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Laser cutting and welding with one tool

Is one head better than two?

By Dr. Dirk Petring
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Today's laser sources have the power and beam quality needed to cut and join metal in an expeditious and repetitious manner. The market demands that type of flexible production, so those characteristics are basic requirements in modern laser devices. The market demands also have promoted the idea of multifunctional processing. That has led to the development of a combination head capable of laser cutting and welding 3-D metal work pieces.

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The "combi-head," developed at the Fraunhofer Institute for Laser Technology (ILT) in Aachen, Germany, can perform 3-D cutting and welding in an arbitrary sequence without retooling (**Figure 1**). Part handling, positioning, and clamping steps are eliminated with this approach. The result is reduced production time and costs, as well as improved manufacturing accuracy.

Figure 1
A combi-head developed at Fraunhofer ILT laser cuts and welds a sheet metal assembly.

Moreover, the combi-head opens up the door to fabricating complex metal components with a range of variants, which could not be produced cost-efficiently before.

While the concept of multifunctional laser processing is straightforward and the market seems to be ready for such a device, some technical problems had to be solved before it became reality.

The Difference Between Cutting and Welding

Cutting and welding functions are obviously very different.

In standard cutting heads, an intense cutting gas flow, traveling coaxially to the focused laser beam, has to provide for effective melt ejection out of the kerf. A high-pressure nozzle guides the laser beam in such a way that the beam focus and the gas jet meet the workpiece below the nozzle exit. A lens in the nozzle's laser entrance aperture provides a gastight sealing of the nozzle chamber and focuses the laser beam. In addition, the nozzle tip serves as a capacitive clearance sensor, ensuring a constant distance to the sheet surface of about 1 mm in cooperation with a closed-loop control of the machine axes.

In standard welding heads with solid-state and diode lasers, the lens optics also serve a focusing function. With CO2 lasers, however, mirror optics are used.

To create smooth shielding and process gas flow, as required for welding, off-axis nozzles mainly are applied a few millimeters from the laser impingement point. Additionally, a compressed-air crossjet is arranged between the optics and the process gas nozzle. The crossjet blows transversally to the laser axis to protect the optics from smoke or spatter emitted from the weld zone. Accordingly, in contrast to the gastight optics in standard cutting heads, a welding head requires an open flow section—which is gas dynamically decoupled from the processing zone—below the optics.

Based on this traditional approach to laser technology, a standard laser cutting head cannot be used for welding, and a laser welding head cannot meet the cutting speeds and quality demanded in most industrial applications. In some laser machine designs, an exchange of heads is possible if the user wants to change between cutting and welding operations. Some laser engineers deal with the challenge by installing two heads, a cutting and a welding head, simultaneously in one machine. But that leads to more complexity, because in addition to the two heads having to be mounted together, a beam switch has to be incorporated between the beam delivery system and the heads or between the laser source and two separate beam delivery paths (tubes or fibers).

One Head for Two Processes

The one-head approach helps to simplify the complexity of the dual-head approach.

The different requirements of cutting and welding heads now have been combined in a modified version of the Autonomous Nozzle, a design developed at Fraunhofer ILT more than 10 years ago. The nozzle design has proven itself in industrial applications with high-power mirror cutting heads up to 12 kW. Cutting results produced by the new combi-head with Autonomous Nozzle and mirror optics using a Rofin DC040 4-kW CO2 slab laser with a beam quality of K = 0.9 are shown in **Figure 2**.

Figure 2
A 4-kW CO2 slab laser and the combi-head with mirror optics cut mild and stainless steel as well as aluminum.

The focused laser beam is transmitted through the Autonomous Nozzle before meeting the workpiece together with the gas jet. By shifting the laser entrance aperture in the vicinity of the nozzle exit and optimizing the transition from an annular gas channel to the cylindrical nozzle exit, a patented flow design is created. The flow design ensures that a minimum amount of gas leaks out through the open entrance aperture above the nozzle exits, where the gas jet is discharged, and provides for a small upward leakage that is needed to avoid suction of air through the entrance aperture by the downward process gas flow. With these design developments, the nozzle can produce a coaxial process gas flow in a wide pressure range, independent from the focusing optics and without a sealing window at the laser entrance. Being "autonomous," the nozzle easily permits the integration of a crossjet between itself and the focusing optics.

This is necessary because the smooth gas jet used during welding cannot protect the optics from smoke and spatter.

Consequently, a crossjet with compressed-air supply, an alternating check valve for cutting and welding gas, and an appropriate numerical control program to change process parameters enable the cutting head to turn into a welding head.

But it's the Autonomous Nozzle, with its rotationally symmetrical, slim design and an integrated capacitive clearance sensor, that is the key component of the universal processing head for 3-D cutting and welding.

