DIRECT DIGITAL MANUFACTURING AT BMW

FORTUS 3D PRODUCTION SYSTEMS

Manufacturing Jigs and Fixtures with FDM

"FDM is taking on increasing importance as an alternative manufacturing method for components made in small numbers."

- Günter Schmid, BMW

Real Challenge

Rapid prototyping has become a standard practice in product development. At the BMW AG plant in Regensburg, Germany, FDM (fused deposition modeling) continues to be an important component in vehicle design prototyping. But moving beyond prototyping, BMW is extending the application of FDM to other areas and functions, including direct digital manufacturing.

The plant's department of jigs and fixtures uses a Stratasys 3D Production System to build hand-tools for automobile assembly and testing. According to engineer Günter Schmid, "BMW has determined that the FDM process can be an alternative to the conventional metal-cutting manufacturing methods like milling, turning, and boring." Schmid and fellow engineer, Ulrich Eidenschink, have shown that financial advantages include cost reductions in engineering documentation, warehousing, and manufacturing.

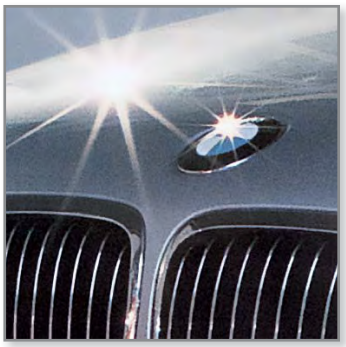
How did FDM compare to traditional CNC machining for BMW?

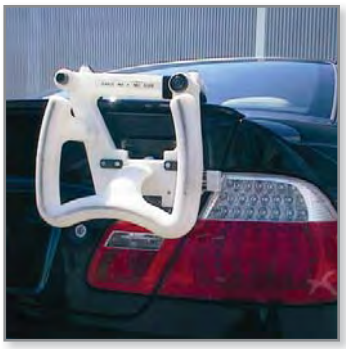
Method	Cost	Time
Traditional CNC Machining (Aluminum)	$420	18.0 days
Fortus System (ABS-M30 Thermoplastic)	$176	1.5 days
SAVINGS	**$244 (58%)**	**16.5 days (92%)**

For hand-held devices used on the assembly line, engineers have discovered that there are even greater advantages that arise from the design freedom that FDM offers. Capitalizing on the elimination of constraints, Schmid and Eidenschink employ FDM to make ergonomically designed assembly aids that perform better than conventionally made tools.

Real Solution

To improve productivity, worker comfort, ease-of-use, and process repeatability, the plant uses FDM to enhance the ergonomics of its hand-held assembly devices. The freedom of design allows engineers to create configurations that improve handling, reduce weight, and improve balance. According to Schmid, "The tool designs we create often cannot be matched by machined or molded parts." In one example, BMW reduced the weight of a device by 72 percent with a sparse-fill build technique. Replacing the solid core with internal ribs cut 1.3 kg (2.9 lbs) from the device. "This may not seem





IIn the jigs and fixtures department at BMW AG, Regensberg, a Fortus system is used to manufacture assembly tools. This tool is used to affix the rear name badge.

like much, but when a worker uses the tool hundreds of times in a shift, it makes a big difference," says Schmid.

Another advantage of direct digital manufacturing is improved functionality. Since the additive process can easily produce organic shapes that sweep and flow, the tool designers can maximize performance while improving handling characteristics. "The layered FDM manufacturing process is well suited for the production of complex bodies that, when using conventional metal-cutting processes, would be very difficult and costly to produce," says Eidenschink. An example is a tool created for attaching bumper supports, which features a convoluted tube that bends around obstructions and places fixturing magnets exactly where needed.

The jigs and fixtures department has developed a simple flow chart to determine when FDM is a fitting option. The criteria are temperature, chemical exposure, precision, and mechanical load. With Stratasys ABS material, which the engineers find comparable to polyamide (PA 6), many tools for vehicle assembly satisfy the criteria. For those that do, designers can create devices that capitalize on all the advantages of the additive process.

Both Schmid and Eidenschink believe that no enterprise can afford to do without rapid prototyping for product development. Yet, they see so much more possibility. "FDM is taking on increasing importance as an alternative manufacturing method for components made in small numbers," says Schmid.

Image 4: Produced with direct digital manufacturing, this tool is used to attach bumper supports.

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FDM Components Help Win Discovery Channel's Biker Build-Off

"Rapid manufacturing gave us a major edge."

- Jesse Hanssen, Klock Werks Kustom Cycles

"The parts met all our requirements for accuracy and strength."

- Todd Snedeker, Klock Werks Kustom Cycles

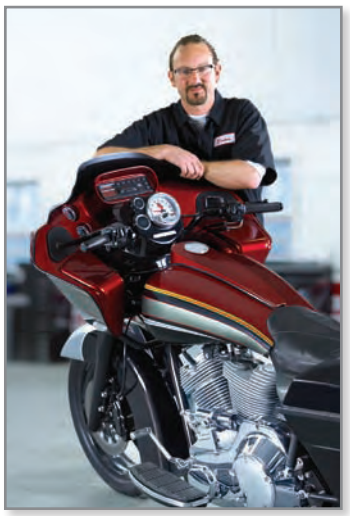

Image 1: Brian Klock with Discovery Channel Biker-Build-Off competition-winning bike.

