Metal vs. Polymer 3D Printing – It's Not a Zero-Sum Game

Comparison Brief

On an average New York winter day in 2012, a not-so-average company filed for bankruptcy. Having survived for 136 years, it enjoyed an almost monopolistic hold on film photography for most of the 20th century. If you haven't yet guessed, the company was Eastman Kodak. There are several reasons for its downfall, but the consensus is that it failed to adapt to the disruptive effects of digital photography while clinging to its primary business model, which was selling print film. The most ironic part of the story is that a Kodak engineer invented the first digital camera – but the innovation was rebuffed.

This might seem to have nothing to do with the aerospace industry or additive manufacturing (AM). But it points out a tendency that can befall any organization, including aerospace companies that use (or don't use) AM. Kodak had a blind spot, failing to see the value in something that might benefit the company. Instead of vetting and possibly capitalizing on the new technology, it clung to what it knew most, believing things wouldn't change.

If the aerospace industry has a blind spot, one could argue that it's a "metal-centric" focus at the expense of non-metallic materials. Of course, composites have played an increasing role in the last few decades, and relative to AM, polymer has made inroads where its champions recognize the benefits. But despite this fact, polymer sometimes takes a back seat to metal, even after material performance characteristics are considered.

The goal of this analysis is to compare metal vs. polymer AM, with a specific focus on the latter's benefits. It also aims to show that investment in one technology doesn't have to come at the expense of the other. Metal AM has its place, but like composites, there are advantages to investing in polymer AM. It has proven its value and continues to do so with many aerospace and defense (A&D) companies, and ignoring its rewards comes at an organization's expense.

Comparing Metal and Polymer AM

When you come right to it, the applications for metal and polymer AM are very different, so there is no point in comparing them. For example, SpaceX chose metal to 3D print its Superdraco engines for obvious material capability reasons – reasons polymer can't satisfy. In contrast, Lockheed Space used FDM® Antero 840CN03 (PEKK) thermoplastic for the hatch covers on the Orion space capsule. Polymer met the lightweighting, ESD (electrostatic dissipative), and easier manufacturability requirements better than metal. The truth is metal and polymer AM can and do coexist, often within the same company, organization, and business unit.

Although the application spaces for polymer and metal AM parts aren't an apples-to-apples comparison, their demands on facilities and personnel can be compared. Anyone familiar with metal 3D printing knows that it comes with technical and procedural challenges:

Facility Infrastructure

Installing metal 3D printers means adopting specific facility requirements. Access to water, an inert gas supply for reactive metals, a stress-relief furnace, and ESD-capable floors or mats are just some of what's required. Additional measures like blast walls may also be necessary, depending on your municipality.

Polymer AM has fewer facility requirements, particularly for extrusion processes such as FDM (fused deposition modeling) and DLP (digital light processing), and printers can be installed in almost any location. Polymer facility requirements may require shop air depending on the type or size of the printer, and powder-based systems require a station for removing and cleaning the parts. However, neither of these poses the same burdens as metal AM.

Safety

Metal AM inherently comes with higher risks than polymer. For example, fire and explosion hazards from metal powders and soot require mitigation. Also, using inert gas poses the risk of oxygen displacement and must be managed accordingly. Safety-related implications also drive the need for compliance with local and higher-level safety regulations.

In contrast, polymer AM does not have the level of safety implications as metal AM. FDM is a very safe process, and safety requirements for powder-based systems mainly involve the use of respiratory PPE when removing parts from the build chamber and handling the powder.

Accessibility

Accessibility refers to the difficulty of addressing the challenges associated with metal AM, from facility requirements to testing and safety, down to personnel training. The more complex a system is, the greater the effort needed for successful operation. Suffice it to say, incorporating metal AM requires a time and resource commitment above what is necessary for polymer AM.

Certification

Since metal AM parts are selected for performance-critical applications (structurally or thermally), they drive strict test and certification requirements. However, the characterization information (material allowables and engineering information) associated with them is nowhere near as established or understood as for legacy manufacturing methods. This drives extensive work and time to vet the processes and parts to ensure they can be repeatedly reproduced with known performance characteristics.

