CASE STUDY: METAL BINDER JETTING FOR FLUID MATTER EXCHANGER

AZOTH INC.

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ABOUT US

Azoth is a world-class, vertically integrated manufacturing company founded in 2018, and headquartered in Ann Arbor, Michigan. We specialize in manufacturing small and complex parts leveraging production-capable additive (3D) manufacturing technology. We offer over 45 different polymers and metals to ensure the right material, process and technology is used in every application.

Azoth's additive technology is a disruptive force in traditional manufacturing through its quick production lead times and **TOMO®** (Take One Make One). The TOMO process is designed to convert physical inventory to digital inventory eliminating supply chain disruptions, inventory obsolescence and saving its partners significant inventory costs and cash flow.

Not just another service bureau – Azoth is your dedicated manufacturing partner.

AZOTH INC.

1099 Highland Drive
Ann Arbor, Michigan 48108

Phone: 734-669-3797
Email: info@azoth3d.com

MADE IN U. S. A. MPIF AIAG CERTIFIED ISO 9001:2015 COMPANY International Traffic in Arms Regulations Compliant ITAR

ABSTRACT

A fluid matter exchanger is a device designed to efficiently transfer heat or mass between two fluid streams, typically liquid or gases. Its primary function is to facilitate the exchange of thermal energy or substances between the fluids without direct contact. This process is crucial in various industrial applications, including heating, ventilation, air conditioning, and chemical processing.

Manufacturing fluid matter exchangers presents several challenges. They must reliably perform in corrosive environments, withstand high temperatures, and endure pressure variations. Achieving the needed desired geometry and surface finishes demands advanced machining and welding techniques. All of which yield expensive products with extensive lead times.

Azoth's expertise in metal binder jetting additive manufacturing revolutionized the way fluid matter exchangers are made. Azoth's technology allows for the creation of complex geometries with intricate internal structures that are impossible to achieve using traditional manufacturing methods. This significantly improves the efficiency of heat or mass transfer within the exchanger. Azoth provides a more resource-efficient process, minimizing material waste compared to subtractive manufacturing methods. The layer-by-layer construction also allows for rapid prototyping and iterative design, facilitating the rapid development of optimized fluid matter exchanger designs. With same equipment and exceptional quality, Azoth seamlessly transfers to mass production to meet market demand.

This paper details a real-world customer's product and is recipient of the **2023 Powder Metallurgy Design Excellence Award, presented by the Metal Powder Industries Federation to Azoth.**

DESIGN CONFIGURATION

This Fluid Matter Exchanger is additively manufactured in a Digital Metal P2500 Metal Binder Jetting 3D printer fitted with a large PB4-186 build box. The raw materials used to print this part are proprietary 316-L stainless steel powder and C20 binder. The Fluid Matter Exchanger is initially printed larger to account for shrinkage of about 20% during sintering. Also, within the build box, sintering live-setters are printed right underneath each part. The sintering live-setters are designed to fit the complex bottom of the part and allow the part to be sintered vertically. Moreover, additional printing enhancers are printed within the build box to facilitate the depowering operations. The part is then sintered in an Elnik MIM 3015 batch furnace.

Figure 1 Fluid Matter Exchanger sintered on a sintering live-setter.

The design of this part is derived from a long collaboration between the customer and the manufacturer, throughout which many previous models of similar components have been manufactured and used by the customer.

Although relatively simple from an outside look, the design of this parts is extremely complex on the inside. CAD cross sections are shown in the images below, and a sectioned part is submitted to show the internal features of this part.

