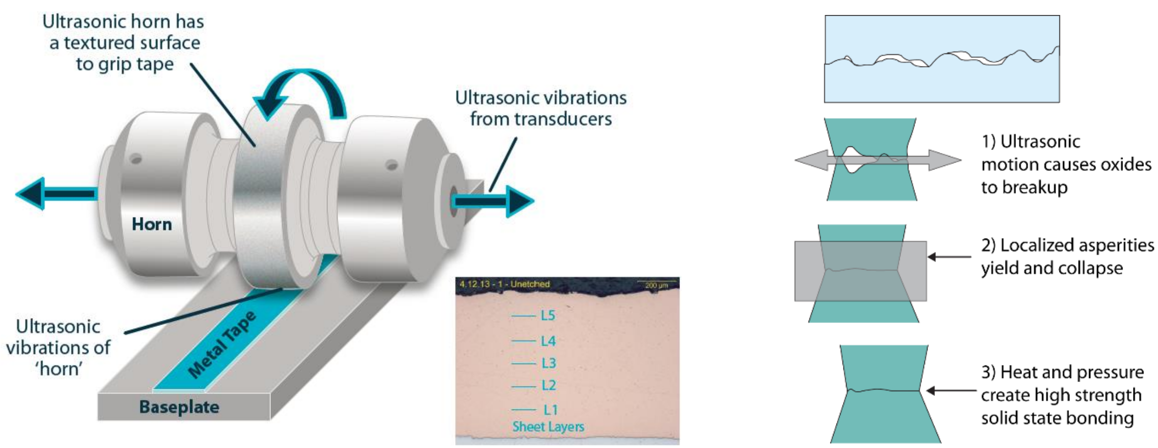
When Additive Is……. Well, Additiv*e to Traditional Manufacturing*

By Mark Norfolk, CEO, Fabrisonic

Some of the popular 3D printing modalities require that the object be fully 3D printed or fully manufactured using traditional methods. There is a misconception in the industry that all Additive Manufacturing (AM) processes require this all-or-nothing approach. However, many AM techniques can be utilized to augment traditional manufacturing as opposed to completely replacing them. One such technology that is often used in series with other processes, is Ultrasonic Additive Manufacturing (UAM).

The UAM process involves building up solid metal objects through ultrasonically welding a succession of metal foils into a three-dimensional shape with periodic machining operations to create the detailed features of the resultant object. As shown in Figure 1(a), a rolling ultrasonic welding tool is used for the additive stage. Ultrasonic vibrations, generated by transducers attached to the sonotrode, scrub the foil against the substrate (much like friction welding), creating a solid-state (no melting) bond between the metal foil and lower substrate, i.e., baseplate or previous foil. Foils used in the process can range from .001-.010” in thickness. The additive stage produces near-net-shape parts using a raster-like pattern like laying bricks in a wall. An integrated CNC stage can be used to impart geometry during manufacture and for final part finishing.



(a) Ultrasonic welding of copper tape **(b) Bonding mechanism for UAM**

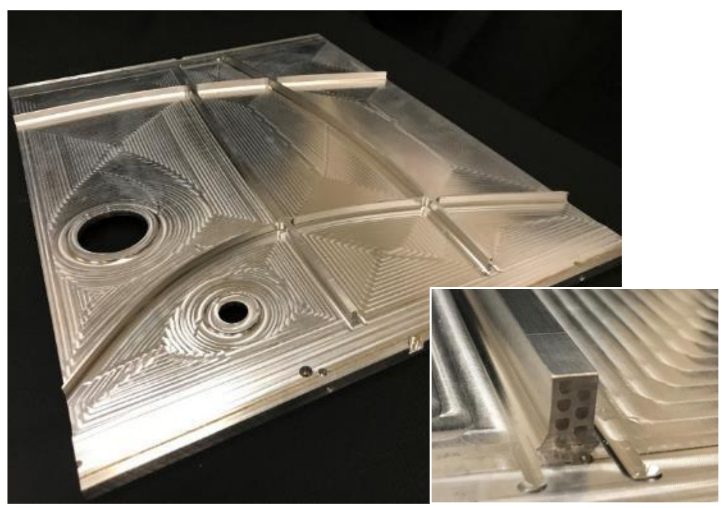
WHY COMBINE PROCESSES

But why would we mix awesome new technology with old stogy ways of doing things? To start, let's consider the cost. While AM techniques can enable wonderous new designs, they tend to be significantly more expensive on a $/unit volume basis. Our established manufacturing base has been optimized over decades to deliver the lowest possible price for each given manufacturing method. Now if a part has been designed from the ground up to take full advantage of 3D printing, every feature in that part may require a printer. However, most parts that come across our desk have only one or two features that REQUIRE 3D printing. For those cases, a hybrid manufacturing method enables a lower price. Use traditional manufacturing for the main body and utilize additive for those features that require it. Now let's look at some common applications where AM can be used in series with traditional manufacturing methods.

