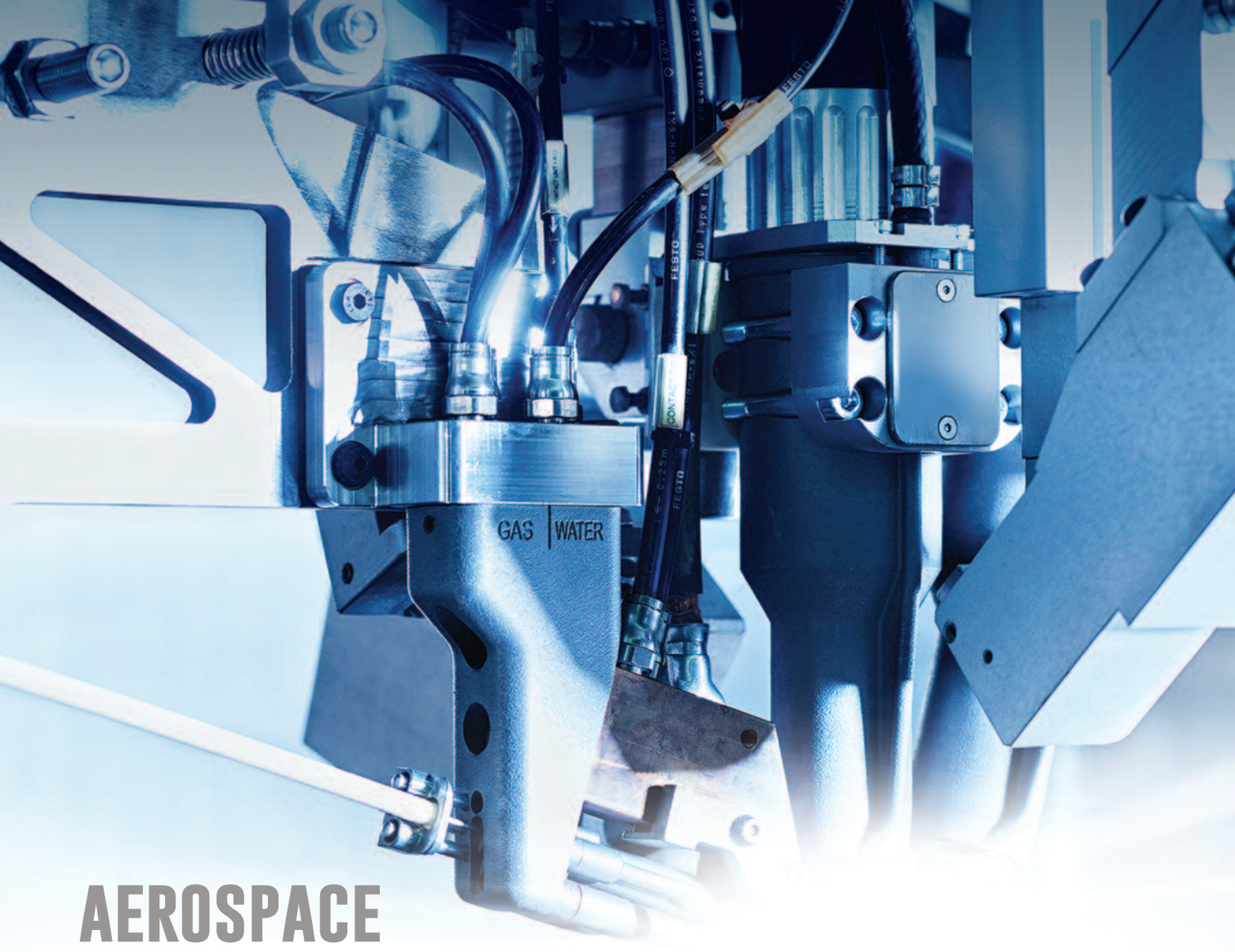
Modern Metals®

The magazine for metal service centers, fabri Ms/end users

www.modernmetals.com blication August 2018

‘PLANE’ MATH

ADDITIVE MANUFACTURING PIONEER NORSK TITANIUM CHARTS THE FUTURE OF FLIGHT



AEROSPACE

THE PATHFINDER

AN **ADDITIVE MANUFACTURING** TECHNOLOGY UNDERGOES TESTS AND TRIALS ON NUMEROUS APPLICATIONS AS IT PREPARES FOR TAKEOFF

Inside view of a Rapid Plasma Deposition Merke IV machine.

"CUSTOMERS WILL NEED TO BUY LESS TITANIUM AND MACHINE LESS TITANIUM AWAY. IT'S JUST PLAIN MATH."

