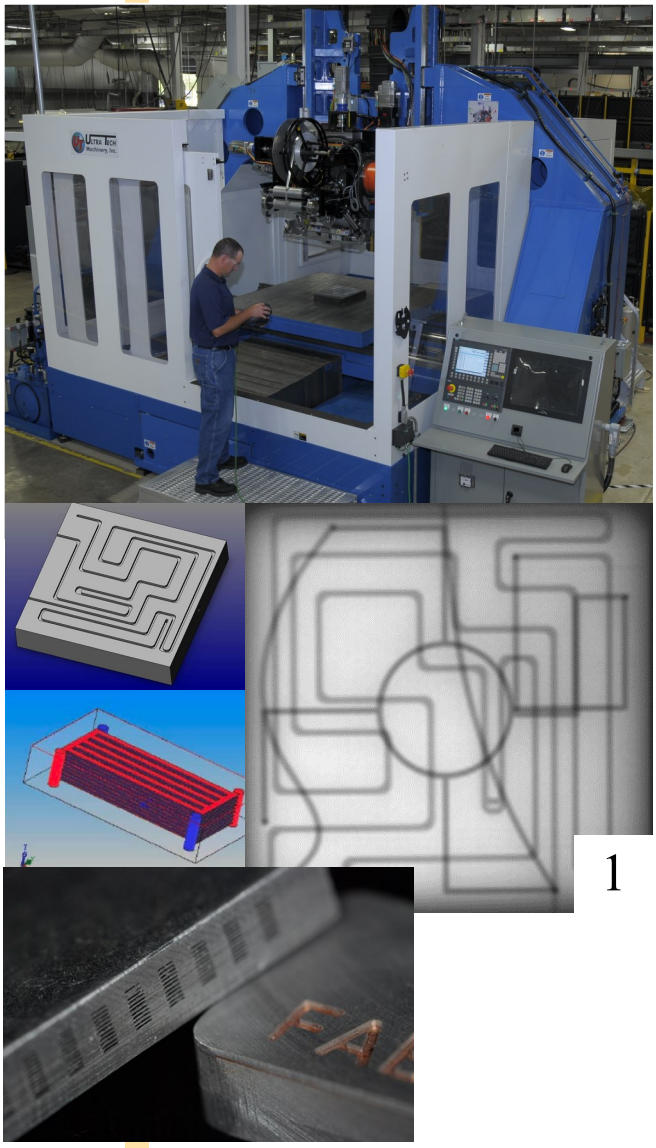
FABRISONIC

Multi-Metal 3D Printing of Custom Heat Exchangers

CHALLENGES OF TRADITIONAL MACHINING

Energy densities in devices are increasing in all industries including power generation, high power electronics, manufacturing, and automotive. Increasingly there is a need for very high efficiency thermal management devices that can pull heat out of a small area at higher and higher rates. Historically these specialty heat exchangers have been made through traditional CNC machining. This limits the shape of the internal passageway to planar arrays of cross drilled holes. More complicated three-dimensional devices can be made with a series of interlocking machined components using brazing or diffusion bonding. However, these are expensive and time consuming to produce and assemble.



1

TECHNOLOGY

UAM is a disruptive technology that will change the way you think about making parts. It is a solid state 3D Printing process for metals that uses sound waves to merge layers of metal foil. The process produces true metallurgical bonds with full density and works with a variety of metals, including aluminum, copper, stainless steel, and titanium. By combining additive and subtractive process capabilities, UAM can create deep slots, hollow, latticed, honeycombed internal structures, and other complex geometries - geometries impossible to replicate with conventional subtractive manufacturing processes. Additionally the solid state nature of the UAM bond allows for welding of dissimilar metals. This enables dissimilar metal cladding, production of custom metal matrix composites, and the ability to embed objects or sensors in a metal substrate.

THERMAL MANAGEMENT WITH 3D PRINTING

Metal 3D Printing technologies have the promise of creating parts with complex internal geometries not possible with conventional manufacturing approaches. However, this goal has not been realized in metal 3D Printing due to inability to build parts composed of metals with high thermal conductivity by most rapid prototyping methods. Copper and aluminum, the industrials metal with the highest thermal conductivity, have been difficult for powder bed 3D printers due to high reflectivity.

The solid state nature of Fabrisonic's welding process, allows UAM to readily bond aluminums and coppers. Additionally all SonicLayer machines are based off of traditional 3-Axis CNC mills. Thus, the welding process can be stopped at any point and three dimensional channels can be machined. Subsequently the additive process continues to build up metal sealing in complex 3D flow paths. The x-ray image at right (1) illustrates the ability for complex internal flow paths which are impossible with traditional manufacturing methods.

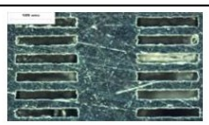
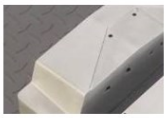
LEARN MORE

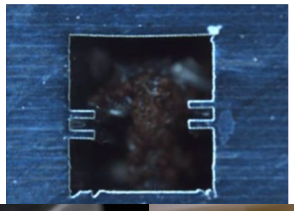
To find out more about the capabilities of Fabrisonic's UAM technology and machinery, contact Mark Norfolk at 614.688.5223 or mnorfolk@fabrisonic.com.

