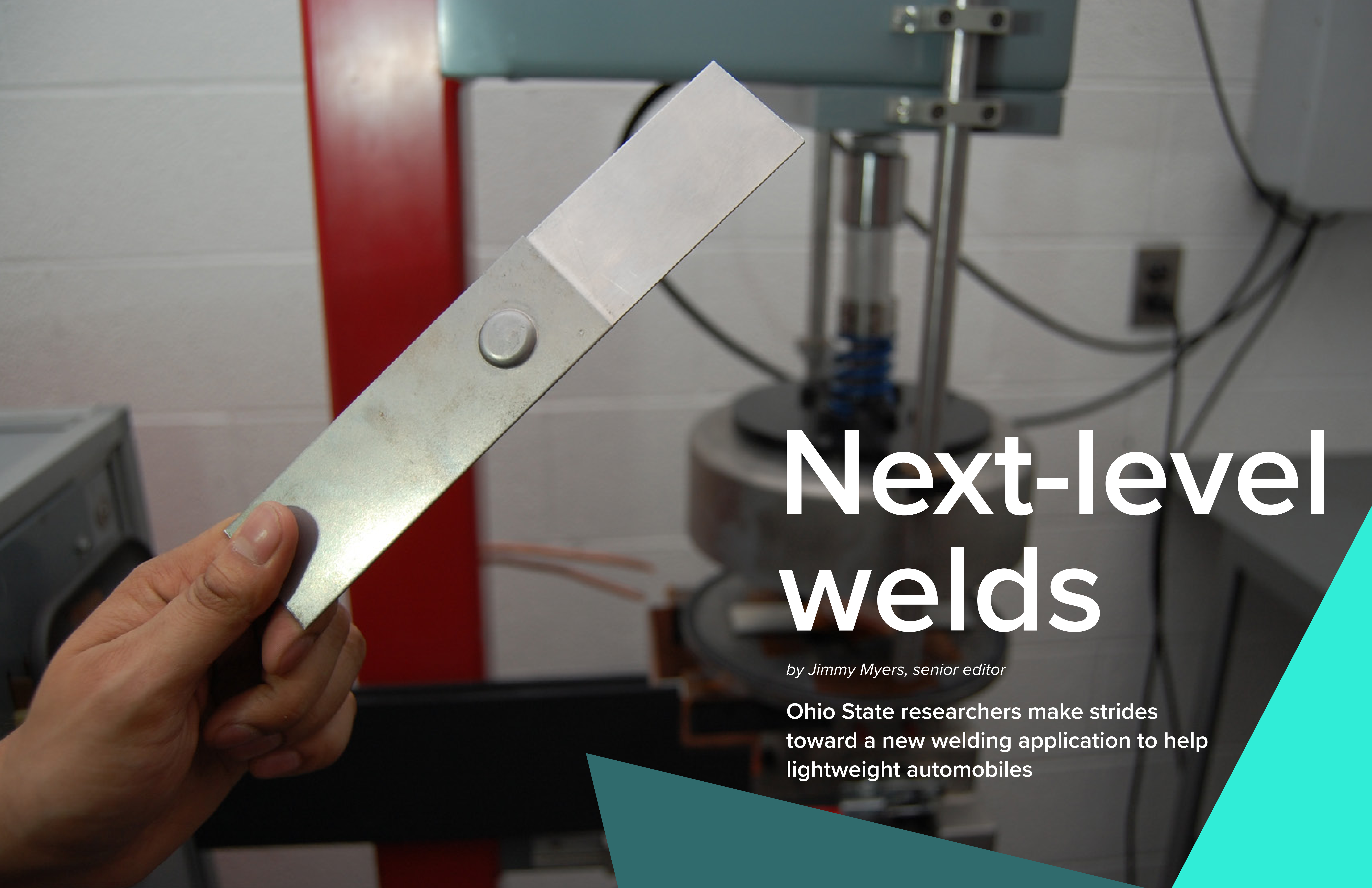


Next-level welds

by Jimmy Myers, senior editor

Ohio State researchers make strides toward a new welding application to help lightweight automobiles

Professor Glenn Daehn wants welders to envision a process where there is no heat or melted metal to compromise the microstructure, where the welds are actually stronger than the base metal. He wants welders to envision a welding process that works on a wide variety of advanced metals and dissimilar metal pairs, but only uses a small fraction of the energy fusion of traditional welding.

"Impossible?" Daehn asks. "Magic? Maybe not."

