



Hybrid Laser Arc Welding — Has Its Time Finally Arrived?

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DURING THIS YEAR'S FABTECH SHOW, LINCOLN ELECTRIC AND IPG PHOTONICS ANNOUNCED A STRATEGIC PARTNERSHIP FOR THE DEVELOPMENT OF HLAW WELDING SYSTEMS. THE PROMOTION OF HLAW BY ONE OF THE WORLD'S LARGEST ARC WELDING COMPANIES SUGGESTS A POSITIVE SHIFT IN HOW INDUSTRIES VIEW THE PROCESS.

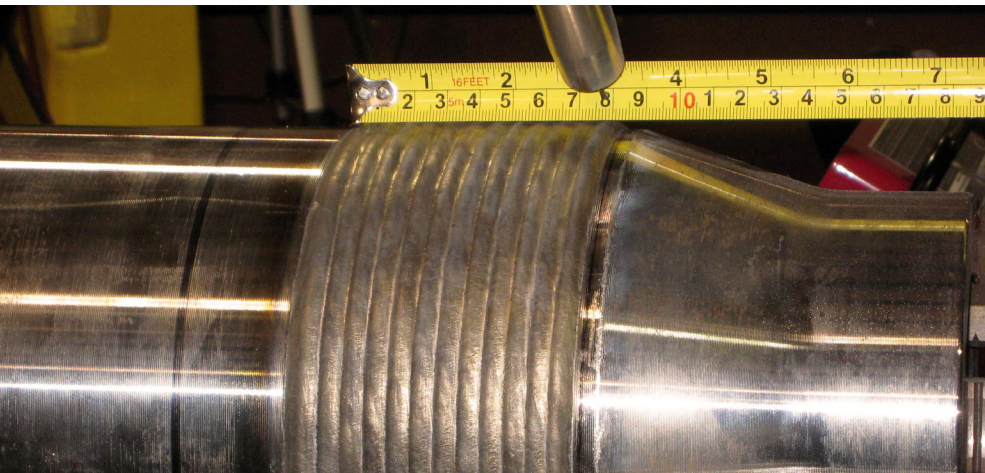


Figure 1 (above): Example of hybrid laser cladding (laser with hot wire) process. Courtesy: Alabama Laser.

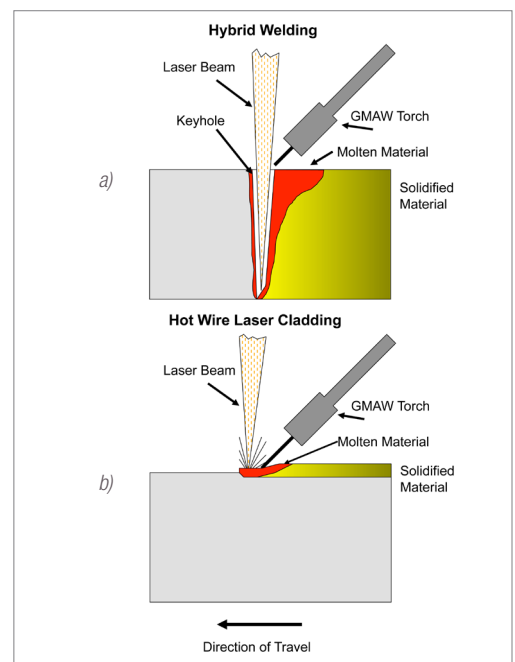
Figure 2 (right): Two presentations of laser "hybrid" processing a) laser with GMAW in a "laser leading" configuration and b) diagram of the HLAW cladding process which uses a GMAW power supply to heat the wire as it enters the laser produced clad pool.

While HLAW has been investigated for a number of years, there were many reasons for its limited utilization. "I felt that a big disadvantage of the work that we were doing was that we were using a big clunky old laser that didn't focus all that tightly," says Vivian Merchant of his research efforts in the early 1990's at the Canadian Defence Research Establishment. He added that their interest for using HLAW was to achieve higher production rates for military applications such as HY-80 material for submarine fabrication as well as for the welding of high strength materials for cross country pipelines. In addition, Vivian says that they recognized that, "Without the laser, it will take 10 passes to weld this one-inch-thick steel. With the laser, we can narrow the groove and weld it with only two passes!"

