Cumberland Additive: Overcoming Technical Challenges in Industrialization of AM for Serial Production

Despite the growing number of additive manufacturing machines and users worldwide, serial production using additive manufacturing (AM) is still very rare. Virtually all industries are finding ways to use the growing technology, however industries that are exceptionally safety-critical, such as commercial aerospace, are taking a more cautious approach to using additively produced parts in their production line. These companies require a trusted partner, with experience in qualifying AM end-use parts, in order to fully make the leap to additive manufacturing serial production. This begs the question: What does it take to make AM successful in the long run?

Cumberland Additive stands out in the field with an experienced technical team focused on data-backed, repeatable quality. Based in Austin, Texas, the Cumberland Additive Engineering team has developed long-term partnerships and technical alliances with aerospace, oil and gas, and defense partners. They have partnered with companies to build and qualify AM powder bed fusion (PBF) production parts in Polymers, Steels, Titanium and Nickel-based superalloys.

Extensive work has been done at Cumberland Additive to successfully establish a serial production program through careful selection of key parameters, development of process control, and achieving a deep understanding of machine behavior. **The essential components are repeatable processes, intelligent data analysis, and trust.** To achieve trust in AM, customers need suppliers that possess cross-functional technical chops and loads of sound data. Many players in the industrial AM supply chain are still coming up the maturity curve. Among many things in AM, a requirement for serial production is process control. This means, knowing your AM process, having control of that process and implementing process control in all facets of your business. This is especially important when it comes to operating multiple AM machines that need to reliably produce the same product. The question always comes up: How do you ensure consistency from machine to machine?

A critical piece to successfully achieve machine-to-machine consistency is data on machine performance. This can be in the form of logging sensor data over time, material testing/characterization and machine calibration data performed periodically or as part of preventive maintenance cycles. At Cumberland, each machine goes through a rigorous test program that includes an internal qualification to ensure it is not only able to meet the minimum specification requirements for the material, but also performance is comparable to an equivalent machine. An example of this data is shown in Figure 1 which maps the spatial mechanical performance of representative systems at Cumberland Additive. Data here is taken from test bars placed across various locations of the build chamber in an AM machine and gives an indication of spatial anisotropy. Data like this is important to ensure each AM system can meet a specification minimum across the entire build envelope and further verifies the optimum key process parameters selected for fabrication were selected. When initially launching a production program, the variation across the build chamber was unmanageable. The anisotropy from one end of the build plate to the other was too large and in some cases the results did not

meet a prescribed specification minimum. The engineering team at Cumberland Additive looked at all data available, launched a root cause analysis, and came up with a **data-driven solution** in collaboration with the machine OEM. Today, the consistency of mechanical properties across the build platform of any single system is well within a 5% variation across the build platform. Most importantly, this root cause also helped develop process checks that were implemented across all machines to ensure machine to machine variability is also maintained.