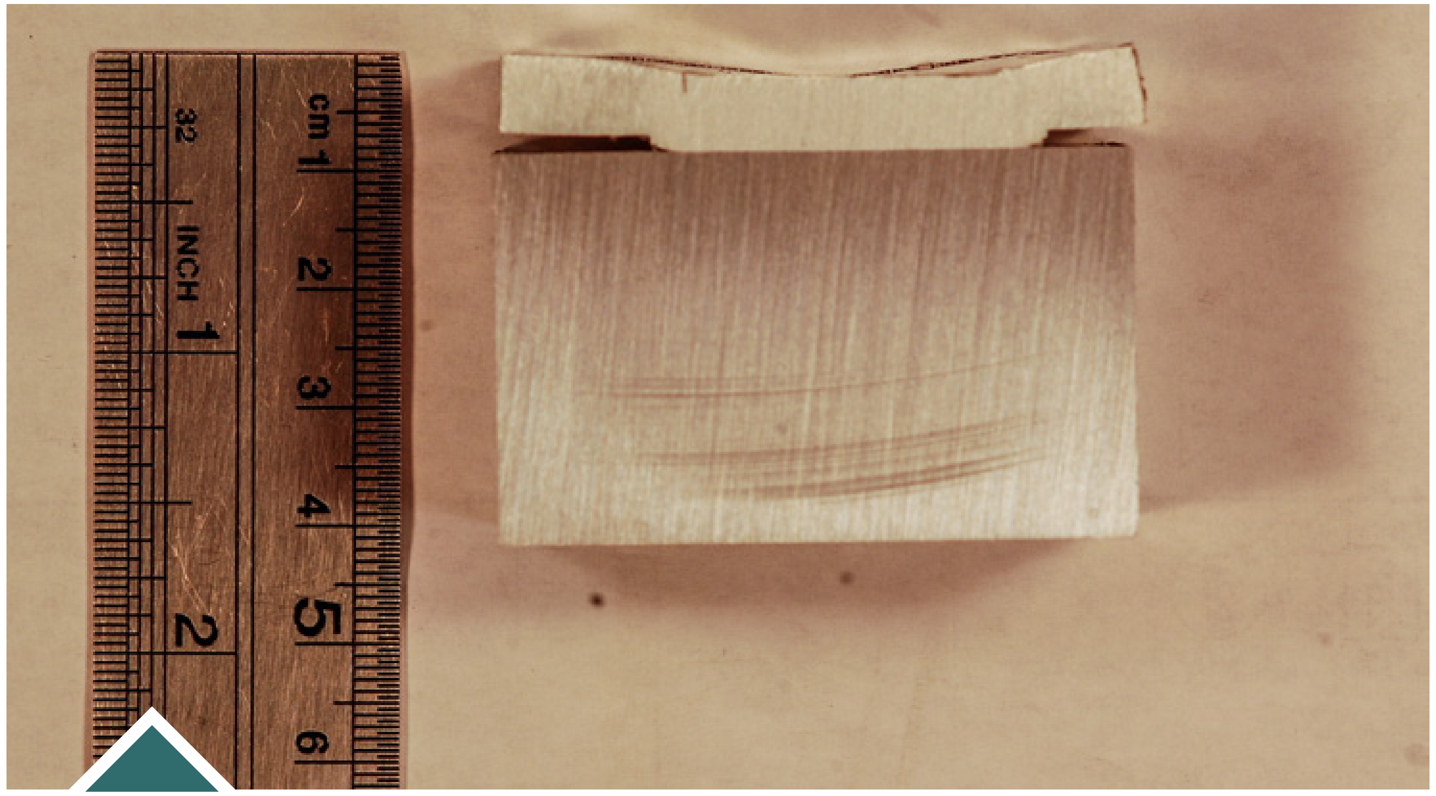
In the 17 months since *Welding Productivity* spoke to the innovative team at Ohio State University's College of Engineering, significant improvements have been made in their efforts to civilize the violent practice of explosive welding. These advancements could result in new lightweighting production opportunities for the automobile industry in the near future.

Research scientist Anupam Vivek and Daehn, who conduct experiments at the university's Impulse Mfg. Laboratory, had their first vaporizing foil actuator (VFA) welding experiment success in late 2011. VFA is a process involving electrically vaporizing a thin piece of metal (a foil) to push two or more pieces of metal together at high speeds, thus creating an impact weld.

With a loud bang, electricity stored in a capacitor was released on that December day in 2011, causing the foil to skip the liquid phase and vaporize, creating a high-temperature gas that causes the high-speed launch and subsequent weld to occur. While the loud bang has now been contained, the process remains similar but is more refined.

Using a similar process, the team, which includes 20-plus graduate and ▸

Glenn Daehn, Ph.D. (right) and Anupam Vivek (left) have focused significant research on joining dissimilar materials. Their work aims to address automakers' need to produce lighter-weight vehicles.



