Next-generation ShAPE metal extrusion arrives: Bringing patented technique closer to industrial applications

April 3 2024, by Oliver Peckham

The second-generation ShAPE 2 machine has arrived at PNNL, where it will help prove the mettle of the ShAPE extrusion technique. Credit: Andrea Starr | Pacific Northwest National Laboratory

Extrusion, which can produce complex parts made of lightweight metals, is an increasingly important manufacturing process for everything from buildings to electric vehicles. Pacific Northwest National Laboratory's (PNNL's) patented Shear Assisted Processing and Extrusion (ShAPE) technique is a step beyond traditional extrusion, capable of creating materials and components with extraordinary properties that cannot be achieved through conventional manufacturing.

Now, the next-generation ShAPE machine has arrived at PNNL, where it will help prove the mettle of the ShAPE technique. "ShAPE 2," which is up and running, is designed to allow researchers to produce larger, more complex extrusions—a major step toward many real-world industrial applications for the ShAPE technique.

"This gets us into the realm of things that can go in real buildings and real cars," said Scott Whalen, co-developer of ShAPE and chief materials scientist at PNNL. "On ShAPE 2, we've already made profiles that meet the needs of real-world parts. For instance, we extruded a tube with a two-inch diameter and a wall thickness of 0.1 inches—the same profile as a roof rail on a Ford F-150."

Getting into ShAPE

Extruded metal components are made by pushing a billet of metal through an opening in a die. Traditionally, metal extrusion uses external heat to soften the whole billet before pushing it through the die.

Not so with ShAPE. Instead, ShAPE combines a rotating head near the die with an incredibly powerful hydraulic press on the opposite end. The hydraulic press forces the billet toward the die, and the rotating head produces friction that heats and softens just the portion of the billet entering the die.

This approach enables the production of parts with unconventional chemistries and microstructures that produce improved material properties, as well as the extrusion of post-consumer aluminum scrap—which can reduce embodied energy and carbon emissions by >90% compared to traditional recycling methods.

Harder, better, faster, stronger

The first-generation ShAPE machine, which debuted seven years ago, has hosted a wide range of research, demonstrating ShAPE's applicability for use cases ranging from automotive components to ultra-conductors. As ShAPE 1 continued to ace test after test, researchers planned for the next step: scale-up.

Enter ShAPE 2. The new machine was designed and manufactured by Bond Technologies and delivered to PNNL's Applied Energy Laboratory late last year. The machine quickly produced its first successful extrusions.

ShAPE 2 was delivered to PNNL in late 2023. Credit: Andrea Starr | Pacific Northwest National Laboratory

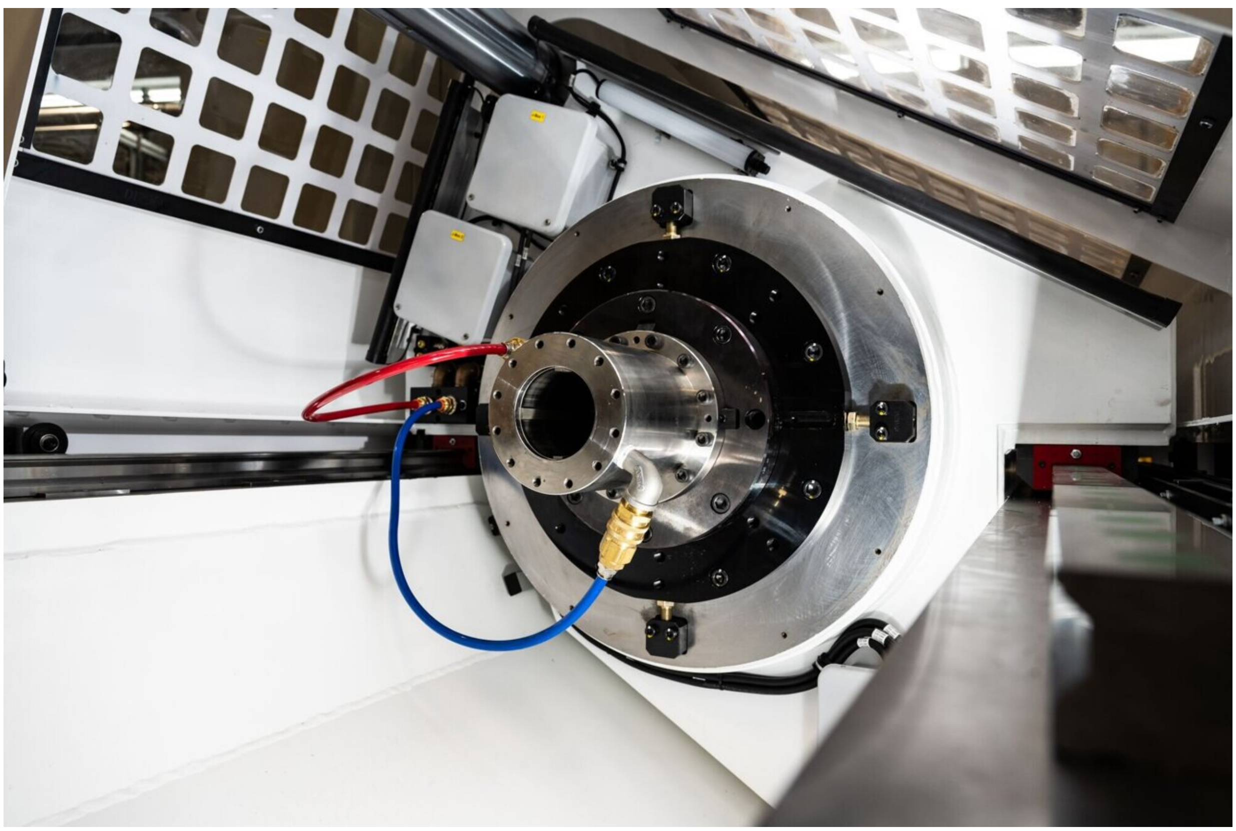
"Compared to ShAPE 1, ShAPE 2 gives us three times the motor power, four times the torque, and 50% more ram force," Whalen explained.