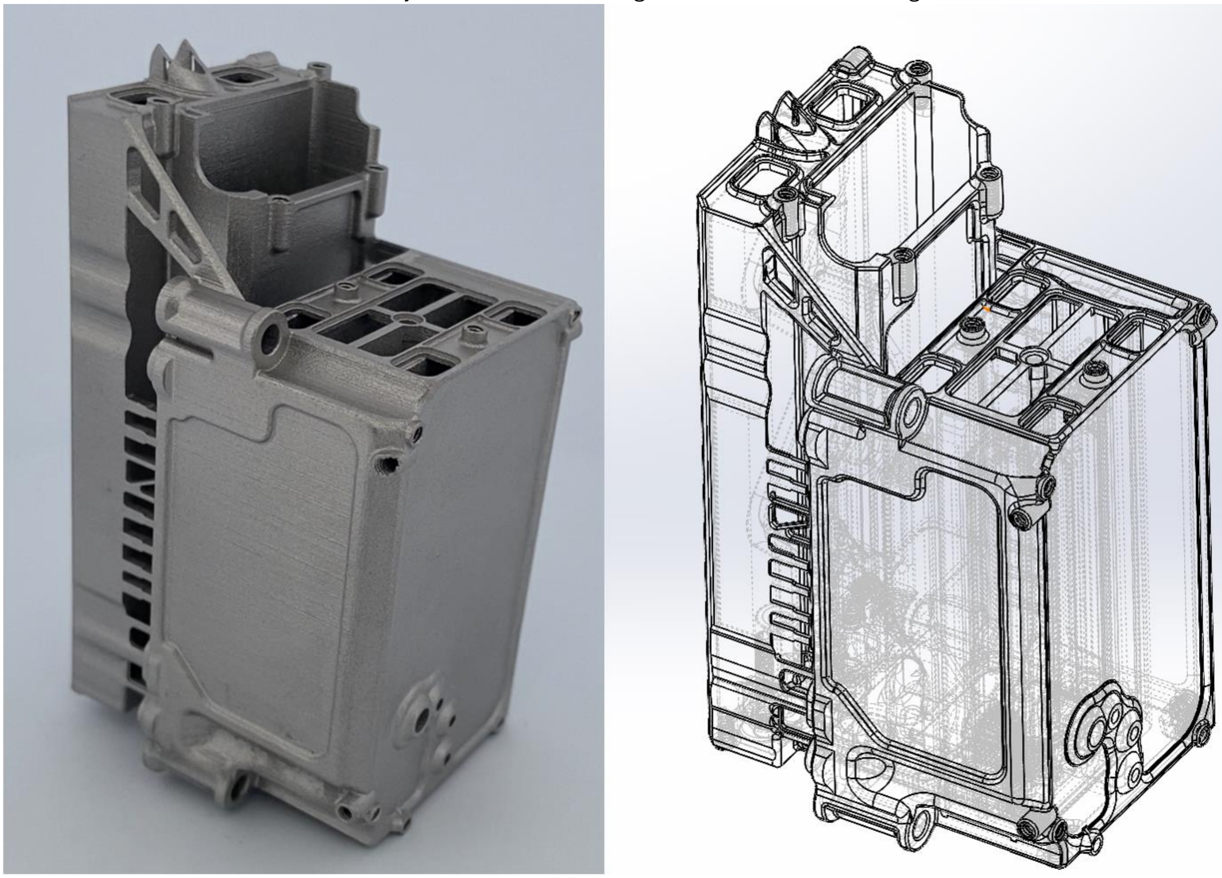

Figure 2 (Left) Picture of the Fluid Matter Exchanger, (right) CAD view of the Fluid Matter Exchanger showing the large amount of hidden internal features.

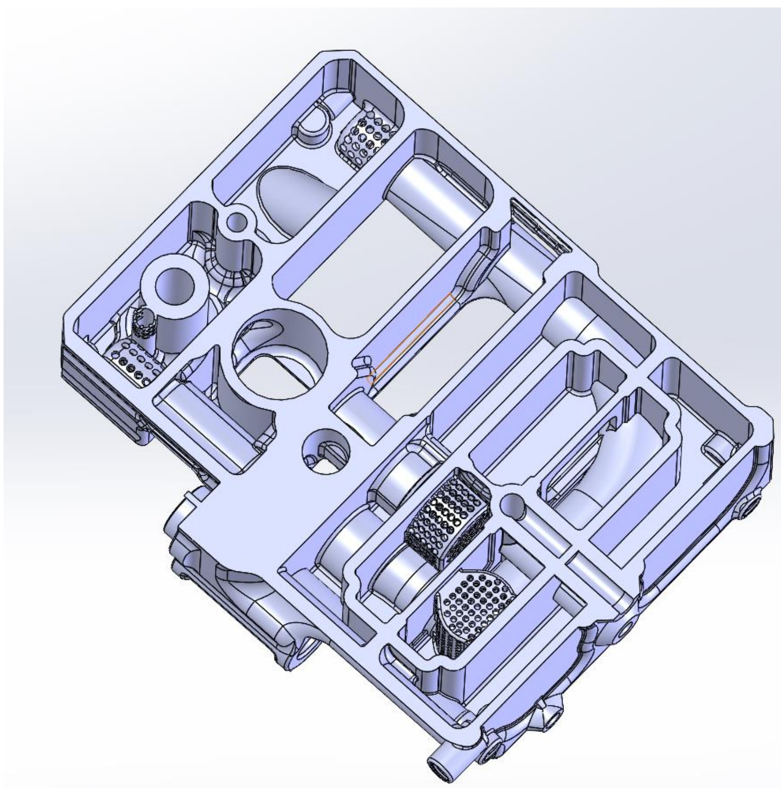

Figure 3 Horizonal cross-section of the CAD view of the Fluid Matter Exchanger showing the large amount of hidden internal features, including multiple hollow chamfers, filters, and channels.