Polymer AM has similar certification hurdles for flight hardware. Still, polymer has many other applications in the value chain where these barriers don't exist – prototyping and tooling are two big categories. The use of metal AM to address these two application families would be overkill and questionable due to the time and cost it would entail.

Level of Investment

Investment in metal AM is a two-pronged commitment involving human and monetary capital. Metal printing technology costs are typically higher than industrial polymer AM systems. And because metal AM is usually used for critical structures and systems, time is another crucial cost factor – time not only to achieve a part in hand after all the post-processing but the time for certification of the parts and process.

Post-Processing

Post-processing metal 3D printed parts can take even more time than the additive process. It starts with separating the parts from the build plate, mandating the use of EDM, a bandsaw or machining. Secondary machining is often needed to bring parts to their final shape and dimensions because printing achieves near-net, not precise, dimensions. Other processes that drive the time clock include heat treatment, surface finishing and subsequent quality assurance steps.

Polymer AM involves some post-processing, but not to the same extent as metal. Parts can be printed to their final shape and there's no post-print heat treat requirement.

Polymer AM has value throughout the manufacturing process, while the level of investment is relatively low compared to metal AM. Perhaps most significant is the speed of investment return. Aside from the qualification of flight parts, polymer AM can produce prototype parts, tools and manufacturing aids in a very short timeframe, often recouping investment costs quickly.

The point is that metal and polymer AM processes have their respective applications. What may not be evident are the scenarios where polymer AM is a good fit – and better than a metal AM counterpart.

Where Polymer AM Excels

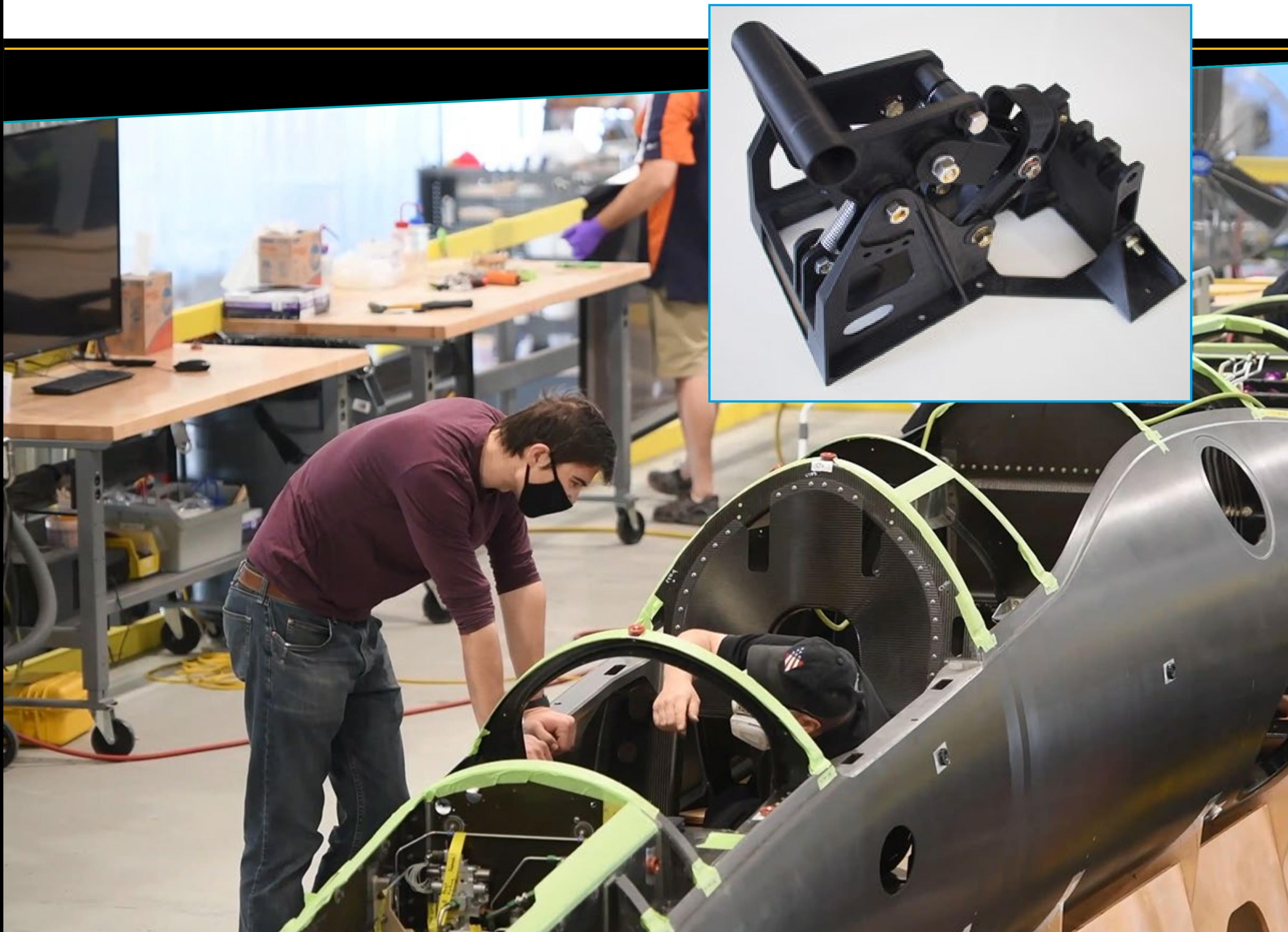
Polymer additive technology offers time and cost savings benefits for multiple phases of aerospace production – from engineering (prototyping and product development) to production (tooling and manufacturing aids) to flight hardware. One of its core values is the ability to integrate across an organization at multiple levels, thereby garnering cumulative benefits. This is possible because polymer AM scales from office-compatible printers – suitable for engineering development work – to factory floor industrial printers making high-value tooling or flight parts. And because of its easy implementation and operation, results come rapidly.

