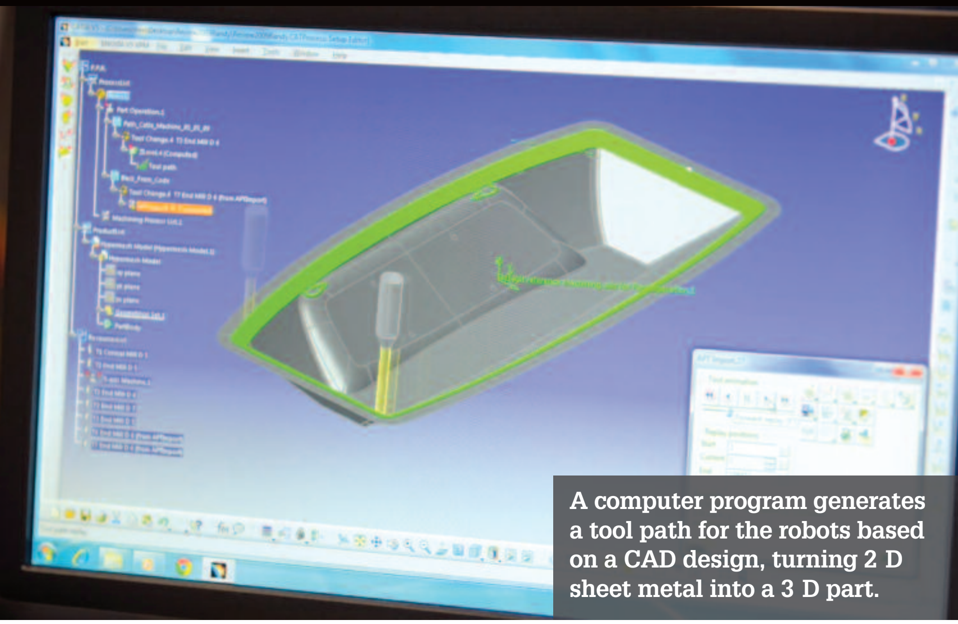
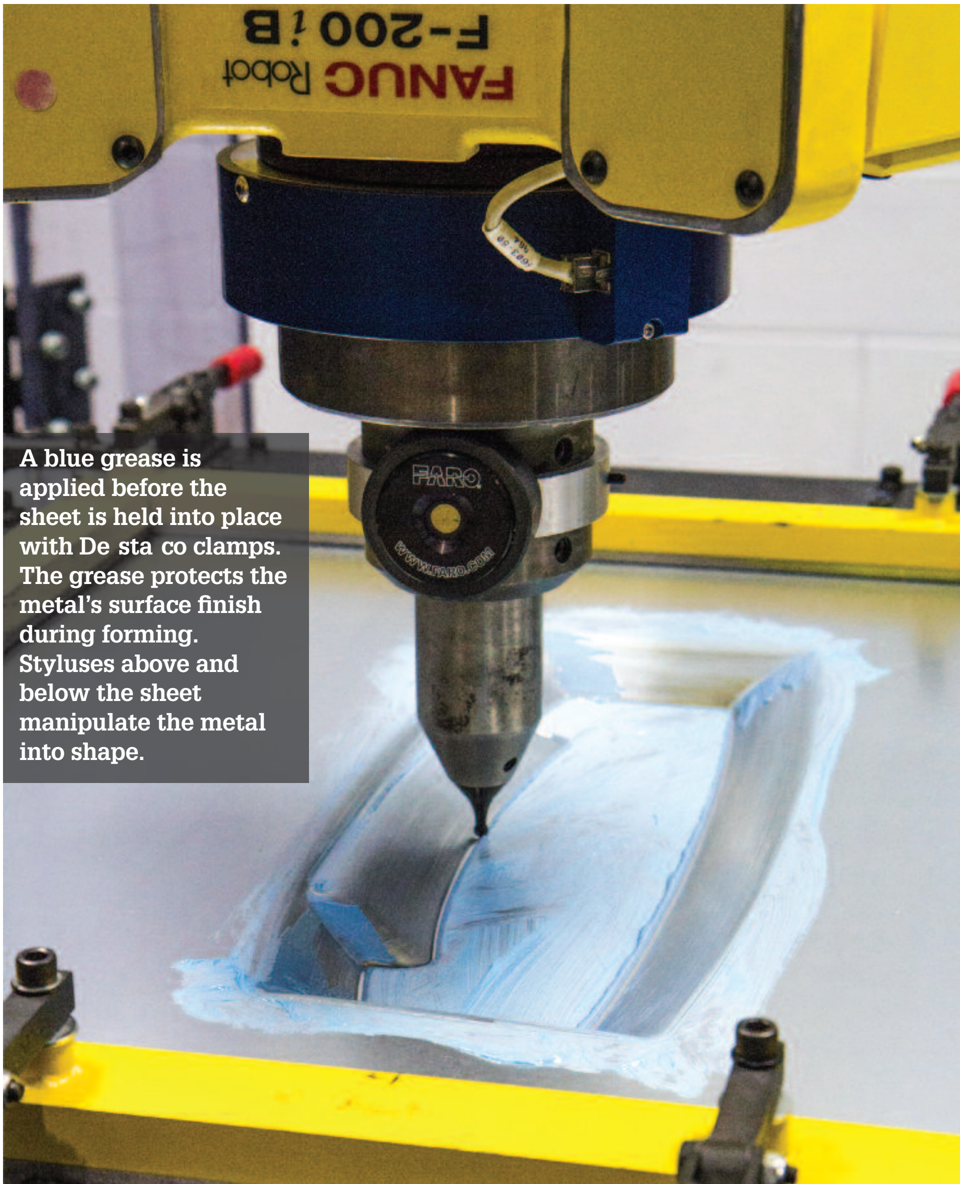
Automotive