CHET FULLER, CHIEF COMMERCIAL OFFICER

BY CORINNA PETRY

It takes years and years, hundreds of millions of dollars and dedicated metallurgists and engineers to create and refine a new technological process. Once the process is validated and the inventive material placed on approved supplier lists, the opportunity emerges to disrupt the old, inefficient way of doing things and cut a new path into the future. This is the challenge Norsk Titanium took on, and it's now in the proving stage for commercial viability and in-flight performance.

Modern Metals featured Norsk Titanium on its January 2016 cover. Quite a bit has happened since then so we asked CEO Michael Canario and CCO Chet Fuller to explain the company's additive manufacturing process—called Rapid Plasma Deposition (RPD), its implications for consuming markets and what's on the horizon.

"In 2015, we had one machine at our engineering and tech center in Norway. Today, we have three machines in Norway and nine at our Plattsburgh Development and Qualifications Center [in New York]," says Fuller, who joined the company when it employed 37 people. "We have over 150 employees now. So a lot has changed. We have been in serial production of Boeing 787 components, three different part numbers, for 15 months. We shipped our first parts to Boeing in May 2017."

Both Norway and Plattsburgh are compliant with ASO 9100C and ASO 9100D standards. Plattsburgh has been added to Boeing's Qualified Producers List. Spirit AeroSystems, a top builder of aircraft structures, named Norsk Titanium to its Approved Supplier List in June.

Of the three part numbers on the 787, Fuller notes "those are the only three structural titanium components on a plane in serial production. The only other AM titanium parts flying are fuel nozzles on the LEAF engine, made by GE. "That is the entire breadth of additive manufactured parts on serial production airplanes. GE and Norsk are the only suppliers. It's kind of daunting."

Norsk Titanium has conducted "thousands of tests for major OEMs and that testing will open up bigger and bigger windows of parts capable of being produced. There are different phases of testing with each OEM. We are engaged with most of them, including Boeing and Airbus," and most recently, Pratt & Whitney.

Laying wire fast

"RPD is really the only way to economically manufacture structural titanium parts. Powder [metal] is great for small, intricate parts. Powder makes cool stuff," Fuller says. "Fuel nozzles are very complex and have to be powder via AM.

"What we print is [titanium] wire with plasma arcs in an argon environment. We lay wire fast," at a rate of several kilograms per hour, or at multiples of the volume of powder metal part production, he says.

A primary attraction of AM, of course, is that a part can be produced to a near net shape. Instead of getting a 20-pound block and machining it for several hours to arrive at a 3-pound part, RPD uses far less material, perhaps only 30 to 50 percent more than the finished machined part itself, reducing cost significantly.

Technician holding finished commercial aerostructure titanium part.

RPD's buy-to-fly ratio (the weight ratio between the raw material used for a component and the weight of the component itself) is much lower than traditional forged and machined components. "Customers will need to buy less titanium and machine less titanium away. It's just plain math," Fuller says.

In addition, the company has achieved machine-to-machine qualification, meaning Norsk can run the same part simultaneously in different factories and each is identical. Says Fuller, "We monitor 600 parameters per second, and that's the result of vigorous mind-numbing process control. That is what it takes." So apart from the machine and process design, Norsk had to invent all that programming as well.

Currently, Norsk can produce structural titanium parts up to 3 feet long by 2 feet wide by 1 foot tall. "We are designing a larger machine to make a 2-meter-long part (about 6 feet). Structural components are typically larger. That's really what RPD is all about: Large titanium structures."

Grueling trials

OEMs that have shown interest in RPD have tested ultimate strength, fatigue, damage tolerance, elevated temperature, constant strain yield and dozens of other characteristics. "We have printed 4,000 kilograms of test material. We will do thousands more tests," Fuller says.

Outside observers have no idea what's required to become commercially viable. At a conference Fuller attended, one speaker suggested additive research and development requires tens of millions of dollars.

"It's really hundreds of millions of dollars. Qualifying a new additive metal process with OEMs is a very difficult thing. Thousands of kilograms more will be done in every shape imaginable. If you want to get into the AM business, that's the kind of investment you'll need. Buying the machine is the least interesting thing you will do."

Delivering fast

Today, Fuller says, Norsk is manufacturing "the pathfinder parts," with which it must make a lot of adjustments. The "disruptive" aspect is that it takes a mere day and a half to complete a month's worth of production for the Boeing 787 part on one machine.

"We have 12 machines. The other machines are quite busy doing test articles and developing the next parts. To get all those OEM qualifications, they don't just hand you a production certificate. Look at how safe airlines are. It's because they pursue so much data. That makes the hurdle pretty darn high to qualify material, process and manufacturing methods.

"The forging cycle is expensive and the lead time is long. Parts made of block may require 20 or 30 weeks. Thirty-six months is standard for some specialty forgings," according to Fuller. That time lag decreases the ability to schedule when an OEM is ramping up. Lead times extend even farther for large parts or unusual shapes.

