Laser Community

Four welds executed under 1013 mbars, 500 mbars, 100 mbars and 10 mbars: Laser beam welding with solid state lasers under low pressure shows striking results. © Foto | Institut für Füge- und Schweißtechnik der TU Braunschweig

PRESSURE DOWN

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Who would have thought that combining the costly vacuum technology of electron beam welding with the beam of a solid state laser could be so effective?

In conventional laser beam welding, the escaping metal vapor sometimes hits the molten layer at the capillary rear wall and causes weld spatter. Solid state lasers (SSLs) have a far greater tendency to generate spatter than CO_2 lasers in this process — and this tendency becomes more pronounced with increasing weld depth and feed rates.

As a general rule, SSLs are therefore the preferred option for thin sheet applications, while CO_2 lasers are considered to be the superior choice for sheet thicknesses greater than four millimeters. Welding applications in certain fields such as gear manufacturing, in which the weld depth is far in excess of 10 millimeters, are completely out of reach for solid state lasers.

Regardless, industry demand for SSLs continues to grow, largely in response to economic considerations, in particular the wish to boost energy efficiency and manufacturing flexibility.

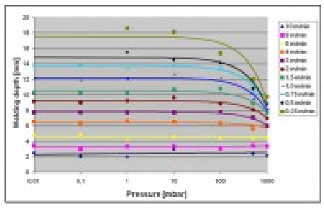
JOINING FORCES

In contrast, electron beam welding enables greater penetration depths and produces high-quality weld seams, but has the disadvantage of requiring a much lower working pressure of approximately 10^{-4}

There is more

ON THE RESULTS

Galerie 1: Correlation between weld depth, welding speed, focus position and pressure at different focus positions between +2 and -8 millimeters



Galerie 2: Humping effect at different focus positions between +2 and -8 millimeters (gray = humping occures; yellow to red = increasing spatter formation).

millibar. In many cases, however, this technique does not actually present a viable alternative.

Part sizes are restricted because of the required vacuum chamber, and cycle times are higher due to the use of a vacuum pump and the need to move components in and out of the chamber. Further disadvantages include the X-rays generated by the process and the fact that capital costs typically tend to be higher.

This prompts the question of whether it might be possible to merge the advantages of both electron beam welding and solid state laser welding by bringing together aspects of both processes in a combined method. As part of a joint research project with TRUMPF Laser- und Systemtechnik GmbH and pro-beam AG & Co. KgaA — one of the leading German manufacturers of electron beam technology, the Institute of Joining and Welding (ifs) at Technische Universität Braunschweig is currently attempting to develop a novel combined technology of this kind, investigate its feasibility, and make it commercially available.

PRESSURE: A PIVOTAL FACTOR

One of the key advantages is the way in which SSLs can be flexibly integrated into production systems. Multiple processing stations and/or vacuum chambers can have access to a single laser beam source and use it for what is, in many cases, a broad range of different welding applications.

One of the most significant results of reduced ambient pressure is that it changes the metal vapor plume that is typically seen in solid state laser welding. Even a slight drop in pressure leads to a visibly narrower plume and a substantial reduction in the amount of weld spatter.

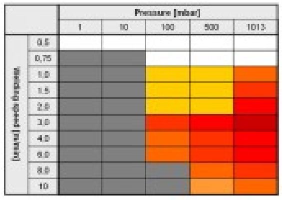
A further drop in pressure to 100 millibar shrinks the metal vapor plume still further, reducing it exclusively to the joining zone and producing only isolated spatter. The plume and spatter formation disappear entirely once a pressure of 10 millibar is reached. The reduced pressure also yields weld seams that, in terms of quality, are on a par with seams produced by electron beam welding.

STRIKING QUALITY

Using a laser power of six kilowatts to weld 10-millimeter-thick mild steel at a feed rate of two meters a minute, the researchers were able to produce remarkably high quality penetration welds without any irregularities. Under atmospheric pressure, this level of quality could not be achieved even with a CO_2 laser.

A reduction in ambient pressure also produces further characteristic features and properties regarding the quality of the weld seam. Using the same process parameters, a drop in pressure leads to an increase in weld depth and changes the shape of the seam cross section.

At a laser power of six kilowatts, the researchers succeeded in producing a 25-millimeter-deep penetration weld under a vacuum of 10 millibar. Welds of this depth would be inconceivable under atmospheric conditions, especially in regard to the power used to produce them.



ON THE RESEARCH PARTNERS

- Institute of Joining and Welding ifs (German only)
- Technische Universität Braunschweig
- TRUMPF Laser- und Systemtechnik GmbH
- pro-beam KGAA

ON THE WELDING PROCESS

- Electron beam welding
- Laser beam welding

ON THE AUTHOR

Prof. Klaus Dilger is the Director of the Institute of Joining and Welding (ifs) at the Technische Universität Braunschweig. One of his areas of specialization is beam welding processes. He is currently conducting research into laser welding under vacuum.

Gallery: A drop in pressure changes the shape of the seam cross section.

A NEW SHAPE OF SEAM

A micrograph of a weld seam produced under atmospheric pressure reveals a seam in the shape of a nail head with a relatively wide bead. Bead width decreases as the pressure drops, with melting principally occurring deeper in the material. At a pressure of 100 millibar, the weld seams have a high aspect ratio and parallel seam edges.

Reducing the pressure by another power of 10 causes a striking change in the weld shape. The weld depth remains virtually unchanged, but micrographs show the seam taking on a vase-like shape. The key characteristics of this vase shape are the inward curve at the center of the seam and a convex broadening in the root area. It almost appears as if the caustic of the laser beam is “frozen” in the micrograph.

Gallery: Penetration welding in the pressure range from 1030 to 10 millibar

NO BEAD DEPRESSION, NO CAVITY

The technique of laser beam welding at reduced pressure offers new potential for laser material processing. Particularly for thick metal sheets, it completely eliminates the problem of the weld seam collapsing during penetration welding. Despite a fourfold excess of energy, weld seams with a depth of 10 millimeters do not reveal any top bead depression or excess penetration bead — two problems that are inherently unavoidable in welding operations at atmospheric pressure due to the higher excess power.

The use of reduced pressure also successfully prevents the undercut typically seen in the penetration welding of sheets with a thickness of three millimeters. The specific features and characteristics of laser beam welding at reduced pressure demonstrate clear quality improvements in terms of spatter formation and weld shape.

WHAT'S NEXT?

As a result, this process represents an opportunity to achieve significant efficiency growth in efficiency in existing markets and opens up multiple new fields of application. For applications where high weld seam quality is particularly important, such as powertrain manufacturing in the auto industry, this new process could very well be a viable option.

In fact, researchers have still only scratched the surface of the potential offered by this new process: For example, it is conceivable that the process could have an equally positive effect on the formation of process pores in laser beam welding.

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