EWI Accelerates 3D Printing of Metal Matrix Composites

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EWI is focused on developing leading-edge capabilities in both additive manufacturing (AM) and nondestructive evaluation. By combining expertise in both technology areas, EWI is accelerating the pace at which 3D-printed components can be introduced into the marketplace. Future advances in computed tomography (CT) such as faster scan speeds and quantitative material differentiation are well-suited to meet the coming challenges of broadly implemented additive manufacturing, including multi-material printing.

The Customer

EWI has been working with Fabrisonic LLC, a manufacturer of metal 3D printing machines. Fabrisonic has pioneered 3D printing of metals at low temperature using their patented ultrasonic additive manufacturing (UAM) technology. This high-productivity, solid-state process enables 1) printing of metal parts with complex internal cavities, 2) welding of multiple dissimilar materials into a single part, and 3) embedding of electronics and non-metallics into solid metal shapes. With a work envelope of 6 ft. x 6 ft. x 3 ft., manufacturers can use Fabrisonic's innovative UAM technology to efficiently produce large components.

Recently, Fabrisonic has been developing the ability to create metal matrix composites (MMC) by using an ultrasonic print head to deposit a combination of aluminum and hundreds of continuous ceramic fibers per square inch. In this process, the ceramic fibers are embedded in a solid aluminum structure as the metal completely extrudes around them. This allows the fibers to carry load through the component. Because the strength of these fibers exceeds 200 ksi, the resulting MMC has a high strength-to-weight ratio. As with any composite, each layer can be oriented in a different direction to maximize strength for a given application. Parts can also be printed with fibers in high-stress regions to tailor mechanical properties as-needed. These advanced materials can be stiff and lightweight: the perfect combination in high-stress weight-critical environments.

The Problem

Additive manufacturing allows a new world of design possibilities; however, standard inspection techniques have not yet been developed for complex new materials such as MMCs. While developing their MMC printing strategies, Fabrisonic had the following questions:

- Were fibers breaking, thus reducing overall load-carrying capacity?
- Were fibers distributed evenly throughout the matrix?
- Was the process leaving gaps or porosity, especially around the fibers?

As shown in Figure 1, Fabrisonic used traditional metallography to study MMC samples. This time-consuming method required samples to be mounted and polished prior to examination under a microscope, and only provided through-thickness snapshots. As a result, Fabrisonic was unable to isolate specific areas of concern and comprehensively assess weld quality using this technique.

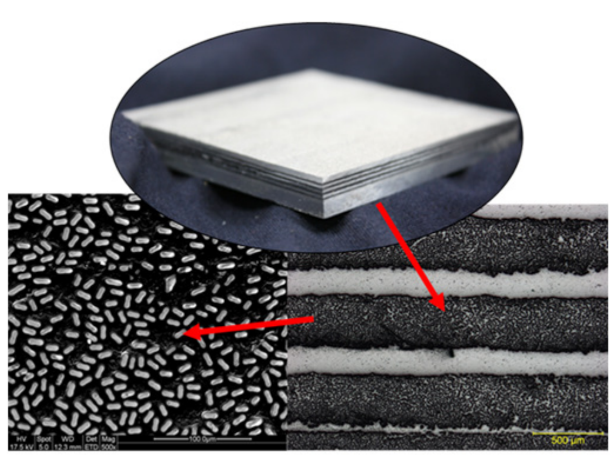

Figure 1: Cross section of a Fabrisonic MMC shown at sequentially higher magnifications

The Solution

EWI recently acquired cutting-edge, computed tomography (CT) equipment at its Buffalo, NY, facility. This technology allows nondestructive through-thickness examination of MMC parts as shown in Figure 2. Here, two individual ceramic fibers can be seen, sandwiched between the aluminum layers. The inset in the top right corner shows the location of the cross section within the part.

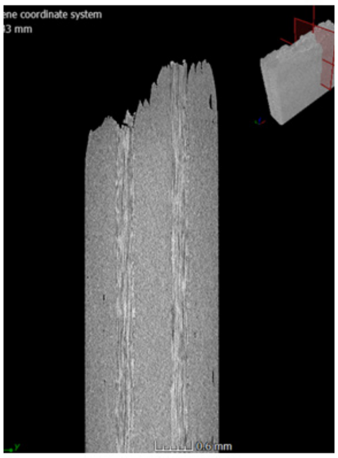

Figure 2: CT cross section of Fabrisonic's tested-to-failure MMC

The CT scans provided by EWI helped Fabrisonic quickly quantify and identify the cause of fiber breakage by analyzing the location of the failures. These scans also allowed Fabrisonic to quickly iterate and optimize their welding parameters. EWI further investigated broken tensile bars to study the failure mechanisms of the MMC at high strain, as shown in Figure 3. In this 3D reconstruction of the part, the identified pores are color-coded per the scale bar and superimposed on the semi-transparent volume. The ceramic fiber locations are indicated by the darker gray region, with the edges color-coded based on the fiber's orientation. Blue indicates that the fibers are vertically oriented.

With a range of available resolutions and penetration depths, and applicability to even the most complex geometries, the adaptability of CT makes it a great fit for AM technologies. As these technologies continually push the limits of design freedom, designers are often held back by conventional evaluation techniques that cannot adequately inspect complex structures. For instance, powder bed fusion systems can create intricate repeating lattices with incredible strength; however, ultrasonic and 2D x-ray inspection methods cannot resolve individual segments of the lattice, and thus cannot provide insight into the quality of the structure. CT scans, on the other hand, can resolve each individual lattice element and quickly provide quality information to designers and machine operators.

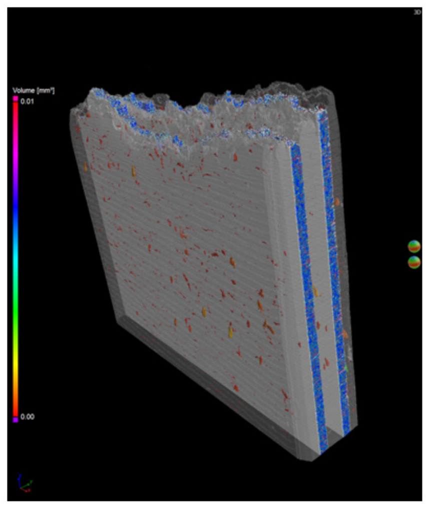

Figure 3: CT analysis of an early, broken MMC tensile bar

Alex Kitt *leads the EWI metrology and inspection team at Buffalo Manufacturing Works in Western New York where he works with customers to identify and solve their metrology needs. He focuses on x-ray and 3D optical imaging and leverages EWI's cross-location expertise in ultrasonics, eddy-current, and thermography. The metrology team works closely with the automation team to implement in-process solutions and to use measured data for feedback and dynamic control.*