Hybrid Laser Welding : Process Advantages and Application for Shipbuilding

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Background:

Hybrid Laser Arc Welding (HLAW) combines the deep weld penetration and low heat input associated with laser welding with the power efficiency and superior gap tolerance of GMAW to create a new welding alternative. The deep penetration and fast weld speeds of laser welding reduce heat infusion into the part and reduce the associated distortion that causes plates to buckle and warp, making fit-up unpredictable and often costly to repair. This deep penetration, however, can limit laser welding's ability to produce acceptable weld fusion in weldments with wide gaps between parts.

Adding GMAW in tandem with the laser, with the addition of a relatively modest amount of filler metal, creates a wider weld bead capable of bridging much larger weld gaps, up to four times as wide as conventional laser processes can handle. Adding GMAW to the welding mix also enhances a finished part's metallurgical stability, and with GMAW's slower cooling rates, produces welds with greater strength and less brittleness. This is especially beneficial for higher alloyed steels sensitive to hot cracking. The hybrid process improves process efficiency and overall productivity, improves weld quality, lowers production costs and offers more versatility than conventional welding processes, setting new standards for productivity, cost efficiency and flexibility in heavy fabrication applications.

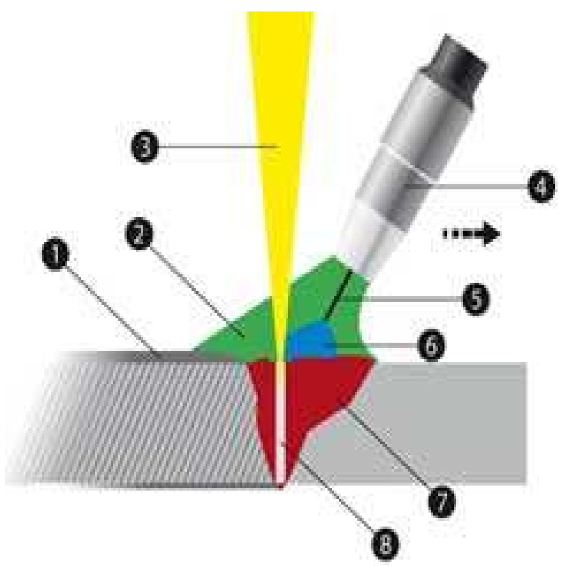

Fig 1 : Hybrid laser welding process
1 Newly formed weld bead
2 Inert shielding gas
3 Focused laser beam
4 GMAW torch
5 Wire electrode
6 Electric arc
7 Molten pool
8 Keyhole

Recent Advances

Latest innovation in this process is to combine the hybrid laser welding technology with the deep weld penetration and low heat input associated with laser welding with the excellent weld properties and superior gap tolerance of Gas Metal Arc Welding (GMAW). A radically new welding alternative, it produces extremely narrow and deep welds at very high travel speeds. In a single pass, such a process can often achieve what might require multiple weld passes using a conventional fusion welding process. Heat input to the part is reduced, as is the associated weld shrinkage and distortion that can make post-welding geometry unpredictable – and costly to repair.

Using GMAW in combination with a laser, the HLAW process solves laser-only welding's limitations, concerning its ability to produce acceptable welds in joints with less than perfect fit-up between parts. This enables a widened, more robust process envelope by a factor of three compared to a conventional laser-only process. GMAW also allows users to add filler metal to adjust the weld's metallurgical properties and create beads and fillets, while the slower cooling rate reduces hardness. These features are especially beneficial when joining high performance carbon and stainless steels.

Characteristics of Hybrid Laser welds

Almost a decade of research conducted on the Hybrid Laser Welding process have conclusively proven that hybrid welds can be at least as strong, tough and ductile as conventional welds in every way. In some ways hybrid welds can be superior to conventional welds. The very fine grain structures and smooth, uniform welds resulting from the low heat input make hybrid welds exceptionally good for high performance alloys. The very smooth, consistent Hybrid Laser Welding welds have been demonstrated to improve fatigue limits on fillet welds by a 300% over similarly sized conventional welds.