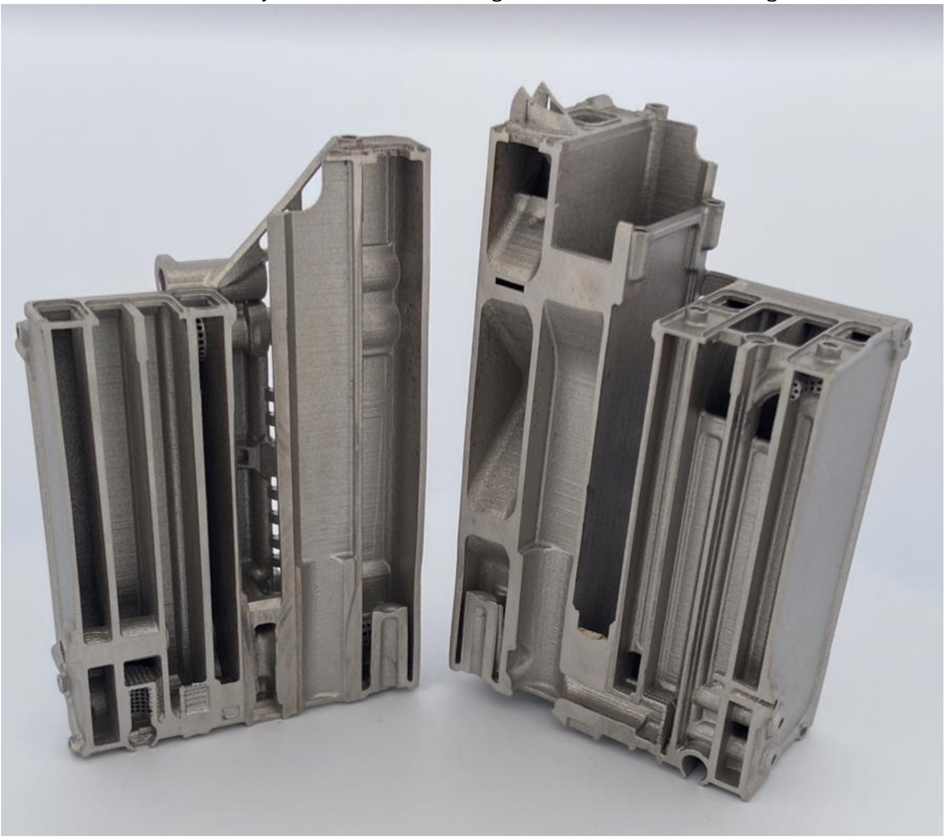

Figure 4 Picture of the sectioned cut of the Fluid Matter Exchanger, showing the large amount of hidden internal features, including multiple hollow chamfers, filters, and channels.

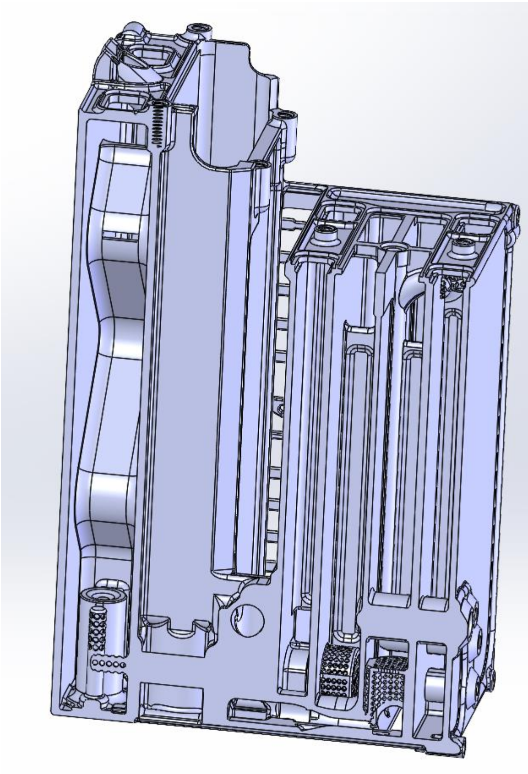

Figure 5 Vertical cross-section of the CAD view of the Fluid Matter Exchanger showing the large amount of hidden internal features, including multiple hollow chamfers, filters, and channels.

