, Grenda tracks patent applications in relevant areas and provides regular e-mail updates.

• Terry Wohlers continues his extensive tracking of absolutely everything RP&M at his website. And you may also want to subscribe to the RM-Platform, the online discussion forum of The European Collaboration on Rapid Manufacturing, for case studies, news, and events.