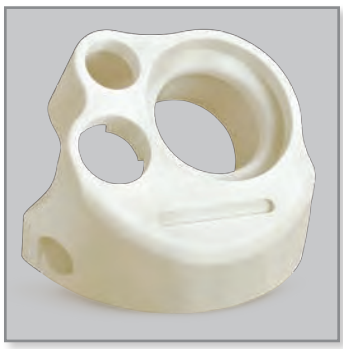

Image 2: Gauge pod built from poloycarbonate.

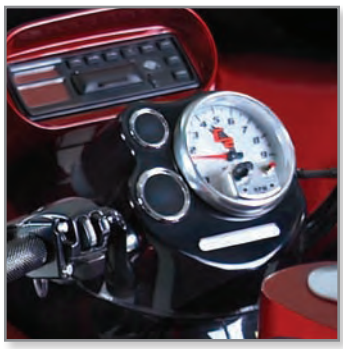

Image 3: Painted polycarbonate gauge pod installed directly on the bike.

Real Challenge

Klock Werks Kustom Cycles builds one-of-a-kind motorcycles including choppers, bobbers, and baggers. Recently, the Mitchell, South Dakota-based company was selected to appear in the Discovery Channel's Biker Build-Off. Klock Werks had 10 days to build a custom bike that was then driven to and displayed at the 66th Annual Sturgis Motorcycle Rally where visitors voted it the best bike at the show.

Real Solution

"Direct digital manufacturing gave us a major edge in the competition," says Jesse Hanssen, Klock Werks mechanical engineer. "The [Fortus] FDM system enabled us to build anything we could imagine."

In building a custom bike for the competition, Klock Werks called upon their own line of bagger parts, purchased some components, and others were one-of-a-kind creations that could not be purchased off the shelf. Most of these unique parts had complex geometries and many also needed to also meet strict functional requirements such as a gauge pod which had to withstand cyclical vibrations without breaking.

"Normally, these parts would be produced from injection molded plastic or machined aluminum," says Hanssen. "But it takes three to four weeks to build parts using either of these methods because they require tooling. Klock Werks had to fabricate all of the components during a five-day filming segment." In addition, the cost of building the parts needed for the competition would have been between $15,000 and $20,000, which would have been far too expensive.

Klock Werks engineers designed the gauge pod, fork tube covers, headlight bezel, floorboard mounts, floorboard undercovers, and wheel spacer cover in SolidWorks. "FDM put no limits on our imagination," says Hanssen. "We built all of these parts in

five days from polycarbonate. The cost of producing the parts with FDM was less than a quarter of the cost to injection mold or cast them."

"The finished parts met all of our requirements for both geometric accuracy and mechanical strength," says Klock Werks partner Todd Snedeker. "The ability to produce fully functional parts using direct digital manufacturing methods was instrumental to our success. Many of the parts on this bike could not have been produced by any other method in the time-frame required. FDM saved us a considerable amount of money and made a major contribution to our winning the Biker Build-Off at Sturgis Week."

After winning the competition, the Klock Werks team raced the bike at the Bonneville salt flats, where they set an AMA Land Speed Record. "The WFB (World's Fastest Bagger) proves the durability of polycarbonate parts at 147 mph.," says partner Brian Klock. "Thanks to our design team and the team at Stratasys."

For more information on Klock Werks call 605-996-3700 or go to www.kustomcycles.com.

Image 4: CAD illustration of gauge pod.

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STRENGTH UNDER PRESSURE

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Polycarbonate Sprinkler Prototype Withstands Testing at 100 psi

"The material for our [Fortus] system is inexpensive: we can build 60 to 70 parts with a single spool of plastic."

– Saroj Manandhar, Toro

Real Challenge

Toro's Irrigation-Products division makes commercial and consumer water sprinklers, valves, and controllers. For the golf-course market, it recently redesigned a sprinkler using FDM (Fused Deposition Modeling) technology. Prototypes for the 800S sprinkler assembly were created from polycarbonate thermoplastic using a 3D Production System from Stratasys.

The assembly had to be precisely engineered and strong enough to withstand high water pressure. Each of the dozen assembly components went through several iterations during design.

Real Solution

"The polycarbonate allowed us to make working prototypes," says engineering manager Saroj Manandhar. "We were able to create components that could handle water pressures up to 100 psi."

"Our 3D Production System generated accurate prototypes. And it took only a few hours for a typical component." Their system enabled Toro to perfect designs for a fraction of what they might have cost. "To tool a traditional prototype and make changes to refine the design the costs would have been prohibitive for such a large scale project."