Even with "clunky" lasers, some applications did transition from the laboratory to the factory floor. Efforts in Germany with HLAW continued to be very active in the 1990's. Researchers at The Welding and Joining Institute (ISF) of RWTH Aachen University worked with companies like Meyer Werft Shipbuilding of Papenburg, Germany to develop and assist in the implementation of the technology.

History of HLAW

Having traditional welding companies embrace a laser based technology has not occurred overnight. The combination of a laser with an arc process to address some of the short comings of the technology is almost as old as laser processing itself. Bill Steen published a paper titled "Arc Augmented Laser Processing of Materials" in the *Journal of Applied Physics* as early as 1981. In most cases, the combination of the laser with an arc process was to address the fit up, chemistry, or power limitation of the laser. And while most hybrid processing has been centered on Gas Metal Arc Welding (GMAW) there have been others who have investigated combining lasers with Gas Tungsten Arc Welding (GTAW) (Diebold and Albright, *Welding Journal*, 1984) and plasma (Walduck and Biffin, *Welding Research Aboard*, 1995).



The result was the opening of a new panel line at Meyer Werft in 2000 for the welding of deck and bulkhead panels with stiffeners using HLAW with CO₂ lasers. Not only did this represent a major acceptance of the technology, but required the development and acceptance of new specifications for shipbuilding by organizations such as DNV and Lloyds.

A major change

The late 1990's and early 2000's saw a major change in laser technologies that would greatly impact the HLAW process. Advances in diode technology, greater power, better beam quality, and lower cost allowed these lasers to be used alone or as pumping sources for advanced laser systems. No more did you have to choose CO₂ lasers for high power (but hard optics) or Nd:YAG for the flexibility of fiber delivery (but limitation of 4 kW). Diode lasers were being used to produce fiber and disk lasers which were not only fiber deliverable and equal to or higher power than CO₂ lasers but were easier to operate and maintain. "The recent appearance of the new high-brightness laser technologies has by far had the greatest impact", says Brian Victor of the Edison Welding Institute. He added, "These new lasers are much less intimidating for potential HLAW users. They're easier to operate and maintain, more robust than previous laser technologies, fiber-delivered for flexible manufacturing, capable of higher powers than possible with previous industrial fiber-delivered lasers, and all at a relatively low cost per kW."

Dr. Simon Olschok, Chief Engineer at The Welding and Joining Institute (ISF) of RWTH Aachen University, states that hybrid welding is used in "...ship building (in use), automotive (in use), vessel fabrication, pipe welding orbital up to 6 mm and pipe welding J-Lay up to 15 mm." He states that since efforts at Meyer Werft, he is aware of a number of companies that have or are considering hybrid welding. These efforts are being fueled by "new laser sources which allow robot usages and the many institutes around the world which now do hybrid welding (that can assist in development and implementation)."

While hybrid processing has occurred in European shipyards since 2000, efforts have also been ongoing in the United States as well. Applied Thermal Sciences (ATS) has worked with the US Navy to qualify the welding of structural HSLA 65 components as well as lightweight sandwich panels (know as LASCOR) out of duplex stainless steel. The LASCOR panels

are targeted for applications on the new DDG 1000 ship. To echo Dr. Olschok's earlier comments, ATS's original efforts in hybrid welding were with high power CO₂ while recent efforts have been with high power fiber and disk lasers.

Hybrid welding is not only for shipyard applications. In Sweden the first industrial application of HLAW was initiated in spring 2005, at Duroc Rail AB in Luleå. This application consisted of using a 20 kW CO₂ laser at Duroc combined with a GMAW source for welding together large, thick high strength steel sheets for rail car applications. This application was developed from the Nordic Network on Hybrid Welding (NORHYB) that had the goal of disseminating this technology to the Nordic industries.

"Non-arc" hybrid processes

While HLAW implies an "arc", there are many other "hybrid" processes that are being developed and implemented that combine laser with other "electrical" processes. In these other cases the laser is being used as a precision heating source and/or the electrical process is supplying an inexpensive heat source to the application.

