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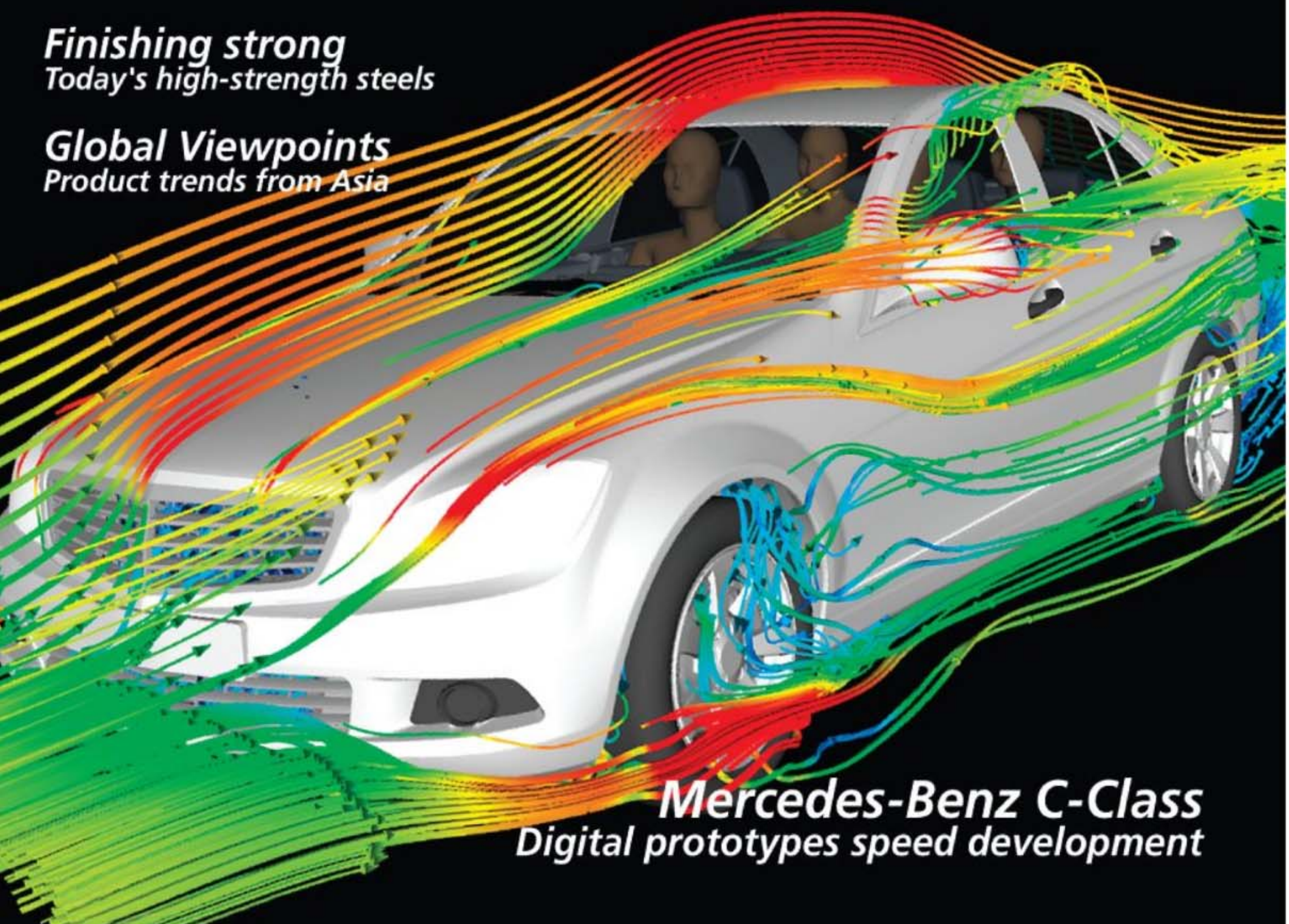

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Quickness defines this process

The **Federal Bureau of Investigation** (FBI) employs rapid prototyping techniques as part of its crime-busting arsenal because it's an efficient and quick way to fabricate complex parts for the job at hand. But the U.S. federal investigative and intelligence agency isn't the only backer of fast parts production.

