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MULTILAYER WELDING IN STEEL CONSTRUCTION WITH HIGH POWER DIODE LASER

THE TASK

In steel construction conventional welding processes such as submerged arc welding or metal inert gas welding form the backbone of technologies to fabricate thick-walled welded constructions. Opening angles of more than 40 degrees are often required to provide access for the welding tools so that they can deeply penetrate into the welding joint. It is typical in steel construction that the weld joint is prepared by plasma or flame cutting. The cuts provide a very large V-shaped joint cross section, which is problematic with respect to the increasing component distortion with thicker sheet thicknesses.

Laser based processes are currently unusual in steel construction. The classic seam preparation techniques are not suitable for laser welding and mechanical preprocessing of the joint would be too expensive. Modern steel construction requires efficient welding processes that can handle large dimensional tolerances of the parts and do not require expensive post-processing. Fraunhofer IWS engineers developed a laser based process to weld thick sheets for steel construction so that the value added potential in this field remains attractive in Germany.

OUR SOLUTION

Fraunhofer IWS researchers developed a laser based multilayer narrow-gap welding process (MPNG) to offer a new approach for the fabrication of welded constructions with thick metal sheets but also for repair tasks. This process removes the classic limitations of laser beam welding of thick sheets.

An approach was already demonstrated for welding thick aluminum sheets. It had to be slightly modified to also work for steel constructions. Instead of a fiber laser, a 10 kW diode laser is used. Its beam quality in combination with the selected optical components yielded a spot diameter on the workpiece of about 3 mm. The component tolerances are about 2 mm and therefore the laser spot easily covers the tolerances.

The minimum opening angle for the joint depends on the laser beam caustic and can be reduced to less than 15 degrees without melting the flanks in the upper areas of the studied 120 mm double-bevel groove weld. The beam is moved statically through the joint to fill the gap with either one, two or three tracks per layer (Fig. 3). A 1.6 mm diameter wire is dragged along the process zone to provide the filler material.

The melt pool sizes remain small, similar to those in classic welding. The advantage of the laser beam welding is the lower and locally limited energy deposition into the workpiece, which reduces the distortions also for thick-sheet applications. The high power density in the focus of the laser beam simultaneously melts the workpiece edges as well as the filler material.

Principle of the laser multilayer narrow-gap welding process (MPNG)

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4a

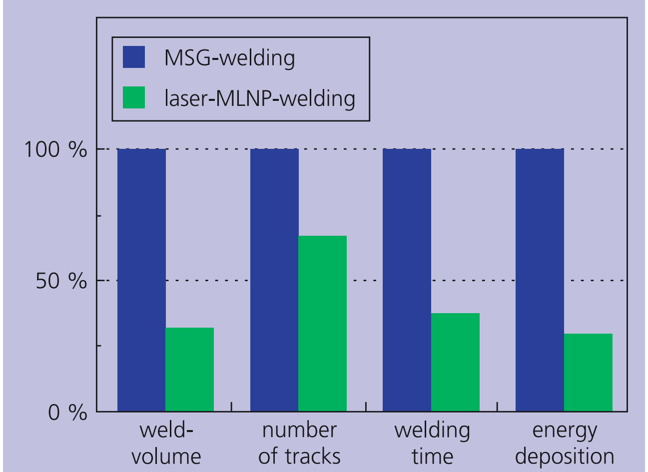
4b

RESULTS

Weld joints were prepared with an opening angle of 12 ° for parts that are similar to actual workpieces. The described optical components were used to weld 800 mm long and 600 mm deep weld seams (Fig. 1, 2, 4). The edges were prepared with plasma cutting methods that are commonly used in the steel construction industry. The special feature is the extremely small opening angle. By doubly welding the single-bevel groove weld it is possible to safely join sheets as thick as 120 mm.

Optimized welding parameters guarantee the reproducible fabrication of homogeneous welds free of cracks and bonding flaws. The laser welded seam has a low pore density similar to that of the conventional weld seam (Fig. 4a and b). It is therefore classified within the best quality level group (B) for imperfections according to DIN EN ISO 13919-1.

Double-bevel groove weld of 120 mm thickness



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The weld seam volume with the laser multilayer narrow-gap welding process is reduced by 32 percent compared to metal inert gas welding (Fig. 5). This reduces the number of individual tracks that have to be welded. For a 120 mm double-bevel groove weld that means the number is reduced from 105 to 70 tracks, which also reduces the overall process time. The process also achieves melt rates of about 5 kg h^{-1}, which is very high for laser applications. An advantage is that the small cross section of the weld seam also reduces distortion. Contributing factors are also the small opening angle as well as the drastically reduced energy deposition per welded layer.

The experiments confirm the high expectations for the laser multilayer narrow-gap welding process with respect to its efficiency, which is an important decision-making criterion in steel construction. The use of diode lasers also reduces the necessary investment as the costs per kilowatt power have been significantly declining over the past decade.

1,2 Laser multilayer narrow-gap welding of a 60 mm thick single-bevel groove with an opening angle of 12 degrees

4 Polished cross section of conventional (a) and laser welded (b) steel sheets

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