Laboratory perfects metal powders for manufacturing

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Closeup of gas nozzle. Credit: Ames Laboratory

Iver Anderson and Emma White, metallurgists at Ames Laboratory, like to show off samples of metal powders encapsulated in custom-made hourglasses to visitors. Dull gray, the powders are barely remarkable in and of themselves, let alone in comparison to each other.

Until the hourglasses are flipped, and observers can compare how the powders flow through the narrow necks of glass. The powder created by traditional manufacturing methods doesn't, exactly. It starts and trickles and stops. It needs shaking and manipulating to get through. The other powder, produced at the laboratory's high-pressure gas atomization facility, pulses smoothly through the hourglass of its own accord.

It's all because of the smooth spherical particles produced by Ames Laboratory's gas atomization method, an improvement over traditionally manufactured powders.

"You can see they're chunky, randomly sized, with rough edges," said White of the traditionally-made powder particles, comparing scanning electron microscope images of the two. "They don't flow past each other, and that's going to require a pulsing mechanism or an agitator in the manufacturing process. That's going to cost the manufacturer more in energy to run their production line."

It's only one of the many benefits of powders created by the gas atomization process, which has garnered the laboratory at least 16 patents over the last two decades, and created a spin-off company, IPAT, recently acquired by Praxair, which exclusively licenses Ames Laboratory's titanium atomization patents and is racing to introduce to an eager marketplace.

Splitting liquid into droplets

Gas atomization is a powder production method that uses high-pressure gas flow to distintegrate molten metal into particles. In the Metals Development building at the Ames Laboratory, Anderson, a senior metallurgist, and White, a post-doctoral researcher, are able to produce experimental quantities of powder with the laboratory's experimental apparatus, about half of a liter volume per production run. Another, larger gas-atomizer at the ISU Applied Science Center can produce around three liters.

The basic operation is the same in both. Metal is melted by an induction furnace and held in a crucible with a stoppered opening in the bottom. When the stopper is lifted, the metal flows through a specially designed pour tube into an atomization nozzle (also unique to Ames Laboratory) that focuses a number of round-hole gas jets on the molten metal in a tight pattern. The individual jets of gas—argon, nitrogen, or helium depending on the test run— knit together to form a supersonic "curtain" that flows directly across the liquid metal flow direction and forces the melt to couple directly with the high kinetic energy of the supersonic gas flow, creating a controlled droplet spray.

"This energetic coupling happens because the gas curtain creates a suction that pulls the melt into the atomization zone and simultaneously forces an upward directed gas counter-flow to form that splits the liquid as though there was an umbrella stuck underneath it and makes it flow sideways, across to the outer edge of that round nozzle," said Anderson. "So it gets presented to the gas as a thin film that is forced by the gas to turn in the gas flow direction so it can shear past the surface of that film, and strip off waves of liquid that break at their crest to form droplets.

"It's the same phenomenon you can see on the surface of a pond hit with a gust of wind. You see small ripples and a spray of water come off that gust."

Once the droplets form, they solidify rapidly as they fall through the spray chamber and are cooled by additional gas halos. The resulting powder particles are separated from the combined gas flow and settle into two powder collector cans that are connected to the end of the spray chamber. The cleaned inert process gas exits through two types of final filter devices and is exhausted from the lab.

Iver Anderson (left) and Emma White explain the metal powders to Kurt Kovarik, a staffer to U.S. Sen. Charles Grassley. Credit: Ames Laboratory

Advantages

Ames Laboratory's gas atomization method produces powders that are customizable, consistently sized and smoothly spherical. The advantages of a perfectly formed powder are multiple. Besides the advantage of smooth powder flow already mentioned, the individual round particles have little internal porosity, and pack together optimally in bulk. Both qualities reduce dead air space and improve the quality of parts produced using these powders.

Using gas atomization, Ames Laboratory has produced powders of iron, aluminum, nickel, copper, tin, magnesium and various other metals and alloys, in addition to titanium, one of its key research accomplishments.

"The titanium industry is extremely interested in powder metallurgy and final-shape consolidation methods," said White. "Titanium is expensive and the large amount of waste titanium produced during machining cast parts into final shapes significantly increases their costs. They see advances in powder metallurgy as an effective cost control strategy by making parts into near-final shapes and minimizing waste titanium."

The powders produced by this method have also been used in the production of stronger alnico (aluminum, nickel, cobalt, and iron) permanent magnets, and in the production of an experimental power transmission cable fabricated out of an aluminum and calcium composite.

And the possibilities of these metal powders don't just look to the future, but may also redeem materials from the past that had been abandoned by researchers and industry as impossible to work with.

"You can create an alloy with fantastic properties, but if you can't make something useful out of it, it will never get off the lab bench. This method enables us to revisit materials that have been around a long time, give them a second chance, and find new potential applications for them," said Anderson.

Impossible shapes out of incredible alloys

Ames Laboratory is seeking to expand its powder production capabilities beyond research capacity, with the goal of being able to produce up to 200 pounds of powder in one production run.

At that scale, new opportunities for research are possible, explained Anderson and White. Large batches provide sufficient samples amounts for shared research projects among multiple national laboratories and industry partners.

With new 3-D printing and additive manufacturing capabilities expanding rapidly, Ames Laboratory will be able to position itself as a provider of custom metal powders for these research areas, continuing to fine-tune the abilities of the gas atomization process.

All is a natural progression of the research goals that Anderson has worked towards for decades. "The ability to make impossible shapes out of incredible alloys is my mission in life. I want to work on ways to get this done."

Provided by Ames Laboratory

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