FABRISONIC

CHANNEL SCALE

UAM has been used to produce thermal management devices with a wide range of channels sizes that range from the micro scale (10-100um) to macro scale (2cm+). The SonicLayer 4000L was specifically designed to create internal structures at the Meso-scale (.1-1mm). The machine is equipped with a laser machining head, in addition to the CNC mill, for quickly scribing small scale features in a build. At the mm-scale, traditional machining is used to create fluid paths with end mills as small as .3mm. Larger channels are easily created with traditional end mills. Using a combination of these techniques, complicated structures with micro channel cooling loops can be built with integral macro-scale headers.

	SIZE	PHOTO
Micro scale	10-100μm	
Meso-scale	.1mm-1mm	
Mm-scale	1mm-5mm	
Cm-scale	5mm-2cm	
Macro-scale	2cm +	



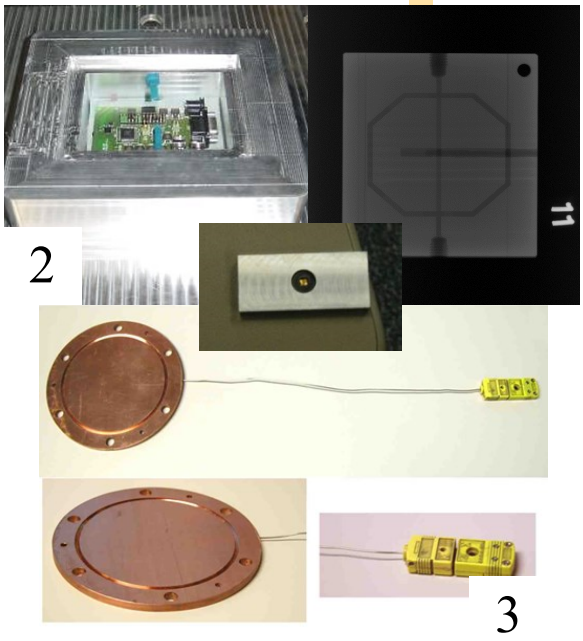
CHANNEL SHAPE

The combination of additive and subtractive processes also enable unique flow path cross sections. If needed, machining can be used at every layer to tailor the shape of the cross section:

- The blue example at left, illustrates the ability to machine in integral fin elements to increase surface area.
- Using a ball mill, traditional round channels can be produced.
- Thin reed-like channels can be produced with .3mm separation between flow paths
- Solid tubing of high performance metal can be embedded into copper or aluminum to meet performance needs (corrosion, pressure, wear) while still having a matrix predominately made of thermally conductive alloys.

EMBEDDED ELEMENTS

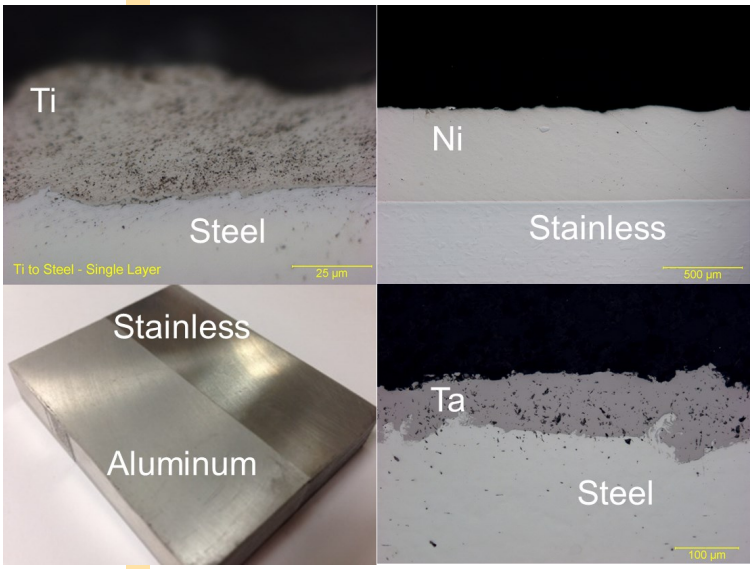
The solid state nature of the UAM bond means that the material in the build never experiences high temperature. In fact, in most aluminum alloys the temperature never exceeds 250 °F. This means that electronics (2) and other objects can be inserted during the build with out any damage to the components. For instance, Fabrisonic has produced heat exchangers with thermocouples embedded in the solid metal where they are safe from corrosion and wear (3). Additionally, Fabrisonic has embedded pressure sensors, monitoring circuits, and even spring/ball combinations for integral check valves.



SURFACE FINISH

Since SonicLayer machines are based off of commercial 3-axis CNC mills, UAM can achieve the same surface finish and repeatabilty as traditional CNC machining. On many parts, Fabrisonic has held tolerances of +/- .001".