Crucially, the much larger ShAPE 2 machine enables the production of larger extrusions. Where ShAPE 1 could only produce extrusions in the 1/2 to 3/4-inch diameter range, ShAPE 2 will enable extrusions with diameters up to 1.5 or 2 inches.

For many other applications, ShAPE 2 can likely produce components at around half-scale, with many industrially extruded components requiring around a four-inch diameter.

"At PNNL, our business is research and development," Whalen emphasized. "But addressing scale-up and other manufacturing questions helps ensure technologies like ShAPE make it out of the laboratory and into the real world. At around half-scale, ShAPE 2 is more industrially relevant than ever. It's big enough that stakeholders and executives can believe in the benefits and possibilities."

Thanks to the increase in extrusion size, ShAPE 2 will also allow researchers to create more complex features—such as intricate webbing—in their extrusions.



Initial testing will explore the capabilities of ShAPE 2. Credit: Andrea Starr | Pacific Northwest National Laboratory

Pedal to the metal

The first question that will be asked of ShAPE 2 is whether scaling up the technique produces any unexpected changes in the microstructures or material properties of the extrusions.

"We expect—although have yet to prove out—that given similar operating conditions, ShAPE 1 and ShAPE 2 will produce similar microstructures," said Scott Taysom, a research engineer at PNNL.

By testing the outputs of ShAPE 1 and ShAPE 2 against each other, the researchers plan to project how a full, industrial-scale ShAPE machine is likely to scale.

"This is a new process, and we think we understand how it will scale, but we need to validate our mathematical projections with experimental data by pushing the limits of ShAPE 1 and ShAPE 2," Whalen said.

Early testing will focus on testing ShAPE 2's upper bounds—both for round extrusions and more complex extrusions—and introducing more challenging materials, like post-consumer aluminum scrap.

"We're excited to make larger components from aluminum scrap that we can then send out to finishing houses to see how our recycled material responds to anodizing, painting, powder coating, and so on," Whalen said.

"For the building and construction industry, it will be important to show that these coatings perform just as well on ShAPE-extruded aluminum scrap as they do on conventionally extruded primary alloys."

While most of the initial research conducted on ShAPE 2 will focus on evaluating the machine itself, other research projects will begin to use the machine by the end of the year. Eventually, ShAPE 2 will be used for research areas spanning applications in buildings, automotive manufacturing, industrial decarbonization, and more—with some of those projects migrating from research on ShAPE 1.

All ShAPEs and sizes

ShAPE 1, meanwhile, isn't going anywhere. "ShAPE 1 is still a fantastic platform which we will always continue to use for doing science," Whalen said.

The team also hopes to use ShAPE 1 as a lower-risk stepping stone to further the scientific understanding of the process and to aid researchers looking to eventually scale up work to ShAPE 2.

"If you're going to use an exotic metal or difficult-to-extrude alloy and you're still figuring out what temperature you want to run at—let's try it on something smaller and cheaper before moving to something bigger," Taysom said. "If you accident[al]ly destroy a die, it's the cheaper die on ShAPE 1 instead of the pricier die on ShAPE 2. And we're an R&D organization that pushes the bounds, so sometimes we trash dies—it's just a part of research."

Forging ahead

"ShAPE 2 will enable us to increase our ability to collaborate," Whalen said. "When I talk to potential research partners, they're impressed with what we're doing, but they always ask: 'What's the pathway to full-scale parts?' This is a step toward helping people understand that ShAPE can be scaled up."

And, of course, the team already has ideas in mind for additional ShAPE machines. Those future iterations might not be larger: instead, they might focus on producing different types of extrusions from specialized materials, leveraging new types of components, or serving more specific industrial applications.

"As researchers at a national laboratory, one of our objectives is to de-risk technologies for industry adoption, be it scaling, throughput, or material properties." Whalen said. "We're trying to de-risk as many areas as we can."

Provided by Pacific Northwest National Laboratory

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