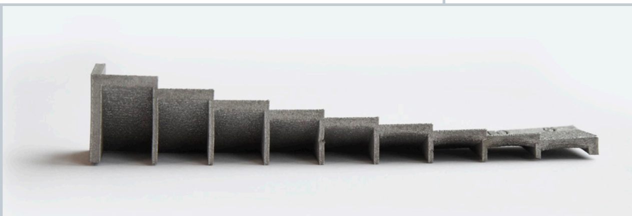
What Effect Does Gas Flow Have in Metal Additive Manufacturing?

By Brent Donaldson

Of all the process parameters in metal additive manufacturing, none may be as consequential and complex as gas flow dynamics. Inert gas, typically argon, is central to the function of metal additive machines, as well as peripheral AM processes such as hot isostatic pressing (HIP-ing), and is the media most often used for quenching during the vacuum heat-treating process.

Sintavia, a tier-one metal additive manufacturing company founded in 2016 by Brian Neff and partner Doug Hedges in Davie, Florida, is so invested in understanding gas flow dynamics that the company recently partnered with Taiyo Nippon Sanso Corporation (TNSC), one of the world's leading providers of industrial gases. Based in Tokyo, Japan, TNSC has extensive experience researching and providing proprietary gas flow solutions for industrial welding applications. The partnership aligns with Sintavia's lab-testing-first philosophy toward metal AM processes. In fact, while the company today is focused on scaled AM production, Neff and Hedges didn't purchase their first additive machine until their lab had conducted tests across metallurgy, metrology, heat treating, mechanical testing, CAD and designing for additive.



A view of the two test components Sintavia printed in order to show the effects of gas flow within a metal 3D printer. Note the rough surface finish and discoloration of the top piece, which was oriented away from the gas flow inside the build chamber. A side-facing view (above) reveals a rounding and thinning of the upper walls as the print angle increases.

To understand the impact that gas flow dynamics have on a typical powder-bed fusion build, I visited Sintavia this March and got a first-hand look at a recent test build. Hedges, the company's president, walked me through the process with one of the company's lab technicians.

The image to the left shows two test pieces grown to show the effects of gas flow on down-facing surfaces. In the machine used for this test, argon gas entered from the right-hand side of the chamber. The argon was slightly over-pressured for the test, running at 12 millibars and flowing at 9.5 meters per second into the chamber in order to keep the oxygen levels at a low extreme. The piece shown on the bottom was grown facing the gas flow, while the piece on the top was grown facing away from it.

A close look at the two pieces reveals clear disparities. The overall geometry of the bottom piece is cleaner and closer to the CAD model than the bottom. A rounding effect can be seen on the top piece, especially at the edges along its top border, which also appear to be thinner. The surface finish of the bottom piece is also smoother, and the piece lacks the slight discoloration that is noticeable on the bottom piece.

Of course, the orientation of the part in relation to gas flow direction is not the only variable that affects these disparities within a build. Multiple parameters and components within the chamber interact with and influence the gas flow, including the rate of that flow, the speed created by the vacuum pump and operational variabilities across the machines themselves. Recoater blades have a similar effect on the flow of gas inside a build chamber. On a dual-direction recoater, the blade moves forward, stops, exposes the layer and moves back. At each point in this process, the argon is reorienting its path around the blade and affecting the flow dynamics of the argon.

In the meantime, as the laser hits the powder, particles (including nanoparticles) shoot out of the melt pools and are caught in the argon stream. Ideally, the gas carries this spatter across the powder bed and into the vacuum where it's trapped inside the machine's filters. But this is not always the case. The longer the exposure time for each layer, the more the nanoparticles and soot build up within the chamber and increase the risk of interfering with the laser intensity. Multiply this contaminant effect over time, and the process degrades the longer it continues.

To illustrate this phenomenon, Sintavia's machine technician lowers the speed of the vacuum pump as we look inside the active build chamber. As he lowers the speed, turbulences form within the chamber, and the soot that had been flowing steadily from left to right begins to trickle upward toward the laser. Sparks escaping the melt pool are elongated upwards rather than bending in the direction of the gas flow.

If you were to look at a 2D cross-section of a part built from these conditions, you would find larger particles of splatter that landed in a nearby melt pool and were re-exposed to the laser. Since builds can take several weeks, it's almost always the case that the powder toward the downstream side of the chamber is "browner, different-shaped and different-sized" than the unaffected powder in the bed, Hedges says. "Different machines are better at dealing with this issue."

Hedges notes that there are numerous adjustments that can be made to keep the chamber environment relatively clean. But some of these adjustments, or "tricks," such as delaying the recoating time in order to let the argon carry the contaminants out of the chamber, add time to the overall process.

Sintavia CEO Brian Neff says that the partnership with TNSC is strictly meant to demonstrate to both OEMs and customers that there are ways to scale production. "Everything comes down to cost and speed," Neff says. "Because of what we know about gas flow dynamics, we can make adjustments with our part orientation, the way we design our supports and so on. But we're not trying to be a leading edge in R&D. We want to apply this to scale production, to get faster build times at lower costs, period."