Additive or subtractive? Which rapid prototyping process is right for your job?

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Subtractive RP—high-speed machining of aluminum alloy molds—is on the rise at Vista and in general.

When most people consider rapid prototyping, they probably think of one of the additive processes that have become well-known over the last decade or so. These include stereolithography (SL), selective laser sintering (SLS), and fused deposition modeling (FDM). Developers of these RP processes and machines continue to make advances in terms of number and quality of available materials, dimensional and surface quality of models, and cost.

However, subtractive rapid prototyping technology—machining using high-speed spindles and relatively machinable aluminum alloys to provide fast turnarounds for tooling and functional parts—has also advanced to a point where it is now a complementary and sometimes competitive alternative to additive RP.

So, which process is right for your job? That depends on several factors, according to Dan Mishek of rapid prototyping and rapid tooling service bureau Vista Technologies LLC (Vista; Vadnais Hts., MN).

"Picking a prototype application can be as difficult as designing your product," he says. "The method you choose can affect your time to market, your budget, and your sanity. From metal to plastic prototyping, there will always be more than one RP process and company that can assist you."

"There is no pat answer as to which technology is best," echoes Dan's father Jim Mishek, president of Vista. "We work with users on a case-by-case basis to determine which RP technologies are best for their application."

Machining on the move. That said, Vista sees a big move among their customers toward subtractive RP based on high-speed machining. "The lure to go to real parts versus an additive RP material is huge," Jim Mishek says.

"We have seen our business go from 65% being form-and-fit prototyping eight years ago to 70% functional prototyping today," he continues. "With the increasing pressure of getting parts to market, companies need to get the most from their prototypes. The more testing and qualification they can do to prove out design and material, the faster they can release production tooling."

Aluminum molds often become production tools, *even for customers who originally intended to replace them with "hard" tooling.*

According to Jim Mishek, the move to rapid CNC machining and rapid tooling was fueled in some ways by the past reluctance of Japanese manufacturers to adopt CAD solid modeling technology. "Therefore, they were not allowed the luxury of using emerging additive RP technologies that the West was using," he explains. "To compete in global markets without the additive RP technologies, they developed new software and manufacturing technology. One of the key developments was high-speed milling."

Rapid tooling was used to quickly produce components for this infrared camera, facilitating the transition from prototype to production.

Vista uses three vertical machining centers with fourth-axis capability. Spindles capable of speeds to 42,000 rpm, CAD/CAM software, and proprietary fixturing allow the company to quickly produce complete tooling packages for injection molding. According to Dan Mishek, the company can produce and prove out molds with undercuts, manual slides, hand pick-outs, and other relatively complex features in 2–3 weeks. Molds can also include features such as runner shutoffs to allow users to sample different plastic materials in the same tool.

Vista machines molds from 7075-T6 aluminum alloy. "It's a consistent, high-grade material that allows us to guarantee a minimum of 5000 parts from a tool," Jim Mishek explains. "We've actually guaranteed more than 20,000 parts from a tool, and we've had users produce more than 30,000 parts on a couple of molds." Part geometry and the plastic material

RP Once Again on the Rise

Industry consultant Terry Wohlers says rapid prototyping reversed a downward trend and grew at a significant rate in 2003, the last full year for which data are currently available.

According to *Wohlers Report 2004*, a comprehensive snapshot of trends in the RP industry, RP machine builders in general experienced growth in 2003: of 28 manufacturers around the world, 17 sold more machines than in 2002. RP service bureaus fared less well than machine builders: revenues at service providers improved only marginally.

Global RP usage increased significantly in 2003. The estimated number of RP models produced worldwide posted a hefty increase, jumping 18.4% to 4.83 million from 2002's estimated 4.08 million parts, according to Wohlers' data. The report says an average of about two copies (2.06, to be exact) of a unique design are built, meaning that 2.34 million different parts were produced in 2003.

The 2005 edition of Wohlers' publication is due out in May, and Wohlers is scheduled to present its main findings at SME's Rapid Prototyping and Manufacturing (RP&M) 2005 Conference and Exposition. For more information or to obtain a copy of *Wohlers Report 2005*, contact Wohlers Associates (Ft. Collins, CO) at 970-225-0086 or http://wohlersassociates.com.

