Additive Manufacturing

Additive Manufacturing: Why the 'concept to component' approach is key for successful implementation

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Additive manufacturing (AM) empowers innovative design with unprecedented benefits. With this rapidly advancing technology, it is crucial to integrate process disciplines and expertise to ensure an optimized product that achieves the desired quality and functionality while avoiding costly mistakes. In order to fully capitalize on AM's potential, choose a provider that can link the full AM production chain together under one roof.

AM can offer tremendous opportunities for innovative design and productivity benefits. However, new technologies and innovations can also pose risks to those attempting to implement them. This article explores the major benefits and the inherent risks involved with this evolving value chain and suggests some best practices to help mitigate those risks.

Introduction: What is Additive Manufacturing?

Additive manufacturing (AM) is the process of manufacturing objects from Computer Aided Design (CAD) model data, usually layer upon layer, as opposed to using methods of subtractive manufacturing (removing material until the desired shape is reached) or formative manufacturing (applying mechanical forces and/or heat through processes such as bending, casting, and molding).

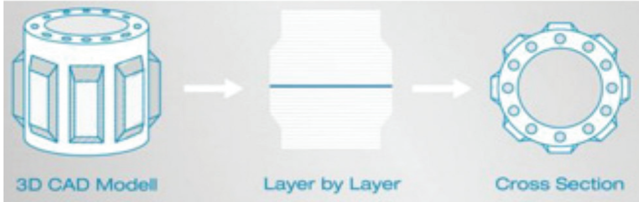

Figure 1 – Illustrative AM conversion of CAD model to cross-sectional layer

Interest in AM has grown swiftly as applications have progressed from rapid prototyping to the production of end-use products. AM equipment can now use metals, polymers, composites, or other powders to "print" a range of functional components, layer by layer, including complex structures that cannot be manufactured by other means. AM technology can be used to build complete parts, add features, or make repairs. This article will focus on metal powder bed fusion technology,[1] in which layers of metal powder typically measuring from 20 to 100 microns are melted into the desired shape. After each layer is fused into the precise design, a fresh layer of powder is added and the next cross section of design data is used to construct the item from the bottom up. This process can build custom tools or parts from a range of metals such as aluminum, high-grade steel, titanium, nickel-base alloy, and cobalt chrome. Applications serve a variety of markets, for example tooling, aerospace, oil and gas, automotive, and medical industries to name a few.

[1] Several metal AM process technologies are available that use different forms of media and energy sources. You may come across terminology such as: wire – cladding (wire arc, electron beam, laser beam); powder – powder bed or nozzle (electron, laser, plasma, cold gas) and foil / sheet – cutting and joining (diffusion or adhesive bonding, ultrasonic welding).

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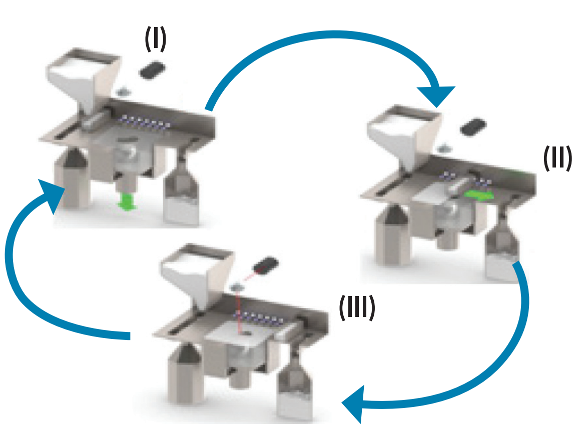

Figure 2 – Illustration of powder bed fusion build technology build process. I) The plate holding the AM item drops incrementally to accommodate each new layer of metal powder. II) A fresh layer of powder is added. III) Precision laser technology fuses the metal powder to the item in the appropriate shape of the layer. The process is then repeated.

Benefits of additive manufacturing

By supporting manufacture for design, not design for manufacture, AM technology inverts the usual approach to design, which has historically been constrained by manufacturing limitations. Traditional manufacturing processes can limit optimal functional design by forcing the question, "Can this be manufactured?" In contrast, AM's build process allows a greater freedom of design for complex geometries.

Additive manufacturing enables:

- Building of complex geometries, including internal features
- Combining multiple parts into one
- Utilizing lightweight lattice designs
- Generating less waste
- Reducing inventory – AM can enable low-inventory business models
- Faster time to market and rapid prototyping
- Potential for smart components and integration of function/sensors

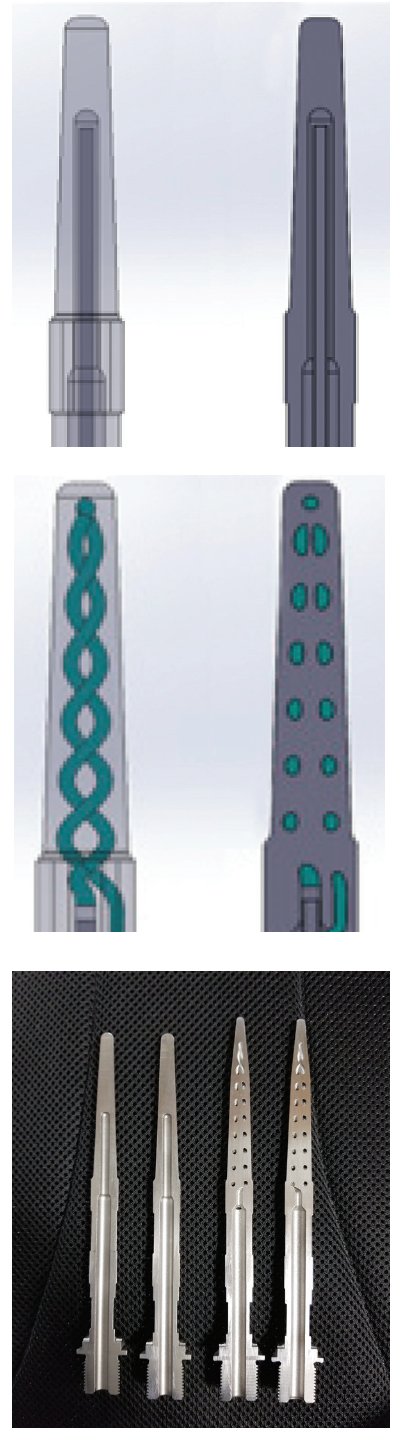

Figure 3 – Core Pins with traditional cooling (top) and conformal cooling (center) with freedom of design afforded by employing AM techniques; section view of each design (bottom)