Tailor Welded Blanks/Selective Reinforcement

The automotive industry pioneered the idea of tailor welded blanks (TWB) decades ago. The idea is that in the same part, different regions have different loading requirements. Instead of taking a large chunk of material, and hogging material away, the TWB brings together two different pieces of material.   Often TWBs are associated with laser welding two or more pieces of disparate sheet metal to make a laminate part, such as a car hood, that has a different thickness in different locations.

Additive is a natural fit for this model. Instead of taking a thick billet and machining away, manufacturers can start with a thin billet and print material in key locations that require stiffness/strength. The picture at the right illustrates this clearly. The panel is a four-foot piece of aerospace aluminum. In the center, the thickness has been doubled via UAM printing. Since UAM is a room-temperature process, the temper and properties of the incoming metal have not been changed. After printing, the panel can move through the manufacturing process to traditional steps like forming, shearing, and even arc welding.



A more complex example can be found in an aerospace application. Because UAM works by layering materials together through ultrasonic metal welding, continuous ceramic fibers in laminate or rod form can be incorporated throughout the structure for tailored properties. The low-energy bonding methods allow full encapsulation of high-strength fibers into a metal matrix without degradation of the fiber. Much like rebar in concrete, these fibers can dramatically improve the load-carrying capacity of the structure. While printing the entire part out of these metal matrix composites is possible, a more attractive price can be obtained by printing reinforcements only in the major loading axis and then only in specific high strain regions.   The cost/strength can be optimized through a relatively small amount of 3D printing.

Embedded Sensor

One unique capability of UAM is the ability to embed sensors and other electronics directly into the meat of a solid metal part. The solid-state nature of Fabrisonic's Ultrasonic Additive Manufacturing (UAM) bond allows for encapsulation of all manner of wires, fibers, and sensors into a metallic substrate. Over the years, Fabrisonic has embedded strain gauges, microphones, thermocouples, and even ultrasonic inspection sensors into solid metal parts. By burying a sensor into solid metal the sensor is:

- Hardened allowing it to operate in more aggressive environments
- Located exactly where the relevant data is needed
- Constrained by metal instead of adhesives, which allows a much larger operating regime

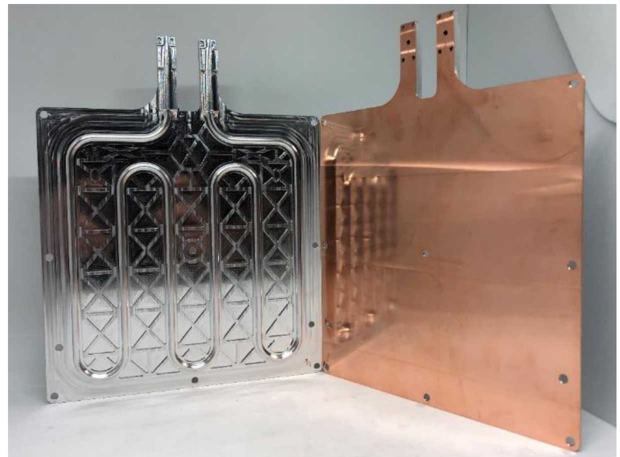
A vast majority of the parts that utilize embedded sensors, start as an existing component to which sensors are added. Often Fabrisonic will start with an existing part number and machine away the region of interest. Sensors are added and 3D printing is utilized to build the part back up to print. By only printing in the region of interest, the cycle time for the print job (and hence cost) can be minimized.