The Fluid Matter Exchanger has large channels running through the part with many smaller channels and filters scattered within the part allowing for matter to flow in specific ways. A total of over 50 independent cavities can be counted within the part.

The hollowness, internal channels, internal filters, and other complex features of the Fluid Matter Exchanger make it a part only viable through additive manufacturing. Some examples of these features include the holes of the filter being 0.5mm in diameter, wall thicknesses as small as 0.75mm, and 21 threaded holes with an #2-56 thread printed directly on the part. Some post processing is done by the end-user, like welding of an end cap and connectors to the Fluid Matter Exchanger.

Due to the intricate geometry, challenges arose during manufacturing; depowdering was of the primary concerns. Through studying of the CAD, the development of innovative air nozzles was essential for clearing out all the loose powder from the various channels and cavities inside the Fluid Matter Exchanger before sintering. No powder can be left inside the channels and filters to allow the proper flow of matter and ensure proper functioning of the apparatus in the field. Due to many of these features being on the inside of the Fluid Matter Exchanger, depowdering the parts took time and a deep understanding of the internal geometry. Even simple handling of these parts in the green state is critical, as the extremely thin walls would crack if too much pressure is exercised on them. Internal and external braces were placed in areas that would not affect the function to reinforce the part for handling during depowdering in the green state and prevent distortion or cracking during sintering.

Being truly designed for additive manufacturing, this part could not be manufacturable by other methods.

ENGINEERING PROPERTIES

The main requirements for this part are dictated by the complex functional fluid dynamics occurring within the part as the part is employed in its application. Most of the requirements were facilitated by attentive design. For example, internal filters were added within the internal channels to control the fluid turbulence as the matter travels through the part. Moreover, the part was designed with a split design, connected solely by thin braces, to separate the operational hot section from the cold section of the part, limiting heat transfer between the section of the parts.

To ensure all loose powder is removed from the part and thus does not obstruct the functional flow of matter, a detailed depowdering process plan is followed, which included verifying the clearance of flow within each of the channels. Prior to sintering, every part is weighted in the green state to match the target weight dictated by design.

The material used for this part is 316-L stainless steel, chosen for its corrosion properties due to the part having matter constantly flowing through the part under high temperatures.

Table 1 Mechanical properties of 316-L stainless steel under Azoth manufacturing processes

Property	S.I. Units	Imperial Units
Yield Strength	180 MPa	26,107 PSI
Tensile Strength	520 MPa	75,420 PSI
Elongation	50%	50%
Hardness	HRB 55	HRB 55
Density	~96%	~96%

After sintering, the Fluid Matter Exchanger is inspected and measured with respect to the tolerances on external dimensions agreed upon with the customer. Advanced tests are performed on each part by the customer, which includes testing of flowability within the many internal channels and sections as well as pressurized leak testing. These tests are critical in validating the performance of the Fluid Matter Exchanger and ensuring it can be used in the final product.