Users of rapid technologies include the automotive, aerospace, and architectural industries as well as the military, jewelry-makers, and the medical and dental communities. The bottom line: rapid technologies are rapidly collecting rave reviews.

"This is cool stuff. Imagination unleashed can result in major breakthroughs," Kevin Ayers, Mechanical Engineer in the FBI's Rapid Prototyping Facility in Quantico, VA, said after giving a quick glimpse of the agency's work with rapid metal parts production at RAPID 2007, a three-day Detroit conference in May sponsored by the **Society of Manufacturing Engineers**.

The forte of rapid prototyping is fast parts making, yet each of the many processing methods available today—such as direct metal, selective laser sintering, fused-deposition modeling, and three-dimensional printing—offers a different set of advantages and disadvantages. "All of these processes have their specific attributes," said Carl Dekker, President of **Met-L-Flo**, an Illinois-based rapid-prototyping service center.

In a broad stroke, "rapid technologies" is a catch phrase for describing an additive fabrication process for building physical models, prototypes, or end-use parts directly from three-dimensional CAD data. Parts are built from plastic, liquid, powdered, or sheet materials by joining thin two-dimensional cross sections layer-by-layer based on the computer model, according to Sheku Kamara, Manager of Operations in the Rapid Prototyping Center at the **Milwaukee School of Engineering**.

A survey conducted by Colorado-based consulting firm **Wohlers Associates** shows that the consumer-products and automotive sectors spent the most money on rapid prototyping equipment in 2006, but a slew of other sectors are actively buying and utilizing the technology.

"Over the years, I have met rapid-technology users from a large variety of industries, such as aerospace, medical/dental, consumer, and military. I am always amazed at the various ways they use the technologies. It is interesting to share knowledge and experiences with the different industries," said Doug Mitchell, Development Engineer, **Ford** Motor's Design Components & Scheduling Department.

Following nearly 20 years of research, development, and usage, the additive-fabrication industry is giving subtractive processes—like machining—a run for the money. "The additive fabrication industry has had an average annual growth of 23% over the past three years," said Terry Wohlers, Principal Consultant and President of Wohlers Associates.

Spurring the sales meter into the red-hot zone is 3-D printers. Wohlers Associates estimates that 3-D printer sales totaled $114 million in 2006, up 17% from 2005. "The additive fabrication industry's growth has been extraordinary, and it's being driven by 3-D printing, which accounted for 73% of all additive systems sold in 2006," said Wohlers.

A pioneer in 3-D printing is Israel-based **Objet Geometries**. The company's patented Polyjet process produces fully cured models via an inkjet head that slides back and forth along the X-axis depositing an ultra-thin layer of the company's propri-

A Brembo brake assembly was produced as a one-piece, composite-plaster part using Z Corporation's Spectrum Z510 3-D printer.

This sample geometry, based on a turbocharger-type application, demonstrates the capability of DMLS. The tiny, scaled-down part from Morris Technologies is made of cobalt chromium.

This clutch assembly, produced on a fused-deposition modeling machine from Stratasys, enabled an automotive supplier to identify and fix problems during concept design.

A scale model (shown) was produced for Germany's DaCar, an automotive company, via an Objet Eden 3-D machine. Once printed, the vehicle was painted to specifications.

etary photopolymer materials onto the build tray. "We have a breadth of applications for the automotive and a number of other industries, including medical, consumer products, consumer electronics, shoes, toys, and jewelry," said Stephanie Checchi, Marketing Communications Manager for Objet Geometries' U.S. office, which opened in January 2007.

