Additive Manufacturing: Peer-to-Peer Network Forum Summary

Cummins and Praxair Surface Technologies led a discussion on March 30, 2021, during Conexus Indiana's Peer-to-Peer Network forum on the topic of additive manufacturing. Peer participants representing six organizations contributed to the dialogue, which resulted in a number of key learnings and insights on the complexity, costs and human resources needed for success.

Cummins Moving a Pipeline of Parts into Production on Multiple Metal Additive Platforms

Cummins is primarily focused on polymer and metal printing. While more than a dozen polymer printers in its technology center make tools, clamps, prototypes and casting cores, polymer printing is not used for production parts. Production is reserved for metal printing. Cummins has a major focus on printing 316L stainless steel. By employing a few Direct Metal Laser Melting (DMLM) machines, Cummins has moved several components into production. These components are carefully selected and qualified as candidates for additive manufacturing and are generally produced in low volumes (hundreds of parts per year). A pipeline of nearly two dozen more components is planned to enter DMLM production in the near term.

Cummins is still in the phase of optimizing, characterizing, and pushing the boundaries of additive technology. For example, the organization has plans to expand into other metal alloys, especially with a focus on binder jet technology. The careful selection of candidate parts, both in terms of scalability and financial sustainability is critical for binder jet, and for the moment, Cummins' production is limited to low volumes and aftermarket components. Binder jet technology may eventually move to high volume production, but the process must be de-bottlenecked before production is scalable to automotive volumes.

Praxair Optimizes Powders and Printer Dynamics for Metal Additive Production

Praxair Surface Technologies opened its presentation with context and background about how its decades of experience in making powders and coatings has translated well into the metal additive space. In fact, Praxair's powders were likely selling into the additive space for a couple of years before the organization was aware of it. The team has several gas atomizers to make metal powders for additive manufacturing, including alloy powders of copper, titanium and other metals. Formulating proprietary powders gives Praxair a unique advantage in optimizing metal printing performance. To that end, Praxair is working on the significant challenge of managing how surfaces of 3D printed tools and fixtures perform in real-world scenarios. The team has been working with Purdue University to analyze textures, grain patterns and stress performance and learn about how characteristics are affected by variables such as powder particle size and printer speed. The goal is to eventually develop new, more robust materials and print techniques. While the process is different for each alloy, a few rules of thumb have become clear. Thick layers result in faster printing speeds, but it possibly comes at the expense of stress and cracking. Also, metals that tend to be difficult to weld tend to be challenging to print.

Praxair supplies metal powders in additive production for select parts in medical, aerospace and automotive. Like Cummins, Praxair has several parts in additive production, but in small volumes (hundreds annually). In the current state of the technologies and cost structures involved, the team is cautious regarding higher volume production (thousands annually). But having said that, Praxair has found an increasing customer reliance on its use of additive-produced masking, fixtures and tooling. The unique shapes and geometries for parts offer significant performance advantages. Additive has a clear path to become the new industry standard, as it's often infeasible or prohibitive to produce the same parts under traditional manufacturing methods.

Performance and quality drive everything. This is especially true in the industries Praxair serves, like medical, aerospace and aviation where certifications are crucial. For example, qualifying a part and its production process for the Federal Aviation Administration (FAA) is already a challenge, but additive processes can complicate this further for reasons mentioned above. Certification might involve validating a certain printer and proving out a powder supply, possibly to a specific atomizer. The key is to look for advantages in assemblies over individual parts: Change the assembly to require a different number or configuration of parts and an opportunity to leverage additive might be found.

Themes from Peer-to-Peer Group Discussion

The presentations were followed by an open group discussion that covered a broad scope of additive related considerations, which including the following:

Expertise for Managing the End-to-End Process is Rarely Under One Roof: From powder to the printer, to post-processing parts, there is a lot to an additive workflow. And comprehensive expertise is rarely found in one location or at one company. Companies are challenged to find the right amount of knowledge in all areas of the process. As mentioned, optimization of technical performance is multi-dimensional. Facilities' concerns, such as material storage, material handling, and environmental controls impact both process performance and protocols for environment, health and safety depending on the additive platform and use case. To put a fine point on the potential health and safety challenges, metal powder particles are in the size range of microns.

Understanding Cost Structure is a Big Deal: Aerospace, medical, and automotive seem to have different cost structures for production and processing. The peer-to-peer participants referred to specific technologies for producing parts and the widely varying performance. Production for many types of parts could be three to five years away due to costs. In an industry like automotive, parts with high performance specifications that benefit from a complex geometric design, such as brake calipers and fuel nozzles, will be the first to go into full-scale production. But even then, these parts might be years away from high volume production.

Innovative Binder Jet Technologies Face an ROI Challenge: Binder jet technology can be slower and more costly than Direct Metal Laser Melting (DMLM), mainly due to its more involved de-powdering and sintering (forming a solid by heating) processes. Two key obstacles to increase the scalability of the technology is overcoming the often expensive, post- or extra-processing complexities, as well as matching the right number of furnaces to the production speed of the printers. For example, multiple furnaces per printer might be needed to scale production initially, but a better business case and ROI will require the ratio to be at minimum, one to two furnaces per multiple binder jet printers.

Building a Talent Pipeline is Crucial, and Not Easy: The talent shortage is very broad and covers almost the entire manufacturing spectrum. Deep expertise is needed in areas like materials science, application engineering for product design and production implementation, production operators, machinists for post-processing, maintenance technicians, and even in peripheral functions, like quality control and environment, health and safety. The sentiment is that universities and certificate programs are not keeping up with the rapidly evolving technologies, and therefore, do not frequently expose students to additive manufacturing during their education. Anecdotally, it seems that entry-level employees for all roles rarely have any experience, or even exposure to additive concepts when they are hired. This makes training and talent development an added element of cost and complexity, on top of the already costly and complex endeavor of investing in additive manufacturing. It was suggested in group discussion that the new Emerging Manufacturing Collaboration Center (EMC2) slated to open in late 2021 in Indianapolis' 16 Tech Innovation District could be leveraged for talent development programs in additive.

It is Necessary to Build a Body of Knowledge Through Research and Development: There is a significant interplay of equipment, materials and end use-cases, and it varies across manufacturers. This is an emerging field, and companies and their employees must be willing and able to constantly experiment and innovate. For example, Praxair has its own proprietary geometric test coupons that they print to characterize and quantify performance sensitivity to adjustments in key parameters. Research and development through a systematic method of trial and error is what will enable an organization to genuinely leverage additive manufacturing and build the body of knowledge necessary to succeed. The accumulation of in-house knowledge will also require a level of uniqueness to the organization's products and the customers it serves.

Standardization is Still in the Early Stages: No two companies approach additive manufacturing in the same way, so best practices are not standardized. Further, each brand of 3D printer is often unique, even when the printers employ the same core technology. The recipe for producing a quality part via binder jet technology is not the same across different OEM binder jet machines. To make a comparison to a more common manufacturing technology, a recipe for CNC milling works across mill OEM's, but this does not hold true in additive.

Additive is a Significant Investment: For metal printing based on the technology investments Cummins and Praxair made, a 3D printer alone can cost $500k to $1M, or more. And as discussed at length, the peripheral equipment, processes, and the facilities to house it all can push that investment much higher. Costs to build out a robust, metal additive manufacturing process can easily be in the range of millions of dollars.