# Does Friction Stir Welding Add Up?

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## Introduction

To say that additive manufacturing (AM) is a hot topic is a drastic understatement. A simple internet search will return a dozen AM conferences and consortium meetings every month, and research is being conducted on all material types for use in virtually every industry sector. The benefits of AM are clear when compared to traditional manufacturing techniques such as conventional machining, where significant effort is spent subtracting material from an oversized section until all that remains is the desired part. Using this approach, the manufacturer not only has to pay for the unwanted material, they also have to pay to have it removed. While AM does require time and energy to turn feedstock into a completed part, a cost benefit can often be realized, especially when overall productivity is taken into account.

EWI's focus in the AM space is primarily in the metals arena. The overwhelming majority of AM techniques in this space use fusion-based processes such as laser or electron-beam powder-bed fusion. While these are clearly enabling technologies, a host of other additive options are also under development.

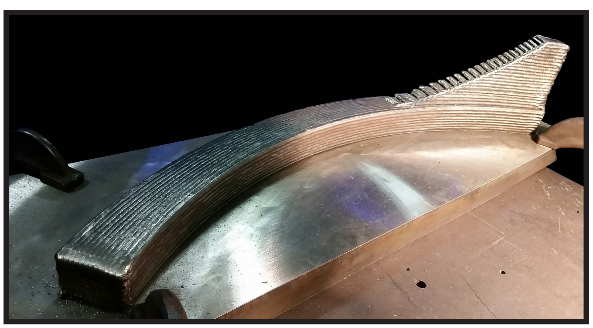

Figure 1: As-welded EWI arc-directed energy deposition demonstrator article

## Arc Welding AM Innovation

EWI recently completed an internal research and development project to demonstrate arc-directed energy deposition (ADED) on the demonstrator article shown in Figure 1 below. This use of automated gas metal arc welding (GMAW) to build an AM component using a bead-by-bead, layer-by-layer approach represents an order-of-magnitude increase in build speed over current powder-bed fusion processes, albeit at reduced feature resolution.

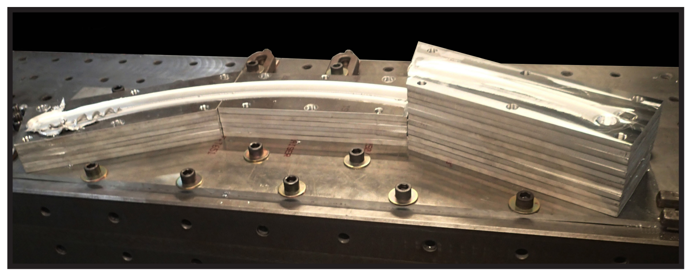

Figure 2: As-welded friction stir welding demonstrator article

## Large-scale AM with Non-fusion-weldable Alloys

While the ADED approach described above was shown to be highly effective, industry has also indicated a desire to additively produce structures from non-fusion-weldable materials. With many of these alloys, material cost can be a limiting factor for large components. For example, when the thickness of aluminum alloys exceeds 5 inches, the material cost by weight often exceeds that of the required machining. In addition, as the material thickness increases, maintaining a homogenous through-thickness microstructure with consistent mechanical properties becomes more challenging.

## EWI's Approach

EWI selected friction stir welding (FSW) to address the challenges associated with producing large-scale complex components from non-fusion-weldable materials. To demonstrate this concept, we reproduced the demonstrator article shown in Figure 1 using 7075, an aluminum alloy which cracks upon solidification and can therefore only be joined using solid-state processes. It should be noted that this component could certainly be built using Fabrisonic's ultrasonic additive manufacturing process; however, the time required to reproduce it with 0.007-in. thick ribbons would be prohibitive.

Aluminum 7075 plates, 0.5-inch thick, were used, and a friction stir tool was selected which would penetrate through the plate and into the material below, resulting in a weld connecting the two pieces. Two or more weld passes were produced side-by-side on each layer to achieve the desired weld width, and a skim-machining pass was completed to remove flash prior to adding the next layer of plates. In future development work, optimized tool design would allow a single pass per plate while welding speed could likely be increased for improved productivity. Additionally, further process development could likely eliminate the need for flash removal between plates.

Figure 2 shows the final as-welded build. The lower section of the mock part required a six-plate-high weld stack-up to achieve a thickness of three inches. Due to the length of this portion of the component, 18 plates were required. The fin section required an additional six plates. In total, twenty-four plates were joined using approximately forty-eight linear feet of weld. The optimized weld speed for this process would exceed twelve inches per minute, resulting in a total weld time of less than an hour.

As shown in Figures 3 and 4, post-weld machining is required to achieve final component dimensions. While the level of required machining is higher

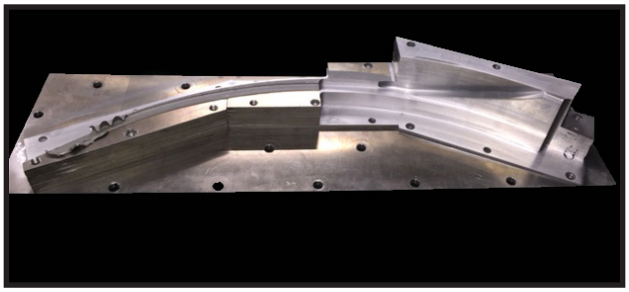

Figure 3: Partially-machined friction stir welding demonstrator article, view 1

than that other AM processes, most metal additive parts are near-net shape and require some level of post process machining. Even with the machining required, this process can yield significant benefits by reducing material cost, as well as overall machining time.

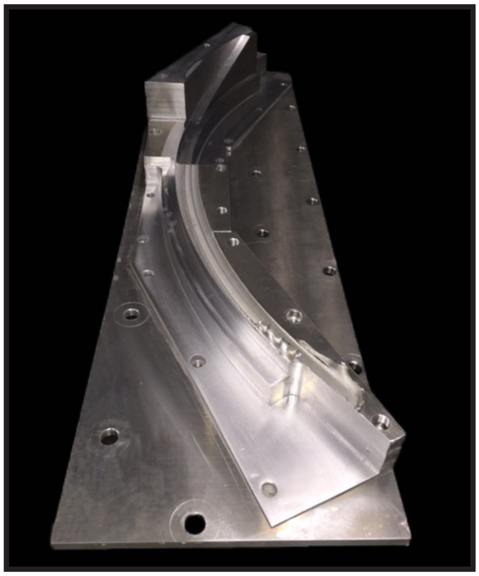

Figure 4: Partiall-machined friction stir welding demonstrator article, view 2

***James Cruz*** *has expertise in various resistance and solid-state welding processes, including flash-butt welding, resistance spot welding, friction welding, and friction stir welding. His materials expertise includes carbon steel and aluminum alloys. James has worked on projects involving tooling and fixturing development, welding automation, procedure optimization, and qualification of weld procedures for manufacturing and aerospace applications.*