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JOM: The Magazine Talks with SLADE GARDNER of Big Metal Additive

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Slade Gardner is president and founder of Big Metal Additive (BMA), a company advancing large-scale metal hybrid additive manufacturing. He was the invited speaker at the Light Metals Division Luncheon at the TMS 2023 Annual Meeting & Exhibition, where he delivered the talk, "Rewriting Design, Cost, and Schedule Paradigms for Satellites with Aluminum Hybrid Additive Manufacturing."

This month, *JOM: The Magazine* talks with Slade Gardner about his company, Big Metal Additive, which has used metal hybrid additive manufacturing technology in projects ranging from unmanned underwater vehicles to satellites made of additive-produced parts.

Could you briefly describe your background and career path? How did you end up in your current role at Big Metal Additive?

Gardner: Ever since my Ph.D. work at Virginia Tech, I was fascinated with materials processing. While many of my peers were studying structure-property relationships, my dissertation was focused on process-structure-property relationships of advanced materials. The 'how' was just as important as the 'what.'

My first job was with Amoco Carbon Fibers, and in less than a year, my manager had me running engineering production orders in the factories. The immense responsibility of 'performing experiments' to trouble shoot manufacturing processes with the company's critical money-making infrastructure was not only thrilling, but also confirmed that the closer that I could connect development to product delivery, the more professionally satisfied I would be.

My next move was to Lockheed Martin Skunk Works® where I found endless appreciation of working on the most advanced platforms for the most important customers: warriors who defend our nation. Fortune favors the bold, and when the group leader of a special advanced manufacturing team asked me to research the use of carbon nanotubes as a structural material for next-generation air/space vehicles, I scoped a project to invent a new composition of matter and a synthetic method enabling additive manufacturing of nanotube structures. Over the next decade, I built my own development portfolio focused on large-scale AM (additive manufacturing) of polymers, composites, nanomaterials, and other advanced materials. Our group was the first to demonstrate large-scale extruder-based composite additive manufacturing. As part of Skunk Works®, our work was done quietly so it was left to other organizations who extended our work to capture the fame and recognition. After a decade of working on aircraft, I transferred to Lockheed Martin Space Systems Company, where I could apply the maturing manufacturing portfolio to space vehicles. Most importantly, we had matured wire-based metal AM sufficiently for producing satellite propellant tanks. I led the development effort, produced the first tank, and gained advocacy from stakeholders in Propulsion Engineering and Production. Years of work followed, and the team brought large-scale wire AM into the factory and qualified 46-inch-diameter satellite propellant tanks.

I found fulfillment with transition of AM to qualified manufacturing and product acceptance. The particular wire AM method we used had poor production

This article is part of an occasional feature series in which *JOM: The Magazine* talks with industry leaders about technology developments and current issues. To suggest a candidate for a future issue, contact Kelly Zappas, *JOM: The Magazine* editor, at kzappas@tms.org.

metrics for cost, speed, rate, and product acceptance, but I saw incredible potential with large-scale AM. I quit my job and founded Big Metal Additive (BMA) to solve the issues of large-scale AM, serve a wide range of customers, and re-define AM as an industrial manufacturing process for factory scale-up.

JOM: What is Big Metal Additive doing that's unique?

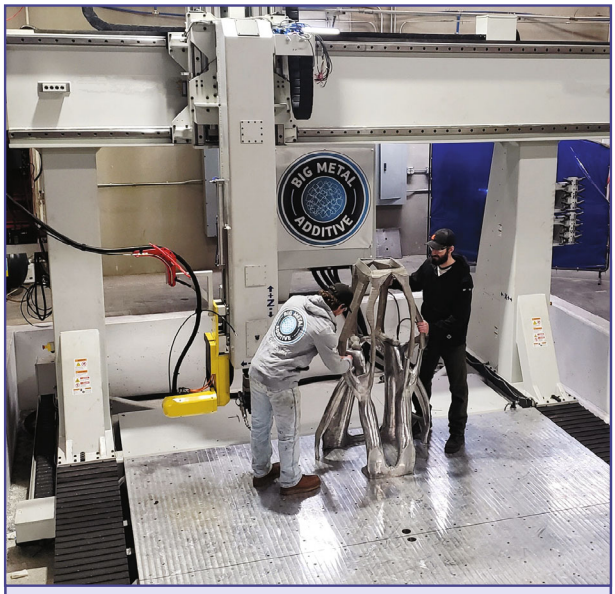
Gardner: When I founded the company, my goals were to solve issues of size, surface finish, and dimensional control with metal AM. I knew success required that the process was affordable and the products were acceptable—truly meaning there was a clear path to product qualification and acceptance. Every decision was guided by priorities using established industrial materials, processes, practices, and equipment. It sounds strange to say the uniqueness of the company is predicated on the commonality of every element, but that is the truth. So many of our competitors try to blend invention into their manufacturing path. My philosophy was that nothing should be invented; existing knowledge, industrial practices, and familiar components should be used and levered. Although a unique feature for BMA is the incorporation of multi-axis computer numerical control (CNC) machining into the AM process, we blend mature manufacturing capabilities, springboarding to a powerful result. We machine as we build and it makes all the difference. BMA can trim, surface machine, and re-establish datum every layer of the additive build. This gives our products superior mechanical properties, dimensional control, and complexity of product. Because our metal deposition is based on gas metal arc welding (GMAW), we lean on more than 60 years of manufacturing heritage, acceptance criteria, workforce training, inspection methods, equipment development, scientific literature, and worldwide trust of critical structure produced with the method. Every day, we drive over bridges in cars, trusting our lives to both, which have been produced and accepted with GMAW manufacturing. Oh yeah, and our machines are bigger than most. Our goal is not to be the biggest, just to be the best, highest quality products that meet customer requirements and expectations.