The combi-head, as it is shown in **Figure 3**, can be equipped with lens or mirror optics and is suited for solid-state lasers as well as for CO2 lasers.

Figure 3
A six-axis robot holds a combi-head equipped with fiber-coupled lens optics for solid-state lasers.

Application Results

The increased flexibility gained by combining the processes in one head really becomes evident when the head is used in combination with robots and fiber-coupled, solid-state lasers. In one 3-D application, the upper and lower shells of a car roof frame fixed in a single clamping setup were welded together, had sections cut out, and had clips welded to them in a rapid sequence of processes. This was done with a Rofin DY044 4-kW, diode-pumped Nd:YAG laser and a six-axis Kuka KR30 HA robot.

CO2 lasers also have proved to be suitable for cutting and welding applications with the combi-head. Lasers as powerful as 12 kW already have been used successfully in the laboratory on sheet metal as thick as 10 mm. Despite those successes, Fraunhofer ILT recommends that the combi-head be used in industrial applications with a maximum sheet thickness of 6 mm and a beam power of 8 kW.

The combi-head particularly shows advantages for three product groups:

- Complex component assemblies requiring multiple quick changes between welding and cutting operations
- Products with a wide range of variants, such as customized fabrications, optional cutouts, and weld-ons
- Components for which exact positioning and orientation between cut contours and weld joints are needed or for which precisely cut apertures or edges are required on an already welded product.

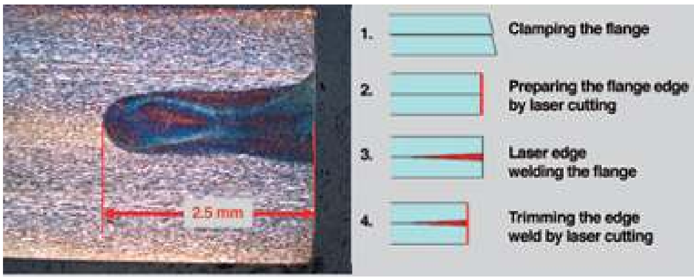

Figure 4
This edge weld on 1.5-mm-thick stainless steel sheet was prepared, welded, and trimmed with a 5-kW fiber laser operated at 3 kW for cutting and at 2 kW for welding. The combi-head is equipped with lens optics and a focal length of f = 300 mm.

The last of these three product groups can be illustrated with a look at welding flanges for frames, housings, or structural components. The flanges are first prepared by laser beam cutting (perhaps being tack welded before to improve the stability of the setup); then laser welded using overlap or edge joints; and precisely trimmed along the weld joint, again by laser cutting, to provide a highly accurate component with, if required, minimum flange width and excellent corrosion resistance.

A corresponding cross section of an overlap flange, cut and edge-welded with a IPG Photonics YLR-5000 5-kW fiber laser (with a fiber diameter 100 µm) is presented in **Figure 4**. The constant tool-center point (TCP) of the combi-head permits the accurate relative position of the different passes to be performed. A basic requirement for a good result is an appropriate clamping technique.

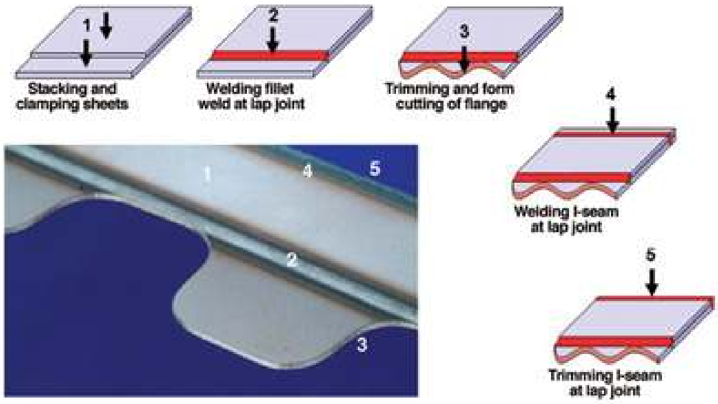

Figure 5
In this example of a patchwork design, one combination head cuts and welds the workpiece.

Another example is the patchwork design in **Figure 5**. The integrated cutting and welding process chain opens up the cost-efficient production of new designs.

Such an approach to laser cutting and welding is suitable for today's manufacturing environments that call for a combination of short production runs and high productivity. The combi-head is flexible as well in that it can work with lens or mirror optics and different laser types.

Taking into account the combi-head's technical features and capabilities, Fraunhofer ILT believes a fabricating operation can reduce its operating costs by a factor of two or more when applying this dual-use technology.

Dr. Dirk Petring is head of the Fraunhofer Institute for Laser Technology's Department of Cutting and Joining, Steinbachstrasse 15, D-52074, Aachen, Germany, +49-0-241-8906-0, fax +49-0-241-8906-121, ***dirk.petring@ilt.fraunhofer.de****.*

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