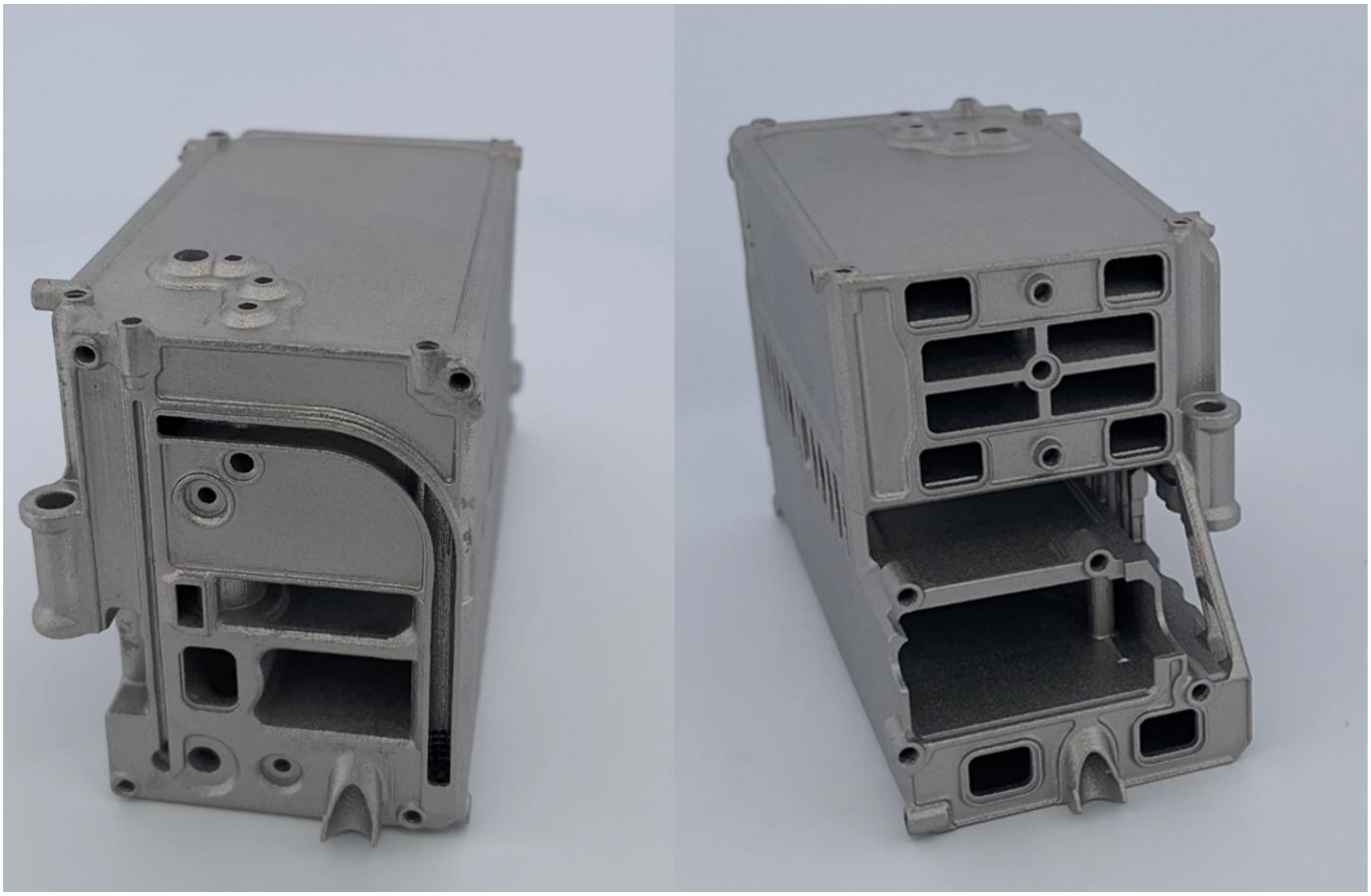

Figure 6 (left) Bottom view of Fluid Matter Exchanger, (right) top view of Fluid Matter Exchanger

SIGNIFICANCE

Currently there is no other way to manufacture a part like this, and this fluid matter exchanger is only possible by means of additive manufacturing. The part demonstrates the superior capabilities of additive manufacturing perfectly. It is a larger than usual part for Metal Binder Jetting but has so many of the smaller more detailed features which Metal Binder Jetting is known for. The duality of this part, being large but at the same time one of the most complex, displays Metal Binder Jetting's capabilities perfectly.

This compact design of this part is a direct result of being able to combine multiple components into one part, which is only achievable through Metal Additive Manufacturing.

All the channels, filters, and other key features packed into this Fluid Matter Exchanger make it a very complex part. The customer estimates, based on previous designs, that over a dozen machined and welded or brazed components would have had to be used to create a design still less efficient than this single Fluid Matter Exchanger.

SUSTAINABILITY

Metal Binder Jetting is a method of additive manufacturing that permits mass reduction that results in a more efficient use of material while not compromising strength and functionality. A great example of this Principle on the Fluid Matter Exchanger are the ribbed walls that provide more support while not fully increasing wall thickness.

In addition, Metal Binder Jetting rids the need for tooling or requalification of the process in different machinery. Within the many 3D printing technologies used for rapid prototyping, Metal Binder Jetting allows the switch from prototyping to production to occur rapidly and within the same manufacturing processes. Moreover, since the order quantity requirements for this part is relatively low, it means that orders can be fulfilled within weeks, allowing the printer and other resources to be focused on other projects immediately after, thus promoting efficient equipment and energy utilization.

Another benefit of Binder Jetting is the recyclability of metal powder. In this specific part, only approximately 15% of the theoretical loose volume is integral to the final part. Since Metal Binder Jetting only uses the amount of material needed to build the part, the excess powder from the build is recycled and remixed to be used for another build. This makes Metal Binder Jetting a great low-waste process that subtractive manufacturing cannot achieve.

Finally, although details about the application cannot be disclosed, it can be said that this part is used in a breakthrough application that will replace the use of fossil fuel and/or rare earth minerals, which is necessary for the world we live in today and the world we will leave behind.