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Figure 4 – Engine hood hinge AM redesign: the bionic structure achieved a 50% weight reduction compared to conventional fabrication and enabled integration of a predetermined break point for additional passenger safety

AM Process Chain

There are four broad interrelated stages to additive manufacturing: Design and Engineering, AM Production Technology and Powder Selection, AM Production, and Finish Manufacturing. Each stage comprises several process elements requiring distinct expertise:

1. **Design and Engineering** begins with understanding the design intent of the component and operating conditions. The design is optimized utilizing simulations to achieve the targets.

2. **AM Technology and Powder Selection** involves selecting both the optimum AM technology for the given component and the suitable powder.

3. **AM Processing (or Build) and Production** includes seting the parameters for the AM process, building the item using AM equipment, post-processing to remove supporting structures, and heat treatment and hot isostatic pressing (HIPping) if required to ensure desired material properties.

4. **Finish Manufacturing** including final machining, polishing, and coatings and final inspection as required to achieve final application readiness.

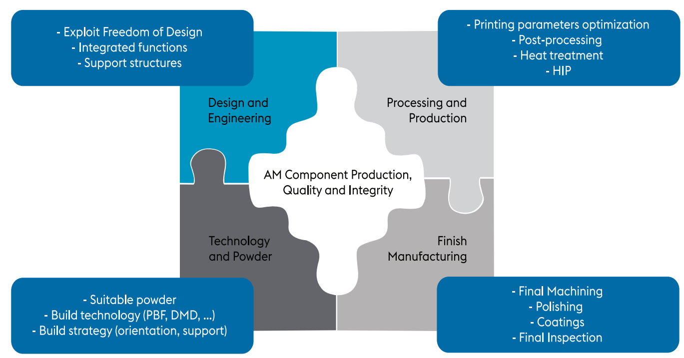

Figure 5 – Illustration of the interdependencies of AM disciplines affecting final product quality and integrity (adapted from voestalpine Bohler Edelstahl GmbH)

Risk of multiple hand-offs

This highly integrated chain demands a superior level of coordination and open dialogue, as misalignment amongst these disciplines can undermine the product's final quality and integrity.

As an example, powders can oxidize if not professionally sealed and protected. Faulty process parameters can result in pores and cracks or deformation. Additionally, lack of optimization and precise control in the heat treatment, HIPping, and final machining processes can affect the quality and integrity of the AM product.

Managing communication among multiple independent suppliers demands a high level of expertise for the project manager, who must understand all aspects of this rapidly advancing technology to ensure quality and component integrity.

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Step	Powder Selection	Parameter Development	Design for AM	Simulation	AM Processing (Build)	Post Processing	Heat Treatment	Final Machining
Failure Mode								
Porosity	●	●			●			
Cracking	●		●		●	●	●	
Oxidation	●				●	●	●	
Residual Stress		●		●	●			
Rough Surface Finish	●	●			●			●
Dimensional Deviation		●	●		●	●	●	●
Poor Mechanical Properties	●	●	●	●	●	●	●	
Poor Physical Properties	●		●	●			●	

Figure 6 – Table of typical AM failure modes and potential sources of failure

The ideal scenario: one source for the AM value-chain

Given the interdependent and highly specialized nature of AM, manufacturers can best exploit this technology by taking advantage of partners that offer a one-stop-shop. By integrating the full AM process chain through one source, such providers facilitate communication among the full suite of experts, reduce delays associated with coordination among different companies, and avoid costly mistakes that can result from poor planning or miscommunications amongst the suppliers.

voestalpine Additive Manufacturing Centers North America offers one example of a fully integrated approach to AM. In addition to producing specialized metal powders (Bohler, Uddeholm), voestalpine brings together in-house modeling and simulation expertise with best-in-class AM technologies. Through a single point of contact, each AM project proceeds seamlessly through powder selection, powder customization as necessary, application design and simulation, additive build, heat treatment, post-processing, polishing, and coating.

Furthermore, because voestalpine caters to high-performance applications such as plastics molding and die cast tooling, oil and gas, aerospace, and automotive sectors, the company's long-established record with relevant industries allow them to combine a thorough understanding of the market's needs with a forward-thinking embrace of innovation. The result is a singular AM solution that simplifies the supply chain, reduces risk, and ultimately provides better solutions to customers.

Conclusion: Optimization utilizing AM

No longer solely a prototyping technology, AM is now being used for the production of series components and tooling for the most demanding applications. Components that would not have been possible just a few years ago can now be made to high standards using a wide range of metal powders. AM promises to enhance production by optimizing design for lighter-weight, more effective parts and tools and reducing waste, tooling, and inventory. For producers looking to leverage these advantages, the greatest value can be gained by working with a full-service AM provider with extensive knowledge of the customer's applications and mastery of the key AM disciplines. This integrated approach is vital to ensuring AM products are not only superior in design but also reliable, robust, and durable.

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