Using additive manufacturing to spur innovation

Swedish factory demonstrates the value of 3D printing

Executive summary

Is it possible to print anything? That is a valid question in the world of 3D technology in which 3D printing, also known as additive manufacturing, can be used to output almost anything via digital simulation, including cars.

Additive manufacturing uses various technologies to produce a part by building layer upon layer. One of its benefits is streamlining the overall manufacturing process by removing the need for costly castings and machined tooling. Production of gas turbines in Finspång, Sweden is a prime example of the technological advancements being made in the overall production process.
Abstract

Traditionally, the production and repair of parts can require taking measurements, designing and producing molds, casting the raw part, finishing, assembling and frequently correcting miscalculations (by repeating this cycle). However, this process is transformed by additive manufacturing. Now technology, innovation and efficiency come together via innovative design and simulation to produce parts that previously required longer lead times due to the trial-and-error nature of the process.
Automation meets production in Finspång

Additive manufacturing presents a tremendous opportunity to improve products by making them more cost-effective to produce, and, therefore, less expensive for the consumer. Manufacturing is on the cusp of change, which is not slowing down.

A phenomenal example of this innovation resides in the rolling hills of Sweden in a centuries-old city called Finspång, on the banks of Skutbosjön Lake, where automation meets production. This 500-year-old factory, which once was used to manufacture cannons, entered gas turbine production in the mid-1950s. As recently as 2008, the factory began an entire chain of additive manufacturing via power specification, process parameters, material properties development, design for additive manufacturing and manufacturing itself.

By 2009, Siemens Gas and Power had begun using metal additive manufacturing systems from Germany's EOS GmbH. Andreas Graichen is the group manager of the Additive Manufacturing Centre of Competence in Finspång, which supports the global industrialization of this technology with Siemens Digital Industries Software’s NX™ software, Additive Manufacturing module.

Graichen states the team initially believed it could do everything it wanted with new designs and materials: "This was only partly true. The engineers quickly recognized there was much work to do if they wanted to realize additive manufacturing's full potential."

However, the company’s engineers soon discovered additive manufacturing technology could be crucial in producing spare and new parts. Facility engineers knew they were on the cusp of something new in 2012 when they used additive manufacturing in a new machine designed strictly for burner repair. Two years later, the Centre for Additive Manufacturing Competence opened, building on previous work using digitalization for rapid design, manufacturing and repair.

In 2016, a specialized automated additive manufacturing facility was opened with eight new machines. Today, the facility houses more than 2,600 employees, 50 of whom are dedicated to additive manufacturing. It produces world-class, efficient and reliable gas turbines with 95 percent of production being exported. “The beauty of the site’s setup is that Finspång has everything in one place that is needed for design, production, testing and aftermarket support,” states Vladimir Navrotsky, technology and innovation manager of Siemens Service Distributed Generation and Oil and Gas. The facility is a comprehensive operation that includes a design team for gas turbines, a facility to test the engines and a state-of-the-art manufacturing facility, including serial production and a service organization that provides feedback from the operational fleet.
The beginnings of innovation

Currently, the Finspång factory uses additive manufacturing to perform burner tip repair via 3D printing technology. The combustor burner is a critical element in the turbine, where the struggle for efficiency and emissions reduction is won or lost. This dynamic creates the perfect opportunity for change and disruption by digitalization. Developing a gas turbine often requires many design changes, but because of the significant costs associated with these changes, there is a limit of two or three design iterations.

Modifying a turbine design for traditional manufacturing can require costly new castings and molds, with long lead times and expensive raw materials. The need to minimize lead-time, costs and iterations drove the adoption of digitalization and the use of additive manufacturing technology into the industrial turbine manufacturing process.

When a burner is installed in a gas turbine and runs in the field, extreme heat from flames and combustion erodes the inside of the turbine. The cost of new burners can be high, so Siemens decided to pursue repair and recertification of burners as a lower-cost alternative.

The long-standing method for repair involves first sending the burners back to Sweden. They are loaded into a milling machine and 120 millimeters (mm) of the damaged area – essentially the front section of the burner – is machined away. A new front section is then welded on, completing the refurbished burner assembly. Although more cost-effective than assembling a new burner, this process was still lengthy and required several manual steps.

As engineers in the Finspång facility became more familiar with the possibilities of additive manufacturing, they wondered if 3D printing could help them redesign the repair process for these burners. Siemens collaborated with EOS on a process in which only 20 mm of the front of the burner was machined away to provide a clean, known surface. A new front section was then additively manufactured directly onto the burner – massively reducing scrap, work and repair time.

To make this process work, the facility worked closely with EOS to design a special version of the M280 AM machine, which incorporated a unique fixture system to load and hold the burner, an optical system to orient the print, and a unique process to print a replacement tip on the top of the machined burner base.