"Over a two-year period, FDM technology has reduced product-development time by 283 weeks [on a number of products], and it has reduced tooling costs and prototyping service-bureau costs by over $500,000. Our 3D Production System has improved design quality and helped toolmakers get molds right the first time. It has even enabled us to skip prototype tooling on some projects."

"We've used FDM technology for several years because we like the ABS plastic parts, but we added a newer 3D Production System to produce stronger models using PC. The system is also faster and more accurate than our older machine. Together, the two machines dramatically improve our productivity and bottom line, and greatly reduce time to market."

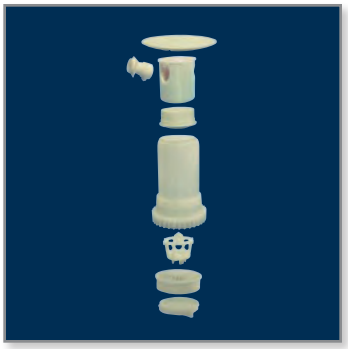

Image 1: Toro polycarbonate prototype components

Image 2: Pressure-testing a working prototype at 100 psi

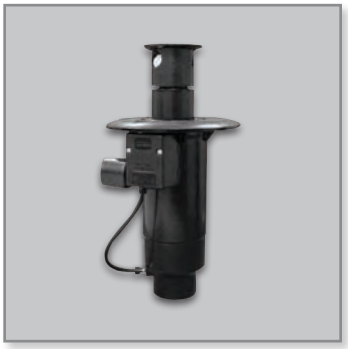

Image 3: Production 800S sprinkler

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Functional Tests Help Improve Headset Strength by 273%

"Had we relied on formulas and CAD models rather than functional models, we might never have found the optimal design."

- Dominic Amae, Logitech

Image 1: Logitech's mobile Bluetooth® headset in use.

Real Challenge

Logitech is known for innovative and well-made accessories for computers and cell-phones. The company's Audio Business unit has a philosophy of "continuous innovation – flawless design." To assist with its mission, the company recently added an Fortus FDM (fused deposition modeling) system.

Prior to using the FDM process, the company's prototypes weren't durable enough for functional testing. "We couldn't run functional tests until late in development, when we made parts from prototype injection molds," says senior mechanical engineer Dominic Amae. At this stage, the time and cost to optimize a design were high, prohibiting engineers from freely iterating designs.

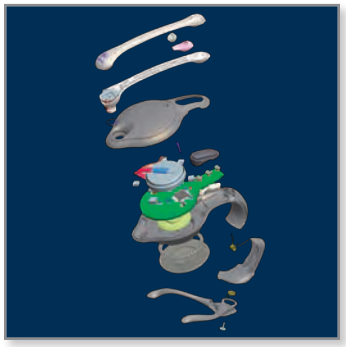

Image 2: Logitech redesigned its headset to improve the microphone boom's strength.

Real Solution

With FDM, the ability to run functional tests resulted in improved reliability and comfort for Logitech's Mobile Bluetooth® Headset. Logitech recently updated the headset design to eliminate a problem that occurred for some users. If handled roughly, the microphone boom could rotate 360 degrees and break the electrical contacts. Investigation showed that distortion allowed the boom to sweep past its rectangular stops. "We determined the solution was to modify the stops to a wedge shape," says Amae, "but we didn't know the best configuration."

Since the boom and stops are tiny, Amae built functional ABS prototypes to allow failure observation. In the lab, weights were added to the boom until it failed. Following each test, the boom and wedge-shaped stops were redesigned. "We're confident that the failure modes seen in the ABS prototypes will be true to that for the production part," says Amae.

Logitech repeated the process of design and destructive testing until it reached peak performance — a 273 percent strength improvement. "We were surprised to find that the best wedge design was counter intuitive," says Amae. "Had we relied on formulas and CAD models, rather than testing functional models, we might never have found the optimal design."

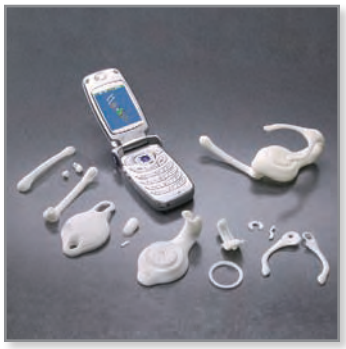

Image 3: Headset components were modeled in ABS plastic, using the FDM process.

"We used to worry about our expensive prototypes breaking during user testing. But now that we use ABS parts, which are robust enough to be handled like real parts, we

don't have that concern," says Amae. "This really gives us the freedom to perform realistic tests." Amae finds that one FDM prototype is strong enough to outlive many SLA parts.

Logitech's investment in FDM technology yielded more than just a quick payback, according to Amae. "We build parts on-site and enjoy faster design cycles. The speed and low cost of models lets us make enough to serve the design team, the marketing team, and the manufacturing team. We now test more designs, in more ways, which results in better products and satisfied customers."

Image 4: Functional tests helped engineers design a new microphone boom that is 273% stronger.

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