BY NICK WRIGHT, EXECUTIVE EDITOR

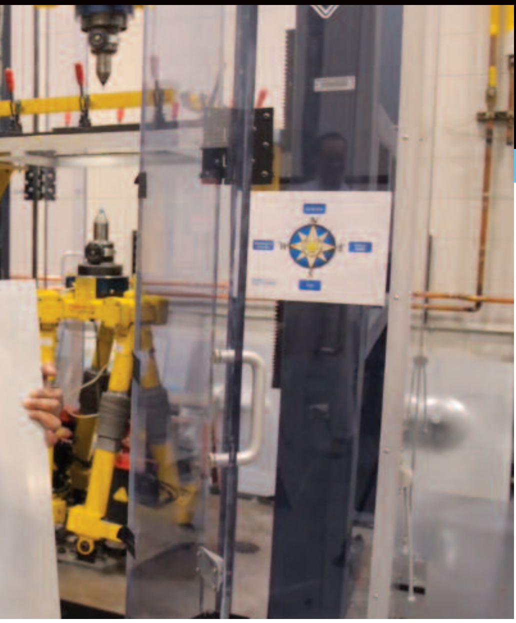


A computer program generates a tool path for the robots based on a CAD design, turning 2 D sheet metal into a 3 D part.



A blue grease is applied before the sheet is held into place with De sta co clamps. The grease protects the metal's surface finish during forming. Styluses above and below the sheet manipulate the metal into shape.

As seen in the April 2014 issue of
FFJournal®



FORMING THE FUTURE

Ford's sheet metal freeforming technology accelerates prototyping, taking stamping tool costs and lead time out of the equation

About 10 miles west of downtown Detroit sprawls the mothership of Ford Motor Co., a complex made up of museums, offices, the historic Greenfield Village and the expansive concrete test track that, at first glance, could be an airport.

At the west end of Ford's headquarters, opposite the test track where cars are put through their paces, is the company's Research and Innovation Center. While burning rubber and whipping through slalom courses are endlessly thrilling, it's at the RIC where some of Ford's more fascinating work takes place. In terms of metal fabricating, one of RIC's big recent developments is Ford's Freeform Fabrication Technology, known as F3T.

Publicly announced in July 2013, F3T is a proprietary process with which a piece of sheet metal—say, a 1 m by 1 m square—is clamped around its edges and formed into a 3-D shape by two robotically controlled styluses. The styluses mirror each other from above and below, carefully manipulating the flat sheet metal into a desired shape. In a blind test, it would be hard to tell a F3T-formed component from one stamped with traditional methods. In fact, you wouldn't be able to tell at all. It's the F3T's tooling and time it takes to make a part, however, where Ford's advancements merit further investigation into what forming sheet metal could be in the near future.