Early stages of manufacturing a cryogenic tank with integral cooling passages.

This optimized lightweight airframe structure has interior and exterior machined surfaces. Photos provided by Big Metal Additive.

JOM: You started your talk at TMS2023 by saying that your company makes impossible parts. What does that mean?

Gardner: There are impossible designs and there are impossible schedules. An impossible design might be an incredibly complex geometry like the topology optimized airframe structure that we produced for an Air Force project or it might be the cryogenic tank with optimized cooling channels built into the tank walls we produced for a NASA project. These products extend the imagination of our customers and present opportunities to optimize for assembly, integration, thermal performance, mass/mass distribution, or contained volume. We have courageous, creative, commercial customers pushing boundaries on their product designs to challenge our shared purview of achieving the impossible. This is not only incredibly



Parts 8 ft tall can be produced on this large BMA machine with a work table 12 ft x 12 ft.

rewarding for me, but it keeps the best of the best interested in working at BMA.

An impossible schedule is another animal altogether. Think of a 12-inch diameter stainless steel valve for a critical application with a 50-week lead time. Plant operations, ships, or submarines are held hostage to these schedule limitations. BMA can produce such an article in a quarter of the time, reducing delivery schedules for pressure vessels, valves, fittings, and other industrial components. Customers appreciate the reduced lead time and are willing to trade higher cost for faster delivery. Keeping their operations and their business moving forward is more important than saving a fraction of cost with months of delay.

JOM: What benefits and challenges does your AM process have compared to more traditional production methods?

Gardner: We are growing to a factory of 100 machines. Our AM process is flexible. We can produce a different product on each machine, or we can load the same Digital Production File on every machine and provide surge manufacturing. Wise customers are recognizing the power of having their products in digital inventory. A qualified 155mm artillery round would bring that product into digital inventory and dedicated production with every one of the 100 machines yielding thousands of rounds per day. When the surge manufacturing need was satisfied, the machines would be loaded with new files and other products would be produced.

The challenges we face are that strategy and wisdom do not always prevail. Many decisions are based on cost alone and do not account for schedule or availability or future orders. The U.S. manufacturing landscape is a testament to this with so many businesses lost over the past few decades because customers would rather send work to competitor countries to save a few bucks.

JOM: At TMS2023, your talk—delivered at the Light Metals Division Luncheon—focused on aluminum. Do you work with other materials as well?

Gardner: We started with one material, and it was aluminum. With startup success and business growth, we have expanded into other materials. We respond to customer demand, bringing materials through development and into qualification with business engagement. Our materials portfolio now includes steel, stainless steel, ultra-high strength steel, Inconel, copper-nickel and other nickel alloys. Importantly, we begin with certified wire feedstock materials and qualify the process and resultant materials we offer for customer applications.

JOM: What's the next challenge ahead for Big Metal Additive?

Gardner: The next challenge ahead for BMA is a giant leap in growth. As we qualify first articles for customers and create digital inventories, we also prepare for assembling factory lines of machines. We are planning that factory expansion to accommodate a variety of customer parts from a range of different materials. Our growth to a factory of 100 machines will likely occur in groups of ten machines at a time. I mentioned a characteristic lead time of 50 weeks we routinely hear from customers for supply-chain-challenged parts. Because our manufacturing philosophy is based on existing and accepted industrial components, we could stand up a factory line of ten machines in less than 50 weeks. Often, we can scale equipment and produce a customer component in less time than they currently wait for traditional product supply times.

JOM: Is there anything else you'd like to add?

Gardner: It's important to know that getting a part into digital inventory is a journey that begins with a prototype that solves challenges and proves feasibility. The next step is a 'first article' that includes creation of a Technical Data Package and then qualifies the part. The result is a digital inventory and readiness for production. All previous process, material, and equipment qualifications are valid for new products, so customers can build on the momentum. A digital inventory can be a cost savings, a schedule savings, or part of a strategic plan. It really is the next big discriminator in manufacturing supply.