This process has been hugely successful, according to Siemens. “We have produced thousands of repairs in this new way of replacing the tip; a fully industrial process,” Graichen says. “Moreover, we have reduced turnover time by 70 percent.”

The newly designed burners were put into service in turbines across the world, but the true test was whether they would last through the required number of duty cycles. After 20,000 hours of operation, the burners were inspected and found to be in good condition, meaning they were able to continue to run in the field without immediate repair or replacement.
As the Siemens team in Finspång gained knowledge about the additive manufacturing process, it envisioned other uses for the technology. The original turbine burner head design called for 13 individual pieces to be machined and welded together. The resulting burner was roughly 800 mm in length and was built using a complicated manual manufacturing process. With their new knowledge about the additive manufacturing process, engineers investigated a complete redesign of the burner head that could consolidate the 13 individual parts into a single unit. They also considered how they might incorporate special features that could only be additively manufactured.

One essential requirement of burner design is low mass. By designing for additive manufacturing, the team found the burner walls could be made slimmer for improved temperature responsiveness and lattices could be introduced to make it stronger at a lower weight, resulting in less thermal inertia with more efficient cooling of the burner tip.

The additive manufacturing design delivered a stronger, more agile product for the turbine’s heating and cooling cycle, enabling a less aggressive heating and cooling routine. This increases the burner’s lifetime and lessens the oxidation and crack formation, which typically damage burners. The team also achieved a 22 percent weight reduction and is working to further refine the design to attain a 50 percent weight reduction.
Collaboration and modern innovation

Collaboration is the key to developing the additive manufacturing process and technology to repair gas turbine burners. By removing internal barriers, using technology to collaborate and developing trusted partnerships, a path was paved for innovation. Siemens believes the accomplishments at Finspång can help other industries advance their additive manufacturing operations on an industrial scale.

“With technology as new as this and that’s moving as quickly as it is, it makes sense to form working relationships with other companies that are near the same development stage as you,” says David Madeley, Siemens Digital Industries Software senior strategist and additive manufacturing expert. “It makes sense to form an ecosystem to connect people.”

The work at Finspång continues to prove how revolutionary additive manufacturing can be. It is now a matter of taking this knowledge and experience into the design of full gas turbine components or subassemblies. The process of moving not just a manufacturing operation, but also a design organization and shop floor operation from prototyping to production is an experience that Siemens believes will pay off throughout the company.

Additive manufacturing integration will also provide new delivery methods and solutions to companies.

Siemens’ work manufacturing products at an industrial scale can help companies to better understand their machines’ ability and capacity to print, as well as to maintain the knowledge required to ensure the necessary support is available wherever additive manufacturing systems are operational.

Additive manufacturing knowledge continues growing at the Finspång facility, along with the ability to take advantage of its incredible potential. As technology’s development continues, the facility is a hub of innovation for additive manufacturing technology at Siemens.

“I can compare this technology with a snowball. As you form a snowball, it gets bigger and bigger,” says Navrotsky. “There’s a positive enhancement with this ball. The same can be said about additive manufacturing enabling enhancement of the components’ functionality, design and manufacturing time reduction, materials reduction and component lifecycle cost improvement.”
Benefitting other manufacturers

Siemens is eager to assist a range of industries in their transformation from prototyping to serial production. With successful research and multiple products completed with many more in the pipeline, the company has the capabilities to assist customers and original equipment manufacturers in maturing this technology.

The benefits of additive manufacturing are massive, and digitalization plays a critical role in ensuring its success. “Without digitalization or simulation of the process itself, you cannot industrialize on a large scale,” said Andreas Saar, vice president of manufacturing engineering solutions and additive manufacturing program lead for Siemens Digital Industries Software. “Advancements in digital technology, simulation of processes, feedback loops and machine learning will be the core assets to make industrialization work.”

Additive manufacturing provides results that relate to most industries and processes by reducing final product weight, power consumption and material usage. It also minimizes costs and environmental impact via fewer materials needed for production – substantial benefits that any manufacturing company would welcome.
Conclusion

Siemens anticipates increasing the number of additive manufacturing production machines in Finspång, creating spare parts on demand, printing parts for new turbines and harnessing printing and job execution via the cloud and digital twins. Autonomy will allow sensors to monitor work as printing occurs, ensuring the right parameters are met and the output will be of the required quality.

The plan is to exploit additive manufacturing as it aims to design a state-of-the-art production facility. Robotics, data security, artificial intelligence and analytics all have a role in the intelligent facility the company envisions.

The intention is for Finspång to serve as a model facility, with industry leaders visiting to see the next generation of industrial production in action.

The people at Siemens Digital Industries Software are working hard to help industries across the world take advantage of this rapidly growing technology. Their ability to design and produce useful parts at scale with additive manufacturing is a proven example for the industry to follow.
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