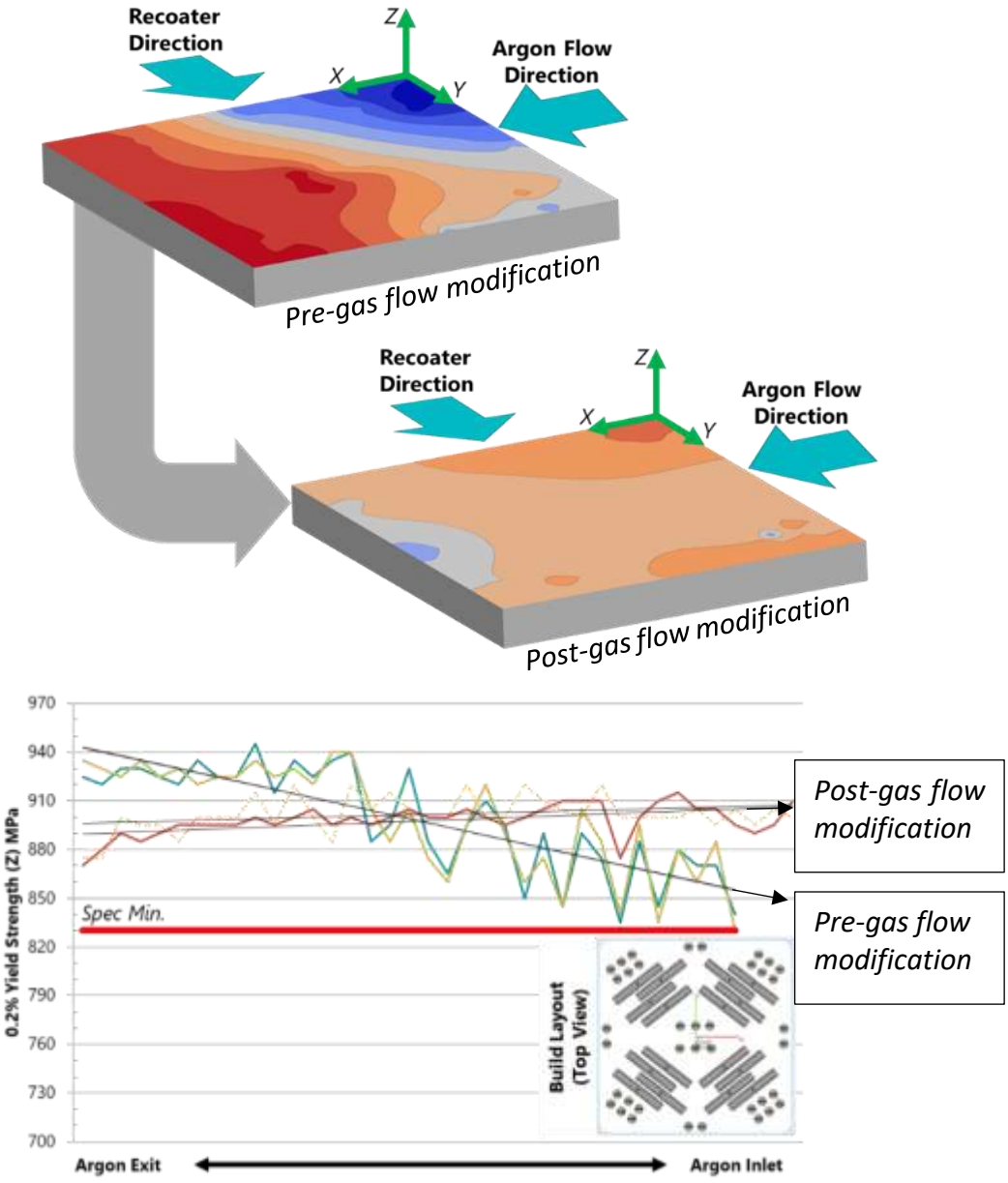
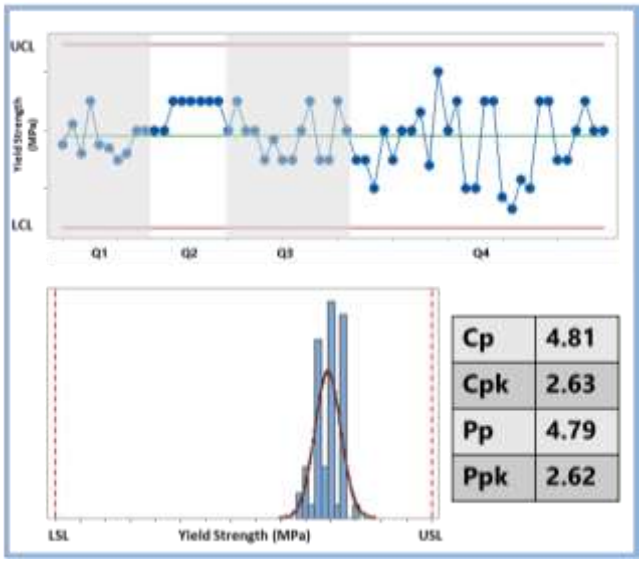


Figure 1: Example of internal qualification data illustrating spatial machine performance.

Cumberland Additive launches a qualification program once a machine is internally validated. Various systems have been qualified for aerospace production and the process control that has been put in place has successfully resulted in consistent performance over time. Cumberland Additive's part portfolio contains **1000+ part numbers, both in polymer and metal, with thousands of individual parts printed since inception**; with drone, aircraft, helicopter, aircraft components produced for high-profile customers like NASA. The technical team also cooperatively developed, qualified, and moved to serial production, components for manifolds, down hole, and wireline tools for the Oil and Gas market.

Examples of serial production capability are shown in Figure 2 and 3. Figure 2 shows mechanical data over time, while Figure 3 shows dimensional data taken of a representative part produced over time.

a)



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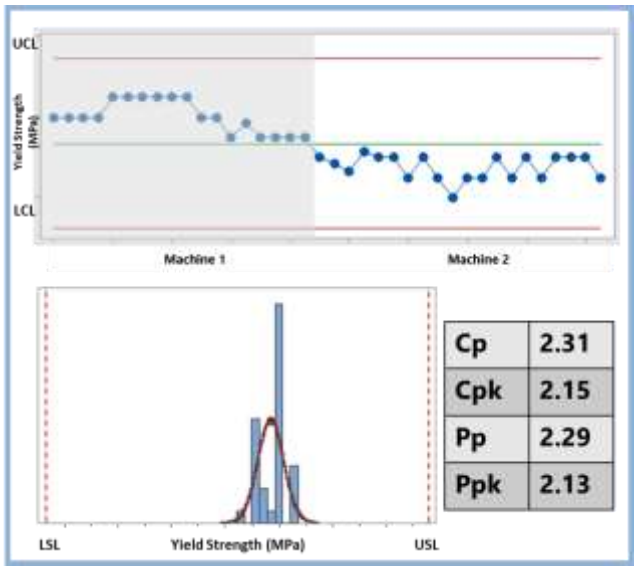

Figure 2: Statistical process data over time showing a) mechanical performance over time for one machine and b) mechanical performance over time for multiple machines