FABRISONIC



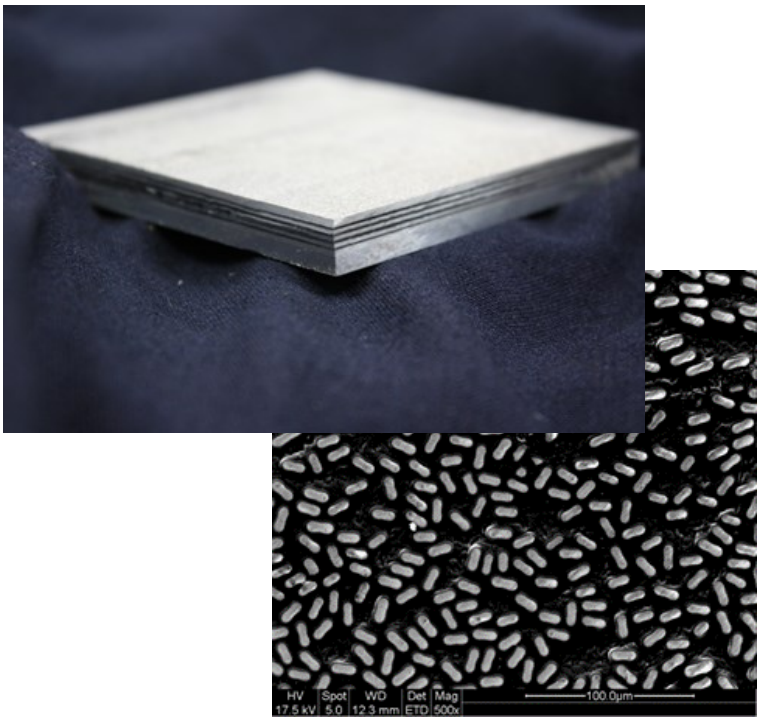
DISSIMILAR METALS / CLADDING

The solid-state nature of the ultrasonic bonding process used in UAM permits joining of dissimilar metals without the formation of brittle intermetallics as seen in fusion processes. A wide range of material combinations have been successfully bonded using the technology. Al/Cu, Al/Fe and Al/Ti are routinely joined. Fabrisonic has also worked with exotic combinations such as Ta/Fe, Ag/Au and Ni/Stainless. This capability allows for the creation of unique high performance heat exchangers. For example, it is possible to make a structure that has copper surfaces adjacent to a heat source, but is made primarily of aluminum for weight savings. At the same time, the same product can have steel inserts for mounting while integrating multiple temperature probes in the solid metal for monitoring. UAM has also been used for simple cladding operations for corrosive environments. Since UAM does not melt the metal, thin layers of corrosion resistant metal (Ni, Stainless, Ta) can be welded to a more affordable structural material resulting in a cost effective but corrosion resistant vessel.

PRESSURE

In aerospace aluminums, Fabrisonic has built thermal management devices with burst pressures in excess of 3000PSI. Leak checks have been performed using Helium leak test equipment.

For higher pressure applications, Fabrisonic has recently been doing development work on printing metal matrix composites. The pictures at right illustrate an aluminum matrix that is strengthened with continuous ceramic fibers to create a very high strength metal matrix composite that is also light weight.



FABRISONIC

SonicLayer® 4000 Ultrasonic Additive Manufacturing Machine

SonicLayer® 4000 Fully Automated System

The SonicLayer® 4000 utilizes the patented 9kW UAM welding head to additively manufacturer solid metal parts. The weld head is fed with 1" wide metal foils through an automated feed system that places foils in 3D space to create the desired geometry. The system is also implemented with integrated CNC machining capability. This includes a standard 50-taper 3-axis vertical machining center with a Siemens 840Dsl controller used for achieving final dimensions at high accuracy. Full machine guarding is included (with a closed top). A water soluble coolant system comes standard with the machine and includes removable screen for chip removal . A secondary alcohol coolant system is also included for use during builds to keep the metal surfaces clean.

SonicCAM® Drive File Generator

The SonicLayer® 4000 is controlled 100% through the use of industry standard G-code programming. To enhance productivity, every machine comes with a copy of Fabrisonic's custom G-code CAM software. This software allows true CAD to part automation. The operator imports native CAD geometry into the SonicCAM and the software generates the tool paths for both welding and machining. The G-code is automatically generated and is then moved to the machine for execution.

Footprint:
- X direction: 12 feet
- Y direction: 12 feet
- Height: 113 in.

Axis Working Travel:
- Powered X Axis: ~40 in.
- Powered Y Axis: 24 in.
- Powered Z Axis: 24 in.

Linear Accuracy:
- Positioning: ±0.0002 in.
- Repeatability: 0.0001 in.

Table Size:
- Length × Width: 44 × 24 in.

Welding Machine:
- US Power: 9 kW
- Welding force: 2500 lb
- Welding speed (max): 200 ipm
- Steel welding sonotrode

Machining Spindle:
- CAT-50 Taper, 25 hp, 8,000 rpm

LEARN MORE

To find out more about the capabilities of Fabrisonic's UAM technology and machinery, contact Mark Norfolk at 614.688.5223 or mnorfolk@fabrisonic.com.