An example of one of these "non-arc" hybrid processes is hybrid laser brazing. This process uses resistance heating between the part and the tip of the wire feeding system to increase the temperature of the wire. The laser then is used to take the brazing alloy, usually a bronze alloy, to a melting temperature while at the same time

heating the substrate to a high enough temperature to allow for wetting without flux. This can occur at very high speeds (> 5 meters/minute) and result in joint quality that can be painted over. Car companies such as Volkswagen, Mercedes Benz, and Chrysler have implemented this process for various uses, including truck lids and roof ditch welds.

Another "borderline" HLAW process is laser cladding. This can be accomplished like laser brazing without an arc and simply using resistance heating in conjunction with laser. Or the laser can be combined with GMAW process for the deposition of a consumable wire. Typically these processes are used to repair a worn or damaged surface and match the chemistry of the substrate or the material being deposited to tailor the surface of the part for improved corrosion and/or wear resistance. Wayne Penn of Alabama Laser reported on their efforts with resistance heated wire-laser "hybrid" process at last years Laser Additive Manufacturing (LAM 2010). Alabama Laser uses the process to clad large surfaces with corrosion and wear resistant material with less dilution and better surface conditions than can be achieved by conventional GMAW processes. Also at LAM 2010, Joel DeKock of Preco reported on their "true" hybrid welding process for depositing wear resistant materials at very high rates with very low dilution.

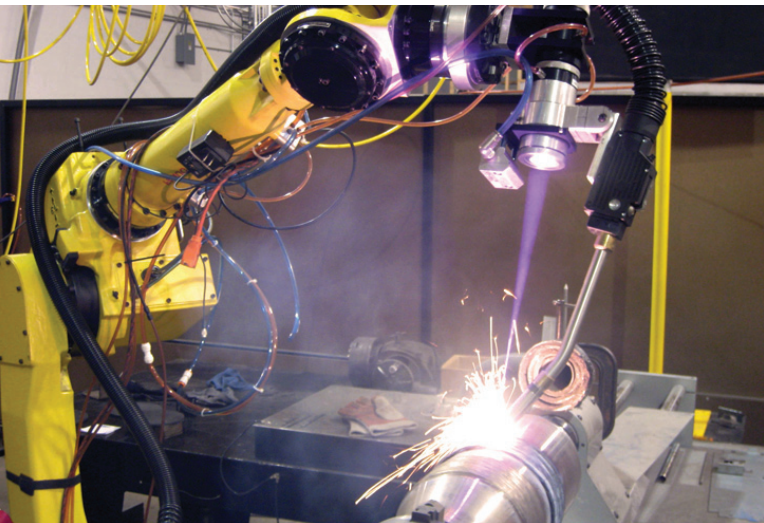


Figure 3 (above): Image of HLAW-deposited clad material. Courtesy: Alabama Laser.



For most “hybrid” applications, the GMAW assists the laser process by:

- Adding filler material at an elevated temperature with little or no additional energy from the laser;
- Permitting welds to be made in joints with greater fit-up issues and gaps than can be normally welded by autogenous laser welding; and
- Sometimes altering the chemistry of the weld metal.

However, in some cases, the laser assists the GMAW process. As reported at FABTECH 2005, under the AWS Technical Sessions, Brandon Shinn reported on how combining a laser with pulsed GMAW welding of titanium resulted in a higher quality weld. Typically, welding titanium is difficult by the GMAW process because the arc cathode is not “stable” and drifts around on the weld bead. The result is an irregular weld bead and spatter. However Shinn found that focusing as little as 200 W of laser power on the weld puddle “locked” the cathode location, resulting in a very regular weld bead. This “laser assisted GMAW” hybrid process could achieve very high welding speeds and small weld beads for use in the welding of thin titanium structures like those used in aerospace applications.

These increases in applications are also driving examination of what is an acceptable hybrid weld. As stated earlier, DNV and Lloyds have already developed standards for hybrid welding for shipbuilding applications. But with the recent activities for HLAW in other industries, there have been additional interest in and need for the development of other standards and specifications by other organizations. The American Society of Mechanical Engineers (ASME) and the American Welding Society (AWS), both of which have had laser specifications for years, are active in the development of standards and recommended practices for hybrid processing. Both organizations are reacting to requests for specifications by companies who are using those specifications to develop their Procedure Qualification Records (PQR's) and their Welding Procedure Specifications (WPS). These standards will address what parameters need to be documented and how much variation or change will be allowed before a process must be partially or fully re-qualified.