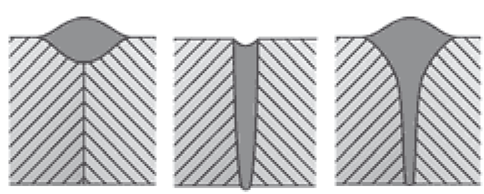

Fig 2 : Graphic illustrating differences between GMAW, Laser and Hybrid Laser Welding weld profiles

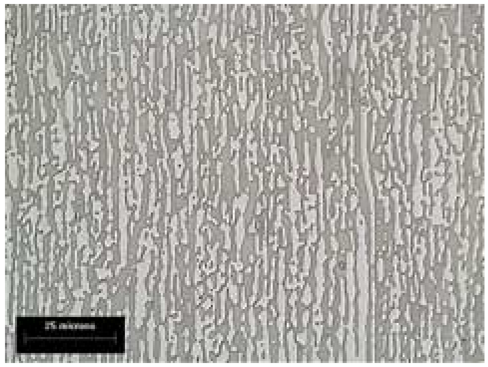

Fig 3: Duplex Stainless – HLAW weld microstructure

Fig 4 : Full-Pen Fillet

Process Benefits

Hybrid welding is not for everyone. It may mean adjusting cutting/machining operations and require changes to downstream operations to fully benefit from the substantial productivity, quality and cost-efficiency gains. Successful implementation assumes access to qualified engineering and technical staff, and introducing such a game-changing new process demands serious investment, not only in terms of resources, but in total commitment from senior management. For those with the right industrial and product profile, however, the potential gains are huge.

From rolling stock and containers, shipbuilding and the offshore industry to construction, pipeline production and the energy sector, this hybrid process will transform your bottom line. If your business is high-volume industrial fabrication, featuring moderate batch sizes and a low part mix, this process could be the answer.

Lower heat input and higher traverse speeds mean this unique fusion of welding technologies is especially suitable for joining high-performance carbon, low alloy and stainless steels to create stronger, stiffer, lighter products. Furthermore, the unique characteristics of the process slash consumables costs and downstream post-weld rework requirements.

Even better, this sophisticated technology is easy to operate. Controlled from a user-friendly PC interface, this flexible, fully-automated weld process requires no advanced operator training. This translates into lower labour costs, increased reliability and accelerated throughput. The result is greater process efficiency, higher overall productivity, enhanced weld quality – and higher margins.

Fig 5 : HLAW Welding in operation

Fig 6 : Parts welded with HLAW vs those conventionally welded

In this process. welding speeds are 3-5 times higher than GMAW and up to ten times higher than Submerged Arc Welding/SAW with heat input reduced by up to 80-90%. Operational savings can be expected of around 50% compared to GMAW and still greater compared with SAW. Most importantly, the unique benefits of deep penetration and low distortion present a whole new range of exciting product opportunities, based on the huge potential of the latest high-performance alloys and advanced lightweight structure designs.

HLAW in Shipbuilding

Hybrid laser welding has been in use for several years in a number of the most advanced European shipyards to build ship decks and bulkheads. Several systems in the US are currently producing components for the next generation of aircraft carriers and destroyers for the US Navy. Hybrid laser welding has allowed the industry to shift to high-strength alloys and lightweight designs without the distortion that normally results from conventional welding of these advanced structures. Some of the technology's most exciting contributions are found in new design capabilities, such as the metal sandwich panel, that were not practical until the advent of newer welding technologies.

Fig 7: New laser welding techniques have made steel sandwich panels a practical alternative to other advanced construction systems.

Sandwich panels can be simply defined as a three-layer structure that consists of two thin, outer skins of high-strength material separated by a low-density and low-weight core material. The core material separates the face sheets that provide most of the strength to the structure.

This creates a panel with excellent stiffness and weight characteristics. The core can assume a number of configurations. The most common is a corrugated structure similar to corrugated cardboard.

Until recently, the majority of sandwich panels have been designed with fiber-reinforced polymer composite or metallic skins glued to structural foam, wood or elastomeric cores. The development of all-metal sandwich structures had been inhibited by the limitations of conventional welding processes.

The first metallic sandwich panels were developed for shipbuilding in the mid 1980s but research was abandoned because no manufacturing system was available that had the capability to mass produce the panels cost effectively.

The new laser welding techniques, however, have finally made such structures practical and shipbuilders are now re-engaged in developing these structures for use on future ships.

