Using AI for smarter metal 3D printing of mission-critical items like propellers

ASU team charts new course for additive manufacturing of metals

By Kelly deVos, ASU News
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Additive manufacturing, also known as 3D printing, has the potential to revolutionize how products are made. Using materials that range from ceramics to nylon, 3D printing allows people to create custom parts and products on demand, for use anywhere — from space stations to gas stations.

But even though we can now 3D print incredibly complex shapes, predicting how strong or durable a printed part will be is still a major challenge.

Faculty members in the School of Computing and Augmented Intelligence, part of the Ira A. Fulton Schools of Engineering at Arizona State University, are developing new artificial intelligence to make the process of 3D printing stainless steel faster and more reliable.

Aviral Shrivastava, a professor of computer science and engineering, and Ashif Iquebal, an assistant professor of industrial engineering, have received a grant from the National Science Foundation for the project “CompAM: Enabling Computational Additive Manufacturing,” to use AI to make metal 3D printing faster and more reliable by predicting how the material will form during the manufacturing process.

In the demonstration phase of the project, the team will 3D print a five-axis, metal naval propeller using 316L stainless steel, a common industrial-grade metal alloy. The goal is to control the printing process so precisely that they can engineer the metal grain size to be less than one micron — about the width of a strand of spider’s silk — which significantly improves the material’s properties.

Why a propeller? Because it’s large, has a tricky geometry and demands precision — exactly the kind of part that pushes current metal additive manufacturing to its limits.

From the forge to the fleet

A critical challenge in the adoption of additive manufacturing technology is that the internal structure of a material, called the microstructure, changes depending on how the part is printed. Tiny modifications in heat or timing during printing can drastically alter how a material performs.

“When we do metal printing, the quality of metal is actually dependent on the cooling curve,” Shrivastava says. “We want to control cooling so we can achieve the desired properties.”

He explains the problem in terms of conventional blacksmithing. Traditionally, blacksmiths cooled metal using different forms of a process known as quenching. Dunking white-hot metal in water cools it quickly and produces hard tools, such as swords or knives. Alternatively, sand quenching cools the metal more slowly over time, resulting in a more malleable material.

Because things such as naval propellers have strict performance and engineering standards, when industry wants to 3D print such components, experts must run complex computer simulations to determine how things like printing and cooling speed will affect the process. Or they must rely on trial and error.

Eager to avoid the waste and uncertainty of trial and error, the ASU researchers are seeking more efficient ways to run simulations. Traditional simulations can be slow and expensive. Using current methods, running simulations on just one set of printing parameters for the naval propeller would take more than 60 days using a 1,000-core supercomputer.

Shrivastava and Iqubal’s team want to change all of that. They are building a physics-informed, AI-powered system that can predict how a metal’s internal structure will form as it’s printed.

The researchers created a smarter way for the AI to learn and apply concepts from physics without needing huge amounts of data or complex math operations. The system learns as it goes, identifying the important data points that should be focused on.

“For many processes, there are actually a lot of studies that have been done,” Shrivastava says. “Physics is just a set of rules that are obeyed in the real world. What we’re doing is we taking these equations and combining them with data-driven learning to make the system learn better and faster.”

The new system will also save time by defining the areas of the material that need more detailed attention than others, skipping over the parts that don’t change much during printing.

Industrial engineering on deck

The project builds on Iquebal’s expertise in smart manufacturing. He says it’s essential to ensure that the work has clear industrial applications.

“The real value of this work is its ability to bridge research and industrial need,” Iquebal says. “In industries like aerospace, defense and energy, the performance of metal components isn’t negotiable — it’s mission-critical. By giving manufacturers faster, more accurate tools to predict and control material properties, we’re enabling a new era of precision manufacturing and reducing the costly guesswork that often slows innovation."

Using a newly acquired, high-tech 3D printer at the ASU Innovation Hub that includes a six-axis robotic arm and lasers, Iquebal and the team will create a large naval propeller using stainless steel and compare the predicted microstructure to what actually forms inside the part. They will then test the accuracy of their new technology by comparing it with traditional simulations and the real printed propeller.

Iquebal and the team hypothesize that manufacturers will be able to fine-tune 3D printing processes to get the exact properties they want with fewer trials. The software and tools will be made freely available, helping researchers in other fields speed up their own simulations.

Shrivastava says that the team also will incorporate the work into graduate-level computer science classes and conduct outreach activities for K–12 students.

Ross Maciejewski, director of the School and Computing and Augmented Intelligence, says that the work demonstrates the important intersection of industrial engineering and computer science that exists within the school.

"This project represents exactly what we strive for — innovation that's deeply relevant to industry," Maciejewski says. "By combining artificial intelligence with materials science, our faculty members are charting a new course for advanced manufacturing. It's a demonstration of how our research is propelling the future of engineering."

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Main image

An illustration of the 3D metal-printing process. Researchers in the School of Computing and Augmented Intelligence, part of the Ira A. Fulton Schools of Engineering, are creating advanced artificial intelligence tools aimed at improving the speed and reliability of 3D printing with stainless steel. Photo illustration by Andrea Heser/ASU