Can you 3D print Damascus steel? Pretty much, yeah

Enlarge / The light-colored layers in this 3D printed block are much harder steel, while the dark layers in between are more ductile.

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Damascus steel—and modern versions of the steelmaking technique—is generally synonymous with artisan forgework. In traditional Japanese sword-making, for example, the steel is repeatedly folded to produce hundreds or thousands of alternating layers, producing intricate patterns in the finished product. That’s not just for the visual effect—the layers alternate between hard-but-brittle and more flexible steel, combining for the best of both worlds.

A new study led by Philipp Kürnsteiner of the Max Planck Institute for Iron Research shows that it is possible to do something very similar with laser additive manufacturing—3D printed metals.

Traditional folded steels combined two steels that varied by carbon content and in their microscale structure, which is controlled by how quickly it cools (by quenching). In this case, the researchers were using a nickel-titanium-iron alloy steel that works well with these 3D printing techniques, in which metal powder is fed onto the work surface and heated with a laser.

Rapid cooling of this steel also produces a crystalline form as in quenched high-carbon steels. But further heat treatment leads to the precipitation of microscopic nickel-titanium particles within the steel that greatly increase its hardness—a pricey material called “maraging steel.”

The team’s idea was to use the layer-by-layer printing process to manipulate the temperatures each layer experienced, alternating softer, more flexible layers with layers hardened by that precipitation process. While printing a cubic chunk of steel, they did this simply by turning the laser off for a couple minutes or so every few layers. The top layer would rapidly cool, converting to the desired crystalline form. Then, as additional layers were added on top, temperatures in the crystalline layer would cycle back up, inducing the precipitation of the nickel-titanium particles.

The first test piece was thrown under the microscope for an incredibly detailed analysis, including a close-enough look at the hard layers to see the precipitated particles. The researchers even *atom mapped* the layers to verify their composition. So the researchers were able to confirm that the process definitely accomplished what they were aiming for.

Enlarge / A close-up look at the layered metal (top left) with atom-mapping analyses showing the dark flecks of precipitated nickel-titanium. Graph at bottom right shows the make-up of the dashed rectangle.

The researchers experimented with different timings for the laser, measuring the resulting temperature patterns. It’s an interesting little 3D puzzle, as temperature at any location within the steel depends on its proximity to the laser over time, which is affected by layer thickness, area of the piece being printed, and the cooling time when the laser is off.

This is just one way of doing things, though—the team points out that laser power and speed could also be varied, and separate sources heating or cooling could be added.

For their strength tests, the researchers settled on a block with just single-printed-layer gaps between the hardened layers. For comparison, they printed another block

continuously, producing no hardened layers at all. Both were stretched until they fractured and failed.

The Damascus-like sample was significantly stronger, holding up to about 20 percent more stretching force. It didn’t reach the strength of a typical, traditionally made maraging steel, but the researchers note that this requires “a time-consuming and costly post-process ageing heat treatment.”

While this study is just on a “proof-of-concept” level, the fact that it provides a potential alternative to an expensive process may boost its viability. And it offers a way to control the steel properties at a much finer scale. “As an example,” the researchers write, “one could manufacture tools that are soft and tough on the inside and only the outer skin is precipitation hardened without the need to apply a coating or a case-hardening treatment.”

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