Over the past 15 years, the European shipbuilding industry, in cooperation with various universities and research institutes, took an interest in the sandwich panel design and made tremendous advances in understanding the behavioral characteristics and advantages of laser-welded steel sandwich panels. Early panel studies focused on prototypes for ship decks but strong interest soon surfaced for a much wider range of applications, particularly in the transportation and commercial construction industries. A multi-industry consortium studied this technology. Their work revealed the following advantages of sandwich panel structures:

Up to 50 percent weight reduction compared to conventional steel construction methods

- 90 percent weight reduction compared to concrete construction.
- 2/3 reduction in structural space requirements.
- Significantly improved fire resistance with appropriate core filler materials.
- And, improved energy absorption and damage tolerance.

Several European manufacturers have adopted the use of steel sandwich panels to create lightweight decks and stairs in cruise ships, lightweight balconies, and even flooring for a multi-level sports arena.

Construction Applications

Due to their stiffness, steel sandwich panels can span longer distances than normal steel panels. The combination of decreased weight and increased span significantly reduces construction cost.

Consider, for example, a multi-story building made with sandwich panels as floor decking. With the floors now a fraction of the weight of traditional flooring, the vertical I-beams also can be lighter weight and the column footings and foundations can be smaller, adding to savings.

The floors have less depth, so when compared with a traditional building of a certain height, the sandwich panel building can hold more floors, producing more rentable space. The result is a building that is less expensive to build yet offers more income-producing potential.

Steel sandwich panels also are being considered in the manufacture of housing. The open areas in the central core of the panels are ideal for running cables and ventilation systems and can be filled with insulation. A residential or commercial structure built from sandwich panels would be fire resistant, wind resistant and termite-proof with improved heating and cooling properties. And, when the time comes to replace the structure, the building material can be recycled.

The result is a home or office that is safer, more economical and more eco-friendly than any current manufacturing style.

The strength-to-weight ratio makes sandwich panels an appealing option in bridge construction as well.

Steel sandwich panels have the potential to be highly competitive, in cost and weight, with conventional bridge deck systems currently on the market. This is currently being explored by the by U.S. bridge builders.

Analysis findings have predicted that a 7.25-in. deep sandwich panel with a self-weight of 48 lbs. per sq. ft. can support full traffic loads over a rather long 15-ft. panel span. The reduced weight and construction cost of such a panel deck allows bridge owners to begin considering the use of more expensive stainless steel materials to produce a low-maintenance bridge deck system with a very long service life.

Sandwich panels offer two key advantages in the transportation industry. First, the reduced weight saves on fuel costs, an important consideration in this age of increasing fuel prices.

Reduced vehicle weight also allows a corresponding increase in product volume and cargo weight which, for many commercial vehicles, increases the productivity and revenue per mile of travel.

Additionally, the sandwich panel structure provides a highly redundant load path. When damaged, the load tends to redistribute and absorb the energy of the crash, protecting passengers and cargo from impact.

Sandwich panels are being developed in Europe for use in the double hull structure of intercoastal tankers. In this instance, one panel design that was tested increased crash resistance by 73 percent, while the hull depth was reduced by 2/3. U.S sandwich panel projects under consideration include a crash-resistant rail car for transporting hazardous materials and portions of the superstructure of ships.

Any applications in which weight, strength and stiffness are important are potential applications for sandwich panels. These include railcars, truck trailers, ships and shipping containers.

Other Advantages

In addition to the favorable strength-weight ratio, sandwich panels created through automated hybrid laser welding feature exceptional straightness and flatness for superior cosmetic appeal.

The panels can be produced in such a way that they are completely smooth and unmarred on one surface. They also are produced by an entirely automated process, thereby reducing labor costs.

Sandwich panels can be made from almost any type of metal.

That allows a fabricator to make use of high strength aluminum, for example, that is not easily extruded. Fabricators can shift away from using plate materials and toward using sheet and coil materials that are less expensive and easier to handle with automated systems.

Sandwich panels allow manufacturers to achieve structural efficiencies comparable to aluminum at the cost of steel and have the potential to drastically change engineering and design in construction, bridge construction, transportation, shipbuilding and more.

Conclusions

New welding technologies are opening entirely new horizons in manufacturing and fabrication.

This new technology has the potential to reduce fabrication costs, improve fatigue and corrosion life, and reduce life-cycle costs, while improving the standard of manufacturing in so many fields.

Designers have just begun to explore their potential. New and even more exciting applications lie ahead. This technology has the potential to completely change the way companies approach the manufacturing of large structures.

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Acknowledgment

1. Management of ESAB India Limited for permission to present this paper