There's no better way to communicate the value of polymer AM than through cases showing how it's helping aerospace and defense manufacturers.

Engineering and Development

Boom Supersonic is building the next generation of supersonic passenger air travel. In developing its XB-1 concept aircraft, the company relied heavily on polymer AM for development, tooling, and flight parts. One example involved prototyping the XB-1's rudder limiter design. Instead of machining all the required components, Boom Supersonic 3D printed the parts using ASA thermoplastic, resulting in a 96% material cost savings and an 86% lead time reduction compared to machining these components.

BOOM

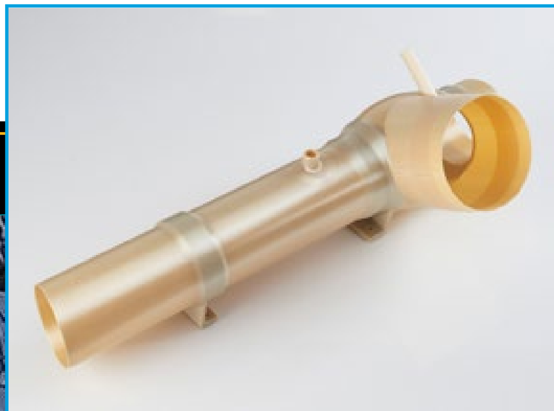


Production

East/West Industries is a tier-one supplier to major OEM aerospace companies. To offload its CNC machining line, East/West purchased a 3D printer and used carbon fiber nylon thermoplastic to make machining soft jaws and metal forming dies. On one particular contract, a forming die was damaged just before job initiation. As a result, East/West 3D printed a replacement die instead of waiting for a conventional metal tool. This solution avoided a seven-week replacement tool lead time and allowed East/West to meet its customer delivery timeline. In addition, the 3D printed tool cost 80% less than its machined equivalent.