Using three rapid processes streamlined development of these small parts. From left: SL model, CNC-machined aluminum prototype, and injection-molded parts in various materials.

being used influence tool life, and tools usually cost between $3500 and $7500, he adds.

According to Jim Mishek, aluminum tooling often becomes a short-run production tool, even for customers who originally intended to use aluminum molds for pre-production and eventually replace them with "hard" tooling. "Probably only about 2/3 of our customers will retool with production tooling," he says. "A lot of people don't need a million parts. They only need 5000 parts a year, and they find out the aluminum tool can do the job."

On the additive side, Vista's "big three" processes—stereolithography (SL), selective laser sintering (SLS), and fused deposition modeling (FDM)—are still the most prevalent, according to Dan Mishek. "SL is still considered to be the best for fit and form, tolerance, surface finish, and small detailed parts," he says. "Improvements in SL stem mostly from materials, which have become more functional in terms of appearance, strength, and heat resistance."

According to Jim Mishek, SL can hold size tolerances of 0.002 ipi; SLS and FDM can hold about 0.005 ipi. Viper machines from 3D Systems Corp. (Valencia, CA), developer of SL, allow hole diameters as small as 0.003" (0.076 mm) and wall thicknesses of 0.006" (0.15 mm), he adds.

FDM and SLS parts tend to be more functional than SL parts, Dan Mishek says. "FDM allows you to build parts layer upon layer from extruded ABS and polycarbonate. The resulting parts mimic injection-molded parts." Improvements in FDM include part surface finish, materials, and larger work envelopes in the machines, which are supplied by Stratasys Inc. (Eden Prairie, MN). FDM is also the most cost-effective method for building large functional prototypes, he adds.

Dan Mishek says SLS is faster than FDM, and can use materials that simulate nylon and glass-filled nylon. "Improvements with SLS have been in dimensional tolerances," he explains. "Parts are more accurate than they were a few years ago. The strength of SLS remains in nesting multiple functional parts on the platform. This allows the best scenario for cost, material properties, and lead-time." SLS machines and materials are also supplied by 3D Systems.

Sophisticated Users. Dan Mishek says another growing trend among sophisticated users of RP services and technologies is use of multiple RP processes at various stages of product development. He cites the example of one Vista customer who had three goals and used RP throughout the design and validation process to achieve them. Goals were:

- Check design for interferences and fit-up
- Allow destructive testing to assure the part would function as needed
- Identify a material to meet functional and production requirements.

A prototype is a compass to production. *Without it, you can lose your direction when it comes to manufacturing.*

"To accommodate the first goal, the customer ran five SL parts for a total of $200," he recalls. "The parts, about the size of a thimble, were delivered within three days. The customer then checked the design and made any needed changes."

"For functional testing, the customer ordered five aluminum CNC machined parts produced from the modified design," he says. "These parts cost $150 each, with a delivery of 8–10 working days. They passed the customer's functional testing.

"Goal three was unique, because it impacted quality, manufacturing, purchasing, and sales," Dan Mishek continues. "The end product passed testing as an aluminum part, but production parts would be injection molded, and the concern was finding a material that would work as well as the aluminum prototypes."

Vistatek made a rapid aluminum injection mold in two weeks for a cost of $6600. "This tool allowed the customer to experiment with different plastic materials and produce thousands of parts," Mishek says. "The customer sampled three different materials, and the rapid tool was modified at a cost of $1800 to accommodate design changes required to go from metal to plastic. Parts off the rapid tool were used in field tests and as a bridge to production."

Total cost of all the RP services used in developing the product was $9200—money well spent, Dan Mishek believes. "Looking back, this was a near perfect use of three RP methods," he says. "This customer benefited from good planning and decision making in their design and prototyping process."

He points out that, had the customer skipped the SL process, they would have used an incorrect design for CNC machining. "The CNC step would have still cost $750 and 8–10 days. And they would have still needed to machine the parts again to prove out the design. Magnify this over dozens of parts every year. It adds up to a lot of money and crucial time lost in getting your product to market," he says.

"The prototype is your compass to production," Dan Mishek concludes. "Without a prototype that fits your needs in time, cost, and quality, you can lose your direction when it comes to manufacturing."■

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