



Pulse Laser Welding Note [24]



Imagine - welding **WITHOUT**

pre- and post-weld heat treatment

microstructure changing

coarse grain formation

graphitisation

distortion and **WITHOUT**

... negative influence of mechanical-technological properties.

In fact, it's NOT just an imagination. **It's possible** by

Welding **WITH** pulsed Light and its Speed.

More inspiration at DSI Thailand Laser-Welding-Academy

Repair welding of spheroidal graphite cast iron: Problem-free without heat pre- and post-treatment

From the classical viewpoint of welding technology, the repair welding of ductile cast iron requires special expertise as well as a high expenditure of time and money. The reasons can be explained metallographically and cannot be avoided if the mechanical-technological properties of the base material are to be maintained. Recent tests have shown that this effort no longer needs to be expended through the use of pulsed laser beam welding, and that heat pre-treat-



Fig. 1 • Machine components made of cast iron, type GJS-400-15 (EN 1563), which should be repaired by local deposition welding. (Picture: Alpha Laser Southeast Asia Co., Ltd.)

ment and post-treatment can be dispensed with entirely – without any negative impact on the welding result. This was demonstrated and proved in a practical application.

Behind the headline, which sounds like an industrial fairy tale from “One Thousand and One Nights”, stands a success story in welding technology. As is so often the case, the challenge was requested by the customer, a manufacturer of electric furnace melting plants, continuous casting plants and rolling mills, producing in Thailand. He required repair welding of ductile iron (spheroidal graphite iron) without heat pre-treatment and post-treatment, which is possible thanks to pulsed laser beam technology. DSI Laser-Welding Academy Thailand, in cooperation with Alpha Laser Southeast Asia Co., Ltd. welcomed this challenge. In the specific case, machine components made of cast iron, type GJS-400-15 (EN 1563), (Figs. 1 and 2) were to be repaired by local deposition welding. Fig. 3 shows an example of the defects to be repaired caused during casting of these parts – by non-metallic inclusions, gas bubbles, hot cracks or blowholes.

The material to be welded is spheroidal graphite cast iron, also known by the abbreviation FCD (Ferro Casting Ductile). The advantage of this material, also known as nodular cast iron, is that it has mechanical properties like those of carbon steel (AHSS, Advanced High Strength Steel).

From theory to practice: technology in the burden of proof

The cast iron components are parts of a machine for the production of continuous cast round steel, which are subjected to high and multiple mechanical stresses in their function as linear plain bearing supports and for radial alignment in 24/7 continuous operation. Since a component failure would lead to the failure of the machine and consequently of the entire continuous casting production, accompanied by economically high losses, the experienced welding engineer and head of the quality department responsible on the customer side not only relied on the results of the visual inspection (VT) and the dye penetrant test (PT) for the repair welding, but also demanded a work sample in advance (Fig. 4). This was to prove the main theoretical advantage of pulsed laser beam welding – no relevant negative influence in the heat-affected zone and thus no microstructural changes in the base material – by means of the practical test.



Fig. 2 • Machine components made of cast iron, type GJS-400-15 (EN 1563), which should be repaired by local deposition welding. (Picture: Alpha Laser Southeast Asia Co., Ltd.)

The problems that arise in classical repair welding, for example manual arc welding, of such a cast iron material are primarily the high time and cost involved, caused by the metallurgy of the base material: high carbon content (over 3 %), brittleness and low elongation at fracture, risk of cracking due to residual stresses, low melting temperature, thin-bodied melt as well as high phosphorus and sulfur contents. In short, the weldability of all unalloyed graphitic cast iron materials depends primarily on the amount of embrittling microstructure constituents, on the pearlite, on the graphite form and on the amount of graphite particles in the area of the weld.

A look into the microstructure: What happens during traditional welding of cast iron?

From a temperature of over 420°C introduced into the workpiece and an exposure time of longer than 1 s (which is always the case with classical welding), the carbon (graphite) present in the ferrous metal matrix of the cast iron dissolves. This migrates to the grain boundaries and forms graphite nodules. Individually depending on the carbon saturation of the respective material and the cooling rate during welding, the very hard and brittle microstructural constituents martensite and – in molten areas – ledeburite are formed. These processes negatively affect the strength and toughness of the welded component.

In order to prevent this deterioration of the mechanical-technological properties – caused by classical welding – suitable countermeasures must be taken. Specifically, the material science relationships must be translated into production parameters that allow the desired weld seam properties to be set in a targeted and process-reliable manner. The main control variables that can be influenced are preheating temperature and, if necessary, postweld heat treatment, and during the welding process also the heat input, which in turn depends on the welding speed and the cooling process. Extensive sets of rules describe the variants of welding processing.

Pulsed welding – with light and its speed

Expertly aware of these welding challenges and the time and expense they entail, imagine a technology that does not need to take any of this into account: pulsed welding with light and the speed of light using pulsed laser beam technology. In just a few milliseconds (one pulse duration), photons (light particles) shoot onto the workpiece surface at almost 300,000 km/s (the speed of light), creating a molten pool (speed = energy) into which the filler metal is immersed, after which it solidifies. Only after complete solidification does the next pulse start – pulse after pulse after pulse, while the structure of the base material does not change due to the speed and the low energy input. The solution to the problem sounds and is sim-



Fig. 3 • Example of defects to be repaired during casting caused by non-metallic inclusions, gas bubbles, hot cracks or blowholes. (Picture: Alpha Laser Southeast Asia Co., Ltd.)