Flight Parts

United Launch Alliance (ULA) used polymer AM to produce an Atlas V avionics cooling duct assembly, redesigned to reduce weight and part quantity. ULA used ULTEM™ 9085 resin, qualifying the material and resultant parts. The final 3D printed duct assembly decreased part count by nearly 90% and cut production costs by 98% while significantly reducing the weight compared to the original metal assembly.



Why Polymer AM Can't be Overlooked

As a leader in polymer additive manufacturing, Stratasys has worked with numerous A&D organizations and witnessed the benefits polymer AM technology has provided them. The scope of opportunities where the technology can be applied is extensive, offering multiple ways an organization can benefit.

Key among them are:

Faster Time-To-Solution

The ability to take time out of the design and production processes ultimately means getting to market faster. Efficiency gains in development and manufacturing add up, leading to a greater chance of achieving desired results sooner rather than later.

Ease of Use

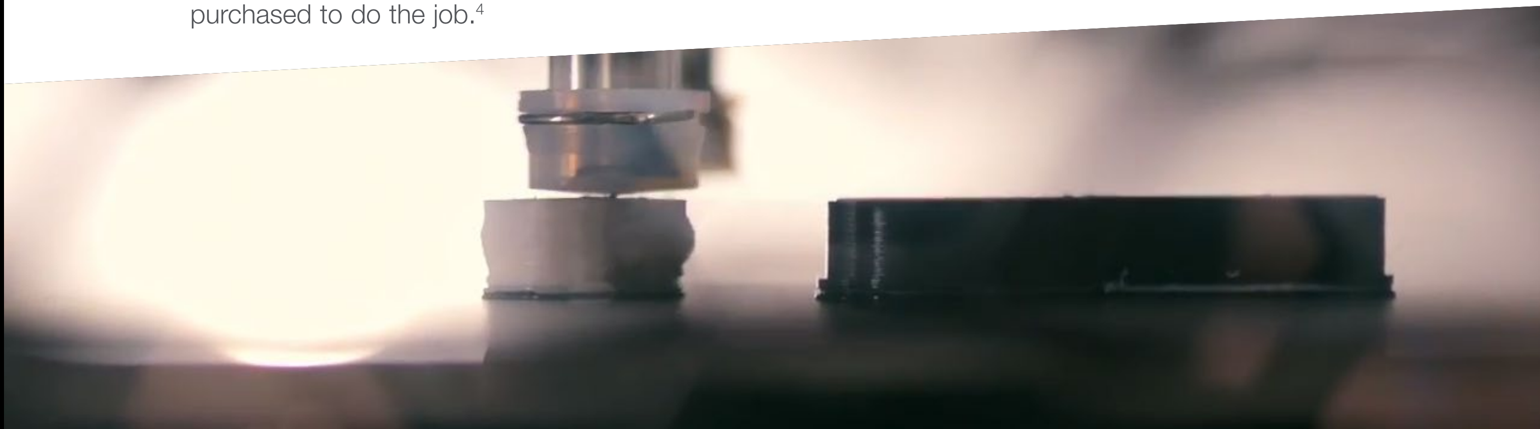
A lower adoption barrier equates to faster and easier implementation throughout the organization. This enables a compounding effect on problem resolution, cost savings, and faster delivery. The FDM process, in particular, is simple to operate and requires minimal orientation.

Ongoing Material Development

Stratasys polymer material development involves industry partners specialized in polymer research and production. The open platform capability on select Stratasys printers also lets users adjust print parameters to vary material properties and develop new materials. The result is faster availability of more materials with specialized capabilities that meet a broader application spectrum.