Shoestring mechatronics

The idea for F3T was born out of a few engineers informally discussing over coffee what the next-generation way to form sheet metal could be—more epiphany than calculated plan. Think of how an English wheel uses hand-held manual force to form a part. It's a simple concept and researchers had bet that they could automate it.

An ad-hoc team formed, found a set of used hexapod robots in an assembly plant and started putting a machine together. The engineers are experts in mechatronics, a catch-all term used to describe a design process involving electrical, computer and mechanical engineering.

"It was really an under-the-table development until they said, 'We can really do this,'" says Matt Zaluzec, senior technical leader and manager, global materials and manufacturing research at Ford. Moving forward came down to determining whether the robots were capable of freeform fabricating metal, and if control technology could accurately place two synchronized stylus-equipped robots over each other.

The supportive director at the time encouraged the team to see what it could do on a shoestring budget. Eventually the group honed the process, and applied for a Department of Energy-solicited grant in 2011. Ford won a three-year $7.04 million cooperative grant to pursue F3T's potential. The results, so far, are impressive.

The technology isn't necessarily notable for making two robots match each other's movements. Rapid prototyping, rather, is where the benefit lies. For example, say Ford wants to develop a new type of B pillar. Instead of designing the stamping press' tool and die, which takes weeks, engineers can upload a CAD file to the robots' controller. Then, the robots go to work, plying the sheet metal, like a child with Play-Doh. In a day or so, the part is done.

But wait. There's something off about that B pillar? Its dimensions aren't quite right? Well, no problem. Operators can analyze and tweak the CAD design and make another part within days. To design the stamping press tooling alone would take weeks—even months—all over again. Not so with F3T. The lower costs and ultrafast delivery times for prototypes are staggering for both steel and aluminum.

Morphing metal

To determine F3T's viability with various material, Ford started out with cold-rolled steel due to its high formability. It worked well, says Zaluzec. Engineers had equal success with high-strength, low-alloy steel. Dual phase steels gave them no problems, either. In any stamping operation, the higher the tensile strength, the harder it is to form material.

They found that F3T is mainly ideal for automotive grade sheet around 1 mm thick. "We couldn't do 4 mm thick, like a truck frame," he says. Ford has stamped aluminum hood panels for about a decade. Because its use of aluminum is growing (as well as other automotive OEMs), it tested both 5000 and 6000 series grades with success.

"One interesting thing is there are some aerospace grades of aluminum that are hard to form. And we can do it with formability limits that exceed what you do in a stamping operation," Zaluzec adds.

At the tip of the stylus is a traditional quench-and-tempered 52100 steel ball bearing. Ford uses all types of hardened steel styluses of different diameter balls for forming radii. The high hardness ensures the stylus doesn't wear out on dual phase steel, which has high hardness elements. If the stylus bearing wears out (which hasn't happened yet), forming accuracy is diminished. The radii range from a few millimeters up to about a centimeter, which depending on the size will provide a sharper corner or profile.

The photos accompanying this story depict Fanuc F200iB robots, though Ford uses ABB, Kawasaki and other robots as well. Faro laser tracking systems affixed above the styluses keep them on target when forming.

"The laser tracking is used to make sure the stylus doesn't get off track mechanically. We haven't had a problem, but the laser is the belt and suspenders," Zaluzec says.

Ford says it could use F3T to prototype hoods, decklids, panels and more during product development, such as for the 2015 Ford F-150 pictured here.

It's important to note that the F3T is limited to research and high-mix, low-volume product development. The complexity and speed of established stamping operations still dominates production. But it's not too far off to say that F3T could indirectly speed up the time it takes for a new vehicle to reach the production line.

"The world isn't a perfect place, and you have to work the tool," Zaluzec explains. "This is where the F3T comes in. If we wanted to make parts overnight and we needed six of them in the build phase, our production development community said this would really be a benefit."

In theory, the time it would take to modify a tool, stamp a part and get into assembly, followed by building a prototype vehicle and crash-testing, would be drastically diminished if F3T were part of the process.