Welding thicker materials – a requirement for automobile manufacturers – is among the many achievements the team at Ohio State has made over the last 12-plus months. This shows ¼ in. aluminum and steel welded by VFA.

undergraduate students and industry collaborators, has made improvements in a number of areas, particularly in joining dissimilar metals, which is an important process in the automobile industry where lightweight, high-strength aluminum needs to be joined to high-strength steel.

JOINING METALS

Daehn, Vivek and a number of other researchers have published many studies on the issue of joining dissimilar materials, including one called "Impact Welding Structural Aluminum Alloys to High Strength Steels Using Vaporizing Foil Actuator," which, in part, addresses the need for automakers to push for lighter vehicles, largely due to the price of energy and fuel efficiency goals, which have been aggressive.

Most car bodies are made with steel, but by substituting other components in the car body, weight can be reduced. Furthermore, these substitutes, which include high-strength steel and structural aluminum alloys, can also offer more strength. The problem lies in joining these dissimilar materials.

Most automotive manufacturers utilize fusion-based welding, such as resistance spot welding. However, this is not suitable for joining dissimilar metals. A work around is to use fasteners, but they add weight and are pricey. Solid-state welding, such as friction-stir processes, has been deployed, but cycle time and geometrical constraints become an issue.

In a separate study, Daehn, Vivek and other researchers address an issue regarding meeting the challenging requirements of multi-material designs; conventional joining techniques aren't always the best approach due mostly to the fact that the material has different thermal properties and melting points.

For example, the screw and rivet method adds weight and corrosion concerns, plus it's expensive. Structural adhesives, which are cured during the paint bake cycle, are lousy under peel type loading conditions. Therefore, finding an alternative joining method is important.

One area that is showing great potential is in impact/collision welding, which allows firmly bonded metals and solid-state joining of similar as well as non-weldable dissimilar metals to be joined. Collision welding also eliminates or minimizes issues tied to heat-affected zones. For example, heat-affected zones often have brittle intermetallic phases resulting in cracking in the fusion weld, according to the study.

In a video posted to YouTube (shown on page 20), Daehn says the goal of the VFA process is 100 percent joint efficiency, which means the joint (or welded area) is stronger than the base metal.

"If you hit 100 percent," he says, "that means you're going to get a break in the base metal, not the joint, and that's what you'd like. Things are stronger that way and they're more predictable, which liberates design."

LESS NOISE, THICKER MATERIAL

The first VFA weld in 2011 was an exciting event, but it was far from glamorous. Vivek says the transfer of energy from the capacitor to the foil was loud, like a rifle going off. Plus, setting up the weld, which includes precise velocity and perfect angles, included a crude metal box (Vivek refers to it as the "boom box") and a time-consuming setup.

In a relatively short time frame, the team at Ohio State has reduced the noise level to 90 decibels, which is so quiet that ear protection is not required. Perhaps even more exciting is that they've jumped from welding materials of a maximum of 2 mm in thickness to metals that are up to a 1/4 in. thick.

"We can take 1/4-in. aluminum and weld it to steel," Vivek says. "That is almost three or four times the thickness limit we were at a year ago, and the energy used is only about 10 kJ, a fraction of what is usually used to join much thinner sheets."