One specific example is instrumented pipe sections. Fabrisonic has produced a litany of instrumented pipes for aerospace, oil/gas, and power generation. A traditional pipe pup is obtained through traditional supply chains. A flat section is milled into the outer diameter (OD) of the pipe creating a landing strip for embedding. A small groove is cut to positively locate each sensor. Once the sensors are inserted by hand, additional material is printed over the landing strip to build the OD back up to spec. After printing, traditional mating flanges are welded on using standard arc welding. Again, 3D printing is leveraged for its advantages while traditional methods are utilized to keep the cost down.

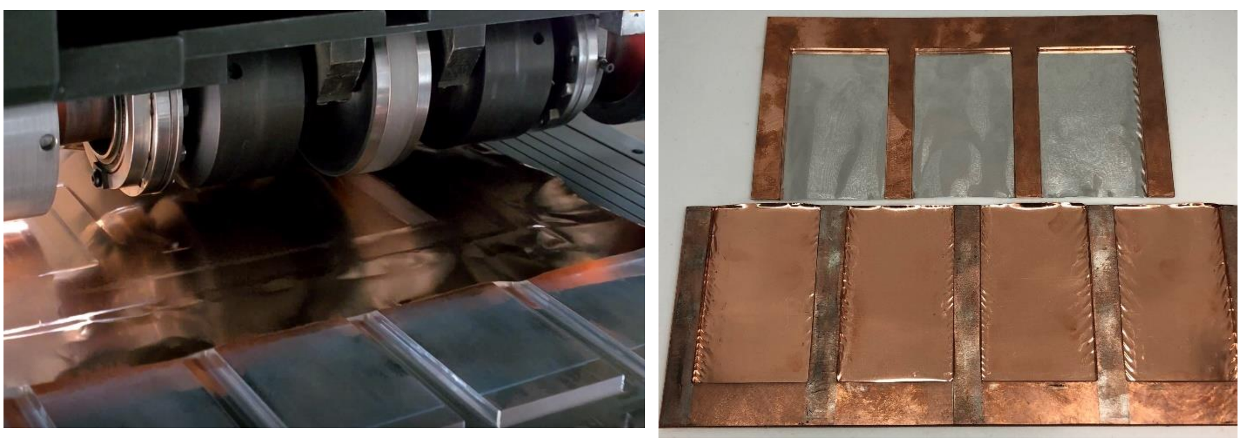
Cladding / Dissimilar Metals

The line between traditional welding processes and additive processes can often be blurred. For decades manufacturers have clad expensive *metal A* onto cheap *metal B* by using lasers, arc welding, and thermal spray. New 'additive' techniques are highly useful for these same applications. UAM relies on solid-state ultrasonic bonding with no change to metal microstructure. The bond permits the joining of dissimilar metals without the metallurgical mismatch issues seen in other additive processes.

UAM has been used in production environments to clad dissimilar metals. For instance, numerous applications have been made using combinations of aluminum and copper. For many thermal applications, a small amount of copper added in the right region can transform the thermal characteristics of a heat exchanger. Traditionally manufactured heat exchangers (milled, brazed, etc) can be augmented by using 3D printing to add copper in specific region. After copper is added using UAM, the entire part continues through the manufacturing line with no special treatment. Subsequent processing using stamping, forming, and machining is not affected by the dissimilar metal combination.



One high volume application is the printing of foils to busbars in high current electrical systems. UAM allows the joining of copper/copper, aluminum/aluminum, and copper/aluminum. Linear welds allow foils to be rapidly welded to underlying bar products on a continuous basis. With specialty automation, production rates in excess of two million parts per year have been achieved. Weld widths of over 1” allow UAM to weld large surface areas increasing the reliability and conductivity of thin electrical contacts. The low-temperature bond achieves high quality without creating high temperatures that might affect adjacent electronics. Again printed components feed directly into downstream manufacturing processes.



Electrification: A high-power ultrasonic seam welder creates a Cu busbar with thin foil attachments (Al and Cu).

Conclusion

Design and manufacturing engineers need to understand the strengths and weaknesses of all their manufacturing techniques, including 3D printing.   By analyzing parts with an eye toward the engineering requirements, teams can use the best that every technology has to offer. Much like we use to use a lathe, a mill, and a drill press, in the future we can use a casting, a mill, and a 3D printer to manufacture new and exciting products.

While 3D printing of metals allows a new world of design possibilities, leveraging these awesome capabilities does not require fully printing every part. By combining the old with the new, hybrid solutions can be brought to market at a price point in line with traditional manufacturing. For more information visit www.fabrisonic.com or call (614) 688-5197