MIT News
ON CAMPUS AND AROUND THE WORLD

MIT team places 3rd in materials design competition with novel 3D printable metal

New material could be used by Tesla to produce all-electric vehicles with just a few massive parts.

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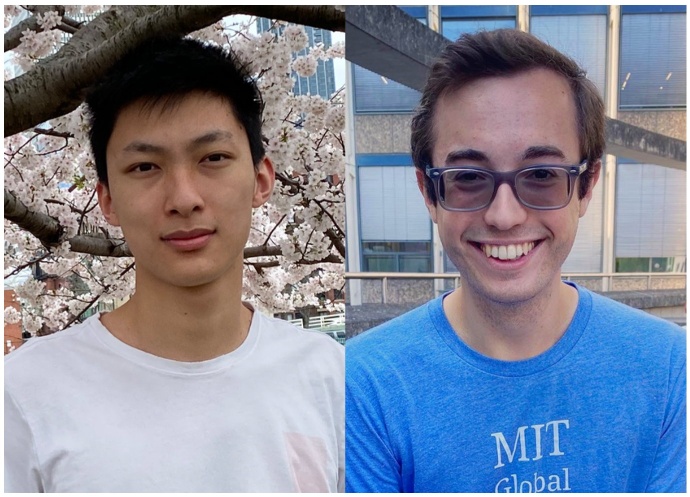

Junior Ian Chen (left) and Kyle Markland ’22 placed third in ASM Materials Education Foundation’s 2022 Undergraduate Design Competition.

Photos courtesy of Ian Chen and Kyle Markland.

The United States might be one step closer to its goal of having half of all new vehicles sold in 2030 be zero-emissions electric vehicles. That’s thanks to a pair of MIT undergraduates and their graduate student coach in Germany, who developed a new type of steel not for the cars’ build, but for the die-casting molds that stamp them out in just a few discrete parts.

MIT junior Ian Chen and Kyle Markland ’22 placed third in ASM Materials Education Foundation’s 2022 Undergraduate Design Competition. The 3D-printable steel alloy that earned them the honor was inspired by an innovative manufacturing approach called Giga-casting, popularized by carmaker Tesla and used to assemble the all-electric Model Y.

Chen accepted the award at a ceremony in New Orleans on Sept. 12, and Chen and Markland will share the $1,000 prize. ASM Materials Education Foundation is the charitable division of materials engineering organization ASM International. Its aim is to promote applied science careers to students and teachers.

A design challenge

Chen and Markland's project has its roots in last spring's class 3.041 (Computational Materials Design), taught by Gregory Olson, the Thermo-Calc Professor of the Practice at MIT. Olson is one of the world's leading scholars of computational materials science, which uses computer modeling and simulation to understand and design new materials. His methodology has been used by Apple to create the Apple Watch, and it caught the attention of Tesla CEO Elon Musk.

"To get affordable electrical cars with good range, he had to make aluminum structures affordable," says Olson, speaking of Musk. "So he looked at the kind of die casting for little car models and said, 'Why not scale it up? We'll cast the whole car.'"

Tesla used Olson's computational approach for the aluminum that could be die cast — that's the metal casting process by which molten metal is poured into a mold to form objects. Cars are typically built using hundreds of die-cast parts — engine cylinders, brackets, and other components — that are later put together on an automated assembly line to make a vehicle. The Giga-casting process — named for the massive casting machines known as Giga Press — instead involves casting just two or three large automobile pieces, vastly reducing the complexity of the process and the associated costs.

The problem is, "when you scale up the process, the heat transfer is slower, and the cycle times are too long," Olson says — that is, the liquid metal takes longer to cool, making the whole process less efficient and more costly.

A technique called "conformal cooling" can help. In it, narrow channels follow, or conform to, the shape of the thing being cast, and coolant or water is run through them to accelerate cooling.

So the challenge took shape. Charles Kuehmann, vice president of materials engineering at SpaceX and Tesla, and a past student of Olson's, confirmed the need: a better die steel, also called tool steel, that's "printable" — a material that could be loaded into a 3-D printer to print new dies with better strength and thermal properties. Conventional steels, Olson said, "are quite brittle and cracking-prone if you try to print them."

Offshore production

For an advisor to the student team, Olson turned to Florian Hengsbach, a visiting student at MIT from Paderborn University who returned to Germany during the pandemic shutdowns in 2020.

Hengsbach's doctoral thesis couldn't have been more apt for the MIT project: tool steel design for additive manufacturing, a term often used synonymously with 3D printing. His supervisor is Mirko Schaper, the dean of Paderborn's college of mechanical engineering, head of its materials science department, and an expert in additive manufacturing.

“Here at Paderborn, we print materials, characterize them down to the atomic level, and determine the process-microstructure-performance correlation,” Hengsbach says — in other words, understand how the material will behave in various 3D printing conditions.

With Hengsbach working in Europe and Chen and Markland in Cambridge, Massachusetts, the team began designing the new metal using CALPHAD, a method for calculating the properties of materials. Using thermodynamic material models, the team could predict what new materials would do in different conditions.

Hengsbach formulated the material at Paderborn’s additive manufacturing center and printed it as a test — making the new metal alloy, melting it, then atomizing it into tiny droplets that solidify, making a powder. Then the powder is layered and melted by laser into an object in a 3D printer.

“This was very successful,” Hengsbach says. “We’ve designed a very promising tool steel, with superior performance regarding thermal conductivity, hardness, and toughness, which can actually be printed.”

The new metal has other potential manufacturing uses, Hengsbach says — injection molding, used often for plastics; or press hardening, which can form high-strength steel in complex shapes; or other processes — “everywhere you want to use conformal cooling channels, this material can be used.”

Hengsbach will return to MIT in February 2023 to work as a postdoc in Olson’s research group.

“You won’t regret it”

The team filed a U.S. patent application for the new printable die steel, and the next step is testing in casting die applications. Talks with Tesla are underway.

In what might be an endorsement of the team’s novel metal, Musk tweeted on Sept. 9 to his more than 100 million followers, “Take Materials Science 101. You won’t regret it.”

For Chen, a junior majoring in materials science and engineering, designing the steel has confirmed that he wants to stay in a materials-related lane for graduate school.

“This project has pushed me toward a more computationally driven materials area,” Chen says, “where computational models are used as a critical tool for materials design and analysis.”

Markland, who graduated in May with a BS in materials science and engineering, recently started working full time at the Ford Motor Company in Dearborn, Michigan. As part of the Ford College Graduate program, he’ll work on different projects his first two years, starting with vehicle paint engineering and corrosion prevention.

“It feels great to have our work recognized by ASM,” Markland says. “Sometimes classwork can feel abstract or removed from the real world, and it’s a refreshing reminder that the project we did has recognition beyond just a class assignment.”

First prize in the ASM competition ($2,000) went to Michigan Technological University for the material characterization, modeling, and optimization of aluminum-cerium-magnesium alloys for extrusion; and second prize ($1,500) went to the University of Tennessee at Knoxville for materials analysis in the restoration of musical organs.