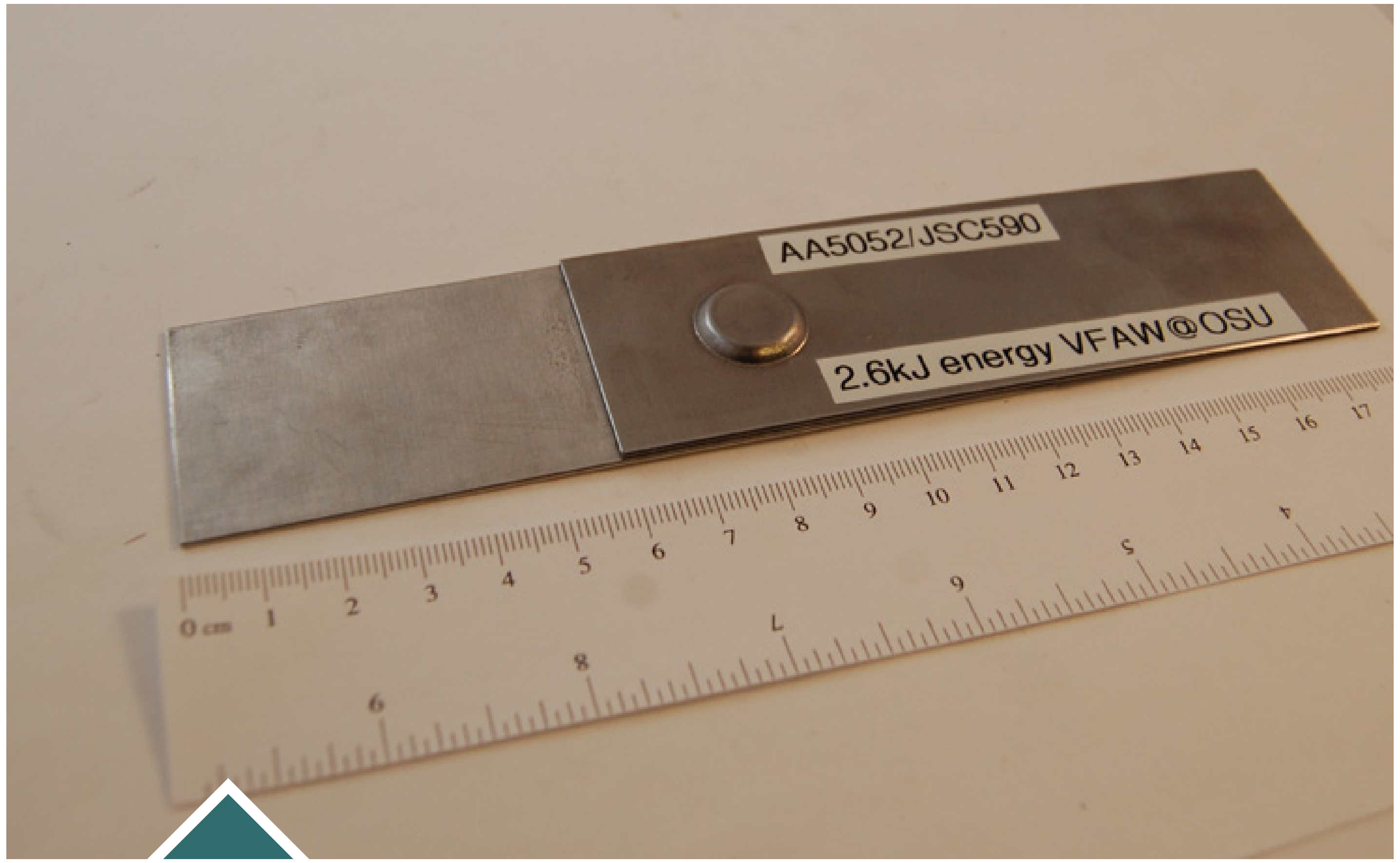
Vivek and his team made the jump by introducing an interlayer between the aluminum and steel, which is an "old trick" utilized in explosive welding, Vivek says, which has similarities to VFA. When two incompatible metals, such as a high-strength steel and thick, high-strength aluminum, are put together, they need something that will be compatible in between them, such as 3000 series aluminum.

"The 3000 series is a little softer," he explains, "so it was able to weld to the steel and aluminum very well."

Regarding the choice for the consumable foil material, Vivek says they opt for aluminum for its lower cost and easy availability as well as its electric-to-mechanical energy conversion properties. Other materials such as magnesium, copper and steel can also be used, but may not provide the same "bang for the buck."

IMPORTANT PARTNERS

VFA is now being put to the test on actual car parts, including the dashboard upper panel of full-size sedans. The Ohio State team is also working with the Department of Energy to make a lighter car chassis, something they've been working on now for about seven months.



Impact spot welding achieves what other types of welding or adhesives cannot: joining dissimilar materials at a lower cost.

"The goal of the DoE project is to take about 25 percent of the component weight out of it at a cost premium of under $3 per pound taken off," Vivek says.

The team is also working on making the process more efficient, taking it from a static, pedestal process to an automated process by attaching it to a robot. Coldwater Machine Co., which has been on board with Ohio State for some time, is working on that presently, and they expect to have a working version of it ready at some point this month. Ohio State's Center for Design and Mfg. Excellence is also collaborating on this issue.

"It's absolutely amazing," Vivek says of the advancements. "Getting to this point where there are all these different entities involved to solve a real-world problem is incredible."

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>
> *Anupam Vivek, research scientist, Ohio State University*

The Center for Design and Mfg. Excellence has a team of researchers that includes professors, graduate students and undergraduate students. Glenn Daehn, Ph.D. (middle left) and Anupam Vivek (middle right) are flanked by two student researchers in their VFA laboratory, Brain Thurston (left) and Yu Mao.

Watch the video for an overview of the solid-state welding method developed at Ohio State University.

Vivek says they are also offering working VFA systems to research and development labs and prototyping shops to accelerate the technology adoption. Coldwater will host one of these systems while another one will be set up at Tri-Rivers Career Center, featuring a welders' training school an hour north of the university in Marion, Ohio. ■

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