Fig. 4 • Work sample with three-layer pulsed laser deposition welding. (Picture: Alpha Laser Southeast Asia Co., Ltd.)



Fig. 5 • left: Micrograph of GJS-400-15 cast material (carbon content 3.25 to 3.70%) with an “alien” deposition welding performed by conventional manual arc welding with a Ni-Fe filler metal; right: Micrograph of EN-GJS-500-7 ductile iron material (carbon content 3.40 to 3.60%) with an “alien” deposition welding performed by the “energy of light”, by pulsed laser beam welding. (Picture: Alpha Laser Southeast Asia Co., Ltd.)

ple: be faster than the undesired reaction. The pulsed laser makes it possible.

Thanapol Pradissun, technological manager of Alpha Laser Southeast Asia Co., Ltd., was in charge of welding supervision during the work test required by the customer. Welding was performed with a fibre laser machine of the type “AL Flak 1200F” manufactured by Alpha Laser GmbH, programmed with the following welding parameters: 440 W laser power, 1.6 ms pulse duration, 42 Hz pulse frequency, fusion pool diameter 1.8 mm.

Comparison of the melting lines

For the deposition welding of the test specimen, a high nickel content (20 to 23 %) “foreign” filler metal (diameter of 0.6 mm) was selected: “Inconel 625” (material no.: 2.4856, trade name “DSI M NICR 625”). This produces a “pure weld metal”. Its microstructure is not in the form of an iron matrix, as is the case with the base

metal, but is austenitic. This is clearly visible in micrographs as a colour difference between the base metal and the weld metal (Fig. 5). Fig. 5 on the left shows the micrograph of the cast material GJS-400-15 (carbon content 3.25 to 3.70 %) with an “alien” deposition welding performed by conventional manual arc welding with a Ni-Fe filler metal. Fig. 5 on the right shows the micrograph of the nodular cast iron material EN-GJS-500-7 (carbon content 3.40 to 3.60 %) with an “alien” deposition welding carried out by the “energy of light”, by pulsed laser beam welding.

The microsection of the conventional weld (Fig. 5 left) clearly shows how the carbon present in the metallic matrix of the cast iron dissolved, migrated to the grain boundaries and formed graphite nodules due to the high heat input not initiated by electricity. In addition, it can be seen how the nickel-containing weld metal in the segregation zone absorbed iron particles from the base metal,

which expressed itself as nickel martensite (speckled black). In comparison, the microsection of the pulsed laser beam weld (Fig. 5 right) shows no changes whatsoever – neither graphitization in the base metal nor a change in the carbon in the segregation zone.

Despite the theoretical knowledge – great astonishment

At the customer's request, the evaluation of the work sample was carried out by an independent third party, the Thai German Institute (TGI) in Chonburi, which was expertly accompanied by Prof. Dr. Gerd Kuschner of GSI – Gesellschaft für Schweißtechnik International mbH, branch SLV Hannover, Germany. Although all those involved in the project were well aware of the theory associated with the technology used – the main advantages of pulsed laser beam welding – everyone, without exception, was equally amazed and delighted by the undoubtedly positive results.

The practical test provided proof of the theory: spheroidal graphite cast iron (GJS/FCD) can be welded without defects at room temperature without any heat treatment. Thus, pulsed laser beam welding technology has removed the almost insurmountable barrier to trouble-free and economical repair welding of ductile cast iron – thanks to its two main advantages of no “graphitization” and no microstructural changes to the base material:

- Very low heat input (welding with light and the speed of light),
- Welding with pulse with ultra-high frequency (maximum 100 Hz).



Fig. 6 • Unchanged base material of the welded work-plate. (Picture: Alpha Laser Southeast Asia Co., Ltd.)



Fig. 7 • Pure weld metal of the welded work-plate (Picture: Alpha Laser Southeast Asia Co., Ltd.)

Ready for further challenges

Saving time and costs, but without compromising on quality: The technology of pulsed laser beam welding has mastered this challenge, both in the work trial and in the machine components that were subsequently repair-welded and are now successfully in continuous use (Figs. 1 and 2).

This practical example shows a previously undreamed-of possibility with regard to the repair and construction welding of materials that are conventionally complex to weld. At the same time, it gives an idea of the wide range of possible applications for customers from a wide variety of industrial sectors.

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Only **welding with PULSED Light and its Speed**
provides **UNIQUE advantages** :

Very **LOW** welding energy, very **LOW** heat input on the component

NO pre- or post-weld heat treatment (PWHT) required

NO critical microstructure changing

Very **THIN** Heat Affected Zone (0,1 - 0,3mm)

NO coarse grain formation within HAZ

NO graphitisation

Almost **NO** distortion

NO significant decrease in ductility

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