Z Corporation's product line includes 3-D portable scanners and 3-D printers. "We can print in full 24-bit color. We literally print a binding agent onto a build powder to produce parts used for a range of applications, including concept models and functional prototypes for the automotive and other industries," said John Kawola, Executive Vice President of Sales, Marketing and Business Development for Massachusetts-based Z Corporation.

The Formiga P 100, which is expected to record its first North American customer installation in the third quarter of 2007, is a plastic laser-sintering machine from **EOS** that can produce walls as thin as 0.016 in (0.41 mm). "In building the Formiga P 100 machine, we took advantage of our own technology. Twenty-three of the machine's components—including the powder funnel, control-switch housing and infrared sensor housing—were laser-sintered by EOS technology," said Alexander Dick, Applications Engineer for Plastic Laser Sintering at EOS.

Ohio-based **Morris Technologies** is considered the world's largest service provider of Direct Metal Laser Sintering (DMLS) parts and inserts. "We see a tremendous interest in using this technology in the aerospace, medical, dental, and automotive industries. In many instances, we're building part geometries that simply cannot be made any other way," said Greg Morris, Chief Operating Officer of Morris Technologies. DMLS parts can be made from metals ranging from stainless steel to cobalt chromium and titanium. "New nickel-based alloys are in development, and other metals—such as aluminum—will be considered for DMLS usage in the near future," said Morris.

Another rapid prototyping process gaining users is fused-deposition modeling. The process is a popular choice in the automotive industry since parts can be made from production-grade thermoplastics, such as ABS, polycarbonate, polycarbonate/ABS blend, and PPSF (polyphenylsulfone). "If you're going to build a prototype, it's important to build that part in the material that's later going to be used in production," said Darin Everett, Senior Sales Executive with Minnesota-based **Stratasys**.

The ability to grasp a part's form, fit, and function is an important aspect of prototyping. "We do a lot of rapid prototyping of interior, exterior, and underhood parts that must match much of the criteria of a production part, because that's what's needed for product design approval," said Thomas Sorovetz, Supervisor of the Rapid Prototype Development Wood/Computer Numerical Control, Plastic Shop for Vehicle Build and Shop Services at **DaimlerChrysler**.

Approvals can also put a rapid-technologies process on the fast track. Electron beam melting (EBM), a powder-based direct-metal process, is inching closer to getting usage certification from the **U.S. Navy**. "The Navy needs small quantities of replacement parts for aging aircraft. Because molds and dies are not necessarily available anymore, EBM would enable the fabrication of these replacement parts without tooling," said Denis Cormier, Associate Professor of Industrial and Systems Engineering at **North Carolina State University** (NCSU).

The first EBM machine was purchased in 2003 by NCSU. "EBM has been commercially available for only three or four years, and as such, the process has now matured to the point where it is finding applications in the real world," said Cormier, adding, "Racecars are one example of being a good fit for EBM because the quantities of parts needed are small and this process can quickly produce parts without the need for tooling."

Even though rapid technologies continue to gain users and applications, a stumbling block remains. "Today, many consumer products are blister-packed by a thermoforming process. But if we said, 'Let's injection-mold that,' it wouldn't work because of the thin wall of the blister pack. Yet we wouldn't conclude that injection molding is a bad process," said Scott Schermer, Senior Rapid Prototyping Specialist at **S.C. Johnson & Son**, whose consumer products include Ziploc storage bags and Pledge furniture polish.

"The point with rapid prototyping is we don't design to the needs of the technology. Designers and engineers from every industry expect rapid prototyping to fit into our existing knowledge of manufacturing processes," said Schermer. In the future, more design and engineering college graduates will have knowledge about rapid manufacturing techniques.

"We've assisted more than 70 higher-education institutions in establishing rapid-technologies training as part of their pre-engineering and technician education programs. Rapid prototyping, rapid tooling, direct digital manufacturing, and reverse engineering are among the rapid technologies that are being adopted by industries, including automotive, at a quicker pace than was the case in previous years," said Ken Patton, Dean and Principal Investigator for the National Center for Rapid Technologies at **Saddleback College** in California.

Kami Buchholz