How fast can an existing part design be changed and enter production using RPD? "If the customer gives us a different drawing, similar but different, it only takes a couple weeks. Really, the verification of the part is a longer process than actually making it. And, if we have a qualified part sitting on a shelf and the customer wants an increased rate of production, that's nothing for us."

Cost-benefit analysis

Michael Canario, Norsk Titanium's new CEO, came from the composite manufac-

Completed commercial aerostructure titanium part next to its near-net RPD form.

turing world, having worked at Hexcel for many years. He finds the testing and qualifying of RPD rather analogous to what Hexcel did with carbon fibers, resins, etc.

"Composites are by nature additive. It's the original AM in the aerospace industry. I spent my career trying to replace traditional metal structures with composites. Now, we are replacing traditional metal with AM structures. We are using the same material but creating the structure in a different process."

Aerospace customers typically take a long time to replace material structures, Canario says. "AM has always benefited from long-term cost structure but you had to wait for the next airplane or the next structure because you had to redesign. But with Norsk using the same materials used in forgings, but with AM methods, we can give the benefits of cost and not take the penalty of changing material."

He believes the industrial world will adopt RPD. "We are bringing the additive world in an efficient way to industry."

Norsk is merely at the starting gate. To date, "we are addressing a niche market segment: Aerospace titanium structural components for commercial airplanes. RPD can get into engine and defense structures. Aerospace is highly regulated and has a tremendous amount of process control. It's a great market to establish oneself," Canario says.

> **"RPD COULD BE A LIGHTNING ROD FOR TECHNOLOGY DEVELOPMENT IN THE METALS INDUSTRY."**
>
> **MICHAEL CANARIO,**
> **CHIEF EXECUTIVE OFFICER**

"We are not limited to aerospace. Anywhere you see titanium forged parts—like oil and gas, specialty automotive and other industrial markets—is a potential end market.

"We are not limited to titanium, either," he continues. RPD can be applied to Inconel and other superalloys in aerospace, oil and gas, turbines. "We think our technology is applicable anywhere you use advanced alloys, where traditional manufacturing is expensive and has long lead times."

Digital, data

"The focus of the company is not just the niche we are in now," Canario says. "It's the broader opportunity." For example, Norsk is bringing the digitalization process into metal manufacturing, especially in machining. "Let's take advantage of a digitized machining world and create a path in that market with a near-net shape, limited machining, and focus on the part of the process that is behind [the curve] in the digital world.

"We haven't started to touch the limits for this groundbreaking technology," he says. "We will open it up further. One of the challenges of powder processing is the large variability between machines. We have proven you can go to machine after machine and make the same part. That's sort of where the world has to get to" for

Production floor at Norsk Titanium's Plattsburgh, New York, Demonstration & Qualification Center.

AM to be competitive.

Another in-house advantage Norsk has, beyond technology development and software programming, are the "massive amounts of data that's being generated, controlling the torch, the movement of the part, the formation of the material on the part," according to Canario.

"Data is cheaper than water and we store a ton of data. We are creating a library of part shapes. Say you have a 90-degree angle that turns into a 45-degree angle. How do you manufacture that? Once it's figured out, on the next part, you just take the feature and drop it into a program."

Investment picture

Norsk Titanium's investors include Aljomiah Group, Applied Materials, Arconic, Empire State Development, Falko, Fortress Capital, Harbert Management Corp., Insight Equity, Rose Park Advisors' Disruptive Innovation, Scatec and Triangle Holdings.

At Plattsburgh, says Canario,"We installed capacity ahead of orders. That gives us the ability to react to new business; we can make prototypes and validate the technology for each new part. We have the capital in place to deliver fully functional parts that we can certify."

He acknowledges that "it's not for the faint of heart to invest in the technology. We have very patient investors focused on the long-term picture. This is a company with well over a $100 billion addressable market opportunity. The time on breakeven depends on how fast we invest."

Norsk won't issue a timeline for ROI. "Our investors want to get the adoption rate moving in aerospace and extend it beyond aerospace. But first we'll answer all the questions we have in front of us now," Canario says.

"We will require additional investment, make more parts, test and validate them, and overtake competing processes. We will launch new alloys, new products and new markets, formulate new databases on new materials, new applications and meet all the necessary requirements."

Canario likens Norsk Titanium to a development company with a production arm. It is seeing the first fruits of getting a Boeing part by receiving queries from other OEMs. He isn't worried about some other technology to threaten RPD. "We are at the front end of disrupting the process and it's been 12 years and nearly $300 million. Additional technologies will come down but we will reinvent our process. Our tech people never run out of ideas. If there is a disrupter, it will probably be something we invented."

Norsk and RPD could become a "lightning rod for technology development in the metals industry," he suggests, because once its success is imminent, "Others will wake up and rethink how they do things." ■

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