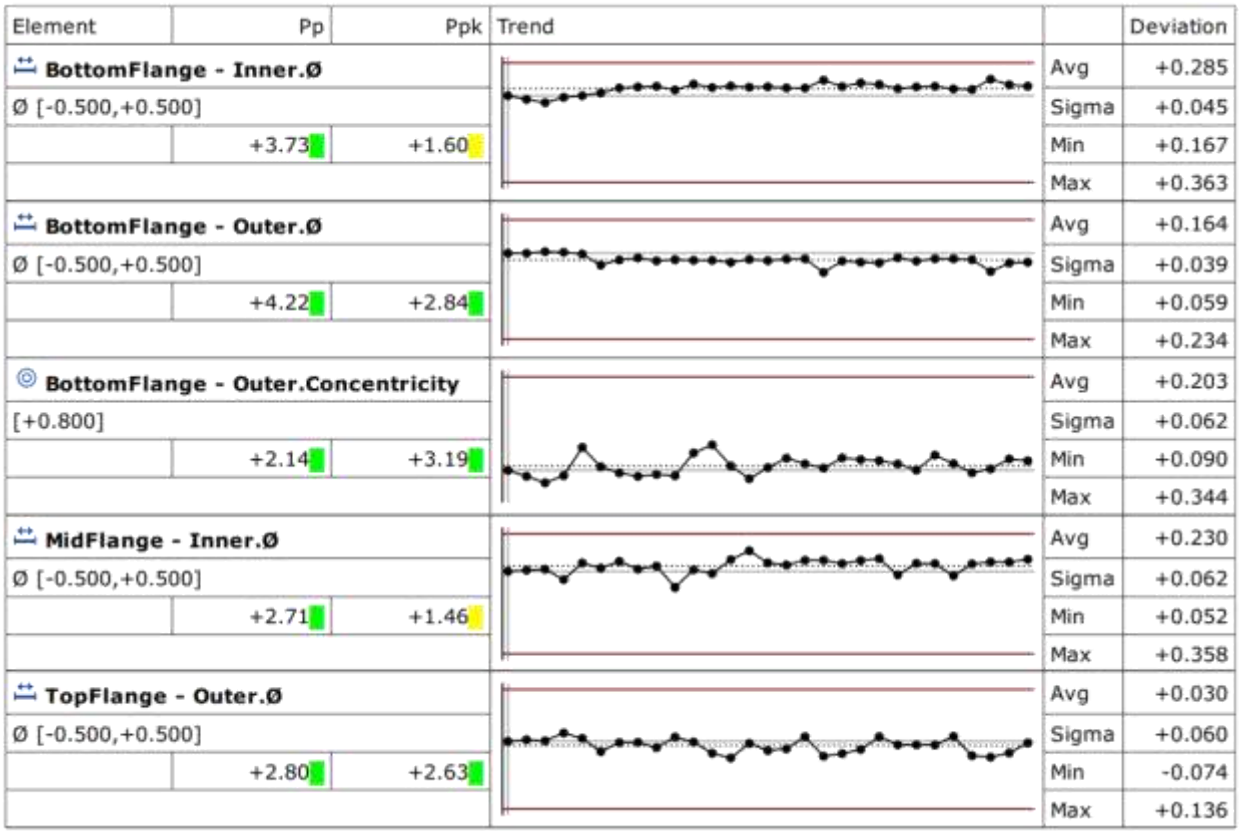

Figure 3: Dimensional data over time of a serially produced part.

These figures demonstrate acceptable values for process capability (Cpk) and process performance (Ppk), indicating good control and actual values well within the upper and lower mechanical limits of the applicable specifications. This consistency is demonstrated for both mechanical and dimensional data. Maintaining dimensional stability is critical in order to ensure the part form observed during product qualification stays true into serial production. Moreover, Figure 2 focuses on mechanical data over time, where Figure 2a shows mechanical data over time for a single machine and Figure 2b shows performance over time for data obtained across two machines. While having consistency on one machine is important, maintaining robust machine to machine performance is much harder to achieve. Typical machine to machine variability is more prone to differences between powder lots, differences in product configurations, and the inevitable slight differences in hardware (setting of valves and fittings), therefore a Cpk of greater than 2 is impressive.

The data obtained through analysis like these allows Cumberland Additive to drive continuous improvement while making data-driven decisions on the manufacturing process. The **volumes of data** collected on a large **diversity of part geometries** produced using various AM materials and technologies, shows Cumberland Additive has true strength in numbers. The multi-skilled team continues to derive insights from the historical success of this data to deliver the right AM solution **to their number one priority: the customer.**

About the Company: Cumberland Additive Inc.*: The Industry's Trusted AM Partner*

Cumberland Additive has a long history of trusted partnerships culminating in the delivery of thousands of high-quality metal and polymer production components using a variety of AM technologies. The company was an **early entrant to AM production 14 years ago**. Presently **AS9100 D certified**, the company's internal systems have been designed to tolerate the rigors of aerospace production while also maintaining the agility to rapidly produce custom parts. The primary build technology of expertise is powder bed fusion in metal with laser and electron beam, and polymer with laser. Developed materials include Titanium 6Al-4V, Inconel 718, Inconel 625, Stainless Steel Alloys, Cobalt Chrome, PA and FR Nylon 11 and Nylon 12 variants, including Carbon Fiber blends.