Faster ROI

Although every organization has its criteria for expenditure payback, the speed at which polymer AM provides results typically leads to a relatively fast ROI. A Sierra Space use case plainly illustrates this point. When the company looked for a more efficient way of making the tools that adhere thermal tiles to its reusable spaceplane, engineers conducted a trade study to compare making them with FDM® technology instead of the traditional labor-intensive approach. They found that the labor savings alone were enough to justify the cost of the printer Sierra Space ultimately purchased to do the job.[4]



The benefits of Polymer AM for flight hardware also can't be ignored. Polymer satisfies a fundamental aerospace design goal to reduce weight. The AM process also fits the low-volume, high-mix production scenario often characteristic of aircraft manufacturing and repair. And to accelerate the qualification of materials for flight hardware, the AM industry actively engaged with the regulatory agencies and the National Center for Advanced Materials Performance (NCAMP) to develop material allowables. The first AM material qualified was ULTEM™ 9085 resin using the Stratasys F900™ printer. What's also interesting to note is that at the time of writing, two of three AM materials currently working through the NCAMP process are polymers.

The bottom line is that while metal has its place, polymer AM 'pays the bills' for the above reasons and applications. It doesn't have the same operational overhead as metal and the differences in applications makes polymer AM a lower risk, which affords faster adoption. Polymer can even complement the metal AM process; prototypes and design concepts that will eventually be printed in metal can be iterated and validated faster and for less cost than doing the same with metal.

So how do you incorporate polymer AM if it's not part of your current manufacturing portfolio? Take a page from the playbook of General Atomics Aeronautical Systems, Inc. (GA-ASI), maker of unmanned aerial defense and civilian airspace aircraft and systems.

Start Small

GA-ASI advocates making the most of "low-hanging fruit" AM applications, such as making manufacturing workstation aids, assembly tooling, and wind tunnel models. And using a distributed co-location plan for their printers, GA-ASI has achieved cost and time savings of over 80% for various applications.

In the words of Steve Fournier, GA-ASI AM Department Senior Manager, "There's really no reason for any other companies out there not to try and get those low-hanging fruit applications, based on our experience." [5]

Use Contract Services

AM service bureaus and contract production facilities like Stratasys Direct Manufacturing are effective means to gain exposure to polymer AM capabilities, effectively letting you test drive the technology. The knowledge gained from this work will help with more informed decision-making should your organization consider bringing the capability in-house.

Start Small

Another recommendation from GA-ASI is to broaden polymer AM integration and application as your knowledge and expertise with the technology grow. Applications might include using polymer parts for ground handling equipment and ultimately moving into flight hardware.

Avoid the Blind Spot

As humans, we're all susceptible to confirmation bias. It's the tendency to prefer information that affirms your beliefs while ignoring or discounting information that contradicts them. The 'metal-and-only-metal' confirmation bias is understandable in an industry that's relied on it for nearly a century as a mainstay resource. So it may seem natural to default to metal when it comes to additive manufacturing. But falling into that trap means ignoring the gains polymer AM provides. It's not a zero-sum game, as there are benefits with both technologies. General Atomics, mentioned in the previous section, is just one instance of a company that leverages both to its advantage.

If one more example helps make the point, Maxar Technologies, a manufacturer of satellite technology for over 60 years, uses metal and polymer AM. In 2019, the number of AM parts Maxar put in orbit exceeded 2500. Of that, the majority – nearly 60% - were plastic. Obviously, Maxar sees a benefit in polymer AM.

Remember the story at the beginning of this article about the blind spot? Don't let the belief that polymer AM doesn't have a role in your organization be your Kodak moment. Polymer and metal AM are just additional tools for the toolbox. Why not take advantage of both?

1. **https://www.additivemanufacturing.media/articles/installing-a-metal-3d-printer-part-2-facilities** "Installing a Metal 3D Printer," accessed March, 2023
2. Interview with Cris Robertson, AM specialist, Lockheed-Martin, February 2023
3. **Costs and Cost Effectiveness of Additive Manufacturing – A Literature Review and Discussion**, Douglas S. Thomas and Stanley W. Gilbert
4. Sierra Space case study, **https://www.stratasys.com/en/resources/videos/stratasys-fdm-tooling-helps-ready-the-dream-chaser-for-space/**
5. Insights into Industrial AM Implementation for Unmanned Aerial Systems & Defense Industry, Stratasys Virtual Manufacturing Event, presented by Steve Fournier – General Atomics Aeronautical Systems, Inc. AM Department Senior Manager, May, 2022

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