

# Printing with **FIRE**

By Steven Mackay



*Drew Snelling uses a common aluminum alloy melted to a temperature of 1,400 degrees to create the final mold, a web-like brick structure that is hoped could be useful for manufacturing (below).*



At the Kroehling Advanced Materials Foundry on Plantation Road — home of the Virginia Tech Foundry Institute for Research and Education, also known as VT FIRE — doctoral and graduate students working with Chris Williams combine old technologies, such as sand casting with 3-D printing, to design and fabricate complex metal structures.

Drew Snelling of North Augusta, S.C, a doctoral student in mechanical engineering, is among researchers using 3-D printers to first build an intricate, webbed brick of silicon sand to use as a “negative” when pouring melted aluminum — at 1,400 degrees Fahrenheit — to create a relatively lightweight, strong metal block.

The brick, according to Williams, could one day be used as armor for the undercarriage and sides of Humvees and other military vehicles used in battlefield conditions.

“I never thought I would be doing any of these things, including additive manufacturing, learning materials science, and working in a foundry,” said Snelling. “I have, since I was 15, been interested in design and working with metal so this is a great fit for me.”

Step-by-step: How to make a metal-ceramic cellular brick via 3-D printing:



Doctoral student Drew Snelling and Associate Professor Christopher Williams, both of mechanical engineering, use a 3-D printed sand mold to cast metal to create an aluminum-alloy brick that may be used for vehicle armor.

**1) Digital mold design:** The Binder Jetting process allows for simple creation of complex mold structures from a 3-D solid model. Using a computer-aided design program, the desired mold shape is modeled to include geometrically complex shapes, such as interlocking web-like cross hatches, which are designed to be lightweight and yet withstand sufficient impact loading.

**2) Mold printing:** The computer model of the mold design is imported into the 3-D printer's accompanying software, where it is oriented, scaled, and positioned. The massive printer, built by ExOne, uses a high-tech glue known as furan to mix and bind with refined coated silica sand. The printed sand mold is capable of casting numerous metals, allowing for greater variety in the final casting product. After printing, excess powder is vacuumed from the internal passageways of the complex mold.

**3) Ceramic tile embedding, mold packaging:** 3-D printing not only enables the creation of complex shapes, it also enables the creation of parts with multiple materials. Before casting the metal into the printed silica sand mold, the team carefully places several ceramic tiles into pre-designed gaps and printed locator pegs. Also, an outer mold "sandwich" — similar to the walls built for

the pouring of a foundation in a building — is placed around the printed mold to direct the molten metal flow as desired. The outer mold allows for additional characteristics to be added to the final product, including allowed space that will create a solid plate both above and below the final brick.

**4) Metal pouring:** Using A356, a common aluminum alloy melted to a temperature of 1,400 degrees F, in a silicone carbide crucible using an electrical resistance furnace, castings are poured along with a chilled spectrometer sample for determining chemistry. From retrieval to pouring, the metal's temperature already has dropped to roughly 1,370 degrees F. The hot metal can burn out enough of the binder in the printed sand mold such that only light pressure on a pointed instrument was enough to break the mold apart. Additional sand binder is removed via heat and then blasts from a shop air gun. The final brick is heated to further strengthen the structure, quenched in a bucket of room-temperature water, and then artificially aged for five hours. The final product is a lightweight, metallic "sandwich" panel that is designed to absorb explosive blasts. The integrated ceramic tiles, which are embedded in the cast metal structure, provide additional ballistic protection. The original printed sand mold? Destroyed in the process.