F3T is also applicable for niche, rare or antique vehicles. If there's a panel that no longer exists for that 1960s GT40 sitting in your garage, the F3T could morph one from new sheet metal. For now the excitement is around prototyping and evolving mainstream product development. The next set of challenges Ford is tackling is how to maintain these forming advancements on a larger scale.

Art is beauty

A familiar engineering term in product development is "art to part," a method of manufacturing something from CAD through final product. In the case of F3T, the forming operation commences and can form metal in a matter of two hours on a 1 m^2 blank. Of course, it takes longer on bigger parts. No matter the part, the tooling cost is still zero. Therein lies the beauty of the process.

The 2015 Ford Mustang's bumpers, fenders and rear decklids are ideal target areas for using the F3T technology.

"It's just a piece of sheet clamped into a fixture," Zaluzec says. Other forming methods, like a bladder press, still require a single-sided tool and a machined block to fit into the press. In general, stamping tools can costs upwards of hundreds of thousands of dollars. "This is a tool-less technology to form a sheet. Yes, there's time and money costs to set it up, but the actual tooling cost doesn't exist."

When the sheet metal is clamped into place, the way a screen printer clamps a T-shirt, only about ¾ of the sheet is actually formable. With any forming operation, the part's periphery cannot be formed. It will eventually have to be trimmed. Thus, F3T doesn't eliminate offal, or scrap, but Ford foresees ways to develop fixtures to minimize waste.

Down the road

Costs aside, the implications for F3T are applicable beyond automotive parts. Ford is collaborating with The Boeing Co., Northwestern University, Massachusetts Institute of Technology, and Penn State Erie to optimize the mechatronics, programming and formability modeling. Boeing in particular is interested in F3T's cycle time because it could make replacement parts or field repairs quickly. When an airliner needs a repair or part, the manufacturer has mechanics do the work on-site.

"Planes are obviously much bigger. Their interest isn't where we've taken F3T to date, because we've formed the high-strength alloys they use. They're interested more in scale," Zaluzec says.

The military has its eye on F3T, too. Instead of aircraft carriers stocking prefabricated parts for jets, it could simply stock aluminum sheet, call up a CAD file, and form the part overnight. The next day, it could be glued and riveted into place. The International Space Station could similarly form mission-critical components without waiting for the next shuttle.

Mark Johnson, Ph.D., is director of the Advanced Manufacturing Office, the office under the DOE that awarded Ford its grant. He says the government is interested in partnering with industry to accelerate the pace of new technologies like F3T to make the U.S. more competitive. In this case, it wanted to help Ford translate F3T from a lab setting to a real-world application.

"In the future, we envision hybridizing this freeform manufacturing with other technologies like machining and additive manufacturing," Johnson says. "It's a brave new world in manufacturing."

The Advanced Manufacturing Office works closely with its counterpart in the Department of Defense—both under the Commerce Department's National Institute of Standards and Technology—to encourage projects within their mission areas and that are broadly applicable to each other. If there's a manufacturing issue that touches energy, it's an area the AMO pursues. The ultimate challenge is: How can technologies like F3T be turned into job creators? "That's the high-level manufacturing competitiveness question," Johnson adds.

Freeforming could be used for critical wind turbine or solar panel parts—even chemical processing or heat exchanger structures. "We're looking at what the cross-cutting capabilities are," Johnson says.

Other OEMs have taken to innovating aspects of their metal manufacturing, such as Honda Motor Co.'s early use of friction stir welding aluminum and steel, as well as Subaru, which reforms scrap metal into gas caps and other components. In terms of demonstrating a manufacturing technique that can create sheet metal prototype parts in mere days at virtually no cost compared to months for traditional methods, it's not a surprise Ford has gained attention from both the private and public sector.

According to Ford, some of its automobiles currently on the road have F3T-formed sheet metal parts incorporated. But like the difference between a traditionally stamped part and a stylus-formed one, we would never know. **FFJ**

Ford Motor Co., Research and Innovation Center, Dearborn, Mich., www.ford.com.

U.S. Department of Energy, Advanced Manufacturing Office, Washington, D.C., www.eere.energy.gov/manufacturing.