Obstacles to greater utilization

While there seems to be an increase in the implementation of hybrid processes, there remain obstacles to greater utilization. When asked what challenges they see, Stan Ream and Brian Victor of EWI responded, “The main limitation is equipment cost. Most of the key HLAW markets are going to be in industries that currently use conventional arc welding. Buying a laser and the associated equipment will be a significant cost increase. To make a large capital investment of a HLAW system, the productivity and other ROI benefits of the HLAW process have to be well understood upfront.” While cost is a factor, others believe there are physical limitations to the process. Dr. Olschok said he feels that as the weld thickness increases, a point will be reached where the ability to produce a “free formed root bead” will be reached. He believes today this limit is between 12 mm and 15 mm, depending on the laser used. Physical limitations were also voiced by the representatives of EWI who commented that while the HLAW process does allow for greater fit-up variation than normally possible for autogenous laser welding for thinner material, as the thickness increases, the limitation of the HLAW process will require industries to improve their fit-up tolerances over what is presently achieved for the arc process. The cost for this improvement will have to be factored against the other benefits of the HLAW process.

Further R&D

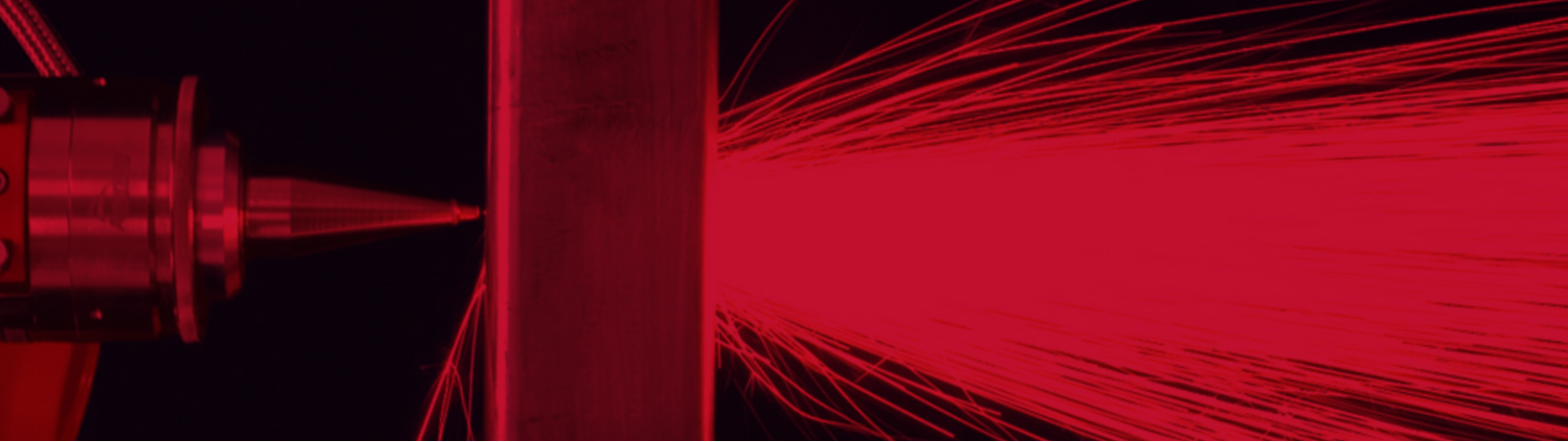
While implementation of the HLAW process is occurring, further research and development is being accomplished for other applications. While it may not be practical to achieve 25 mm thick welds in a single pass with an HLAW process today, it may be possible to achieve this with multiple pass welds. Researchers are investigating this approach for pipeline and other thick section applications using HLAW for the root pass and with the subsequent pass being HLAW or conventional arc welding. There is also work being accomplished in the use of multiple wires for greater fill or cladding applications as well as efforts to have the laser and the GMAW power suppliers working together to achieve even greater performance and control.

As has been demonstrated, the “hybrid age” may have been slow in coming but has accelerated in the last few years. This acceleration has been driven by improvements in lasers, especially high brightness lasers. These new lasers have allowed for easier integration into systems and lower ownership cost which have positively impacted the ROI of the process. In addition, as new standards become available, there is a potential for the technology to be accepted and implemented. Further implementation will be driven by additional advances in the lasers and processes.

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