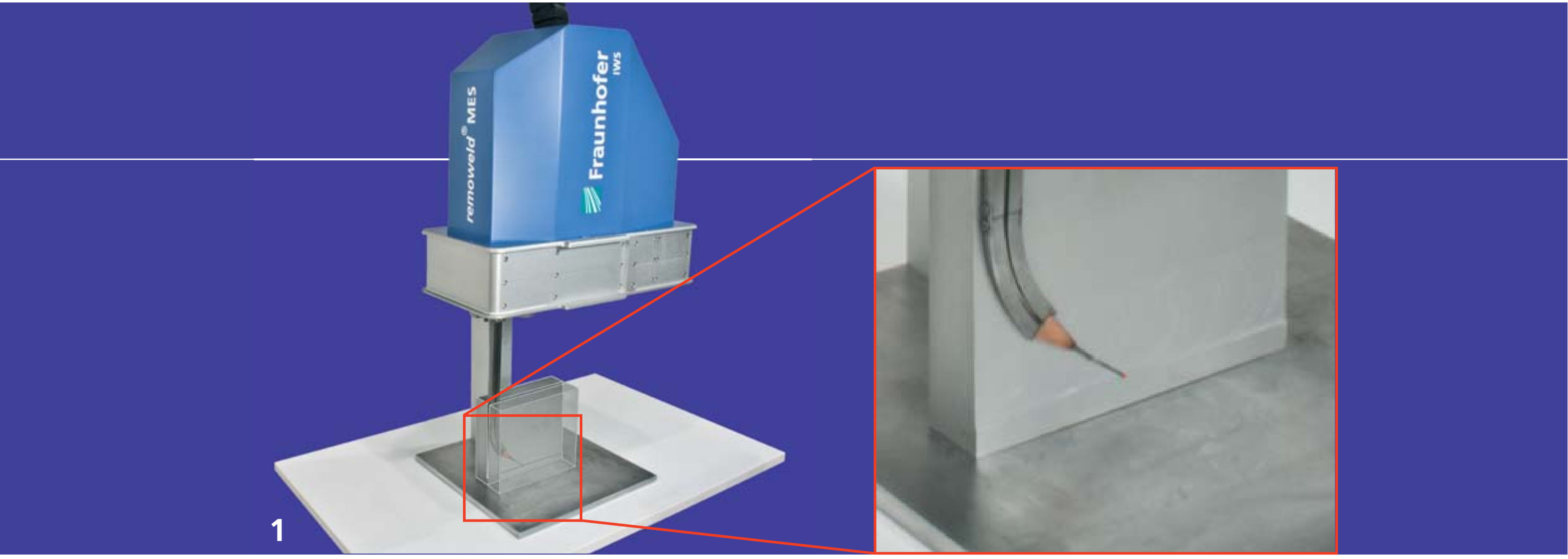

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JOINING OF NICKEL-BASED SUPER ALLOYS BY LASER-MULTI-PASS-NARROW-GAP WELDING

THE TASK

Policy changes related to renewable energy sources that aim both to protect the environment and to conserve resources are undoubtedly the only choice. In future, it will thus be very important for energy generation to operate powerfully and highly efficient thermal power stations to guarantee the basic energy supply.

With nickel-based super alloys, global power station manufacturers can achieve an increase in energy efficiency of both existing and planned thermal power stations of up to 50 percent by increasing the vapor temperature to 700 °C. The nickel-based super alloy 617occ is a promising material for use in the so-called 700 °C power station. Joining of thick-walled components made of nickel-based super alloys, in particular of the alloy 617occ, in high-temperature processes is a major challenge. Conventional welding techniques can significantly impair the high-temperature characteristics of hot crack prone alloys (for instance in creep behavior and creep rupture strength) due to the unacceptably high heat input.

To cope with current materials developments and to maintain the huge potential for adding value to the manufacturing of thick-walled components (> 30 mm) made of the nickel-based super alloys that are popular in Germany, the Fraunhofer IWS Dresden developed laser-multi-pass-narrow-gap welding (Laser-MPNG)- a laser-based welding technique for low-damage and hot crack-free joining of nickel-based super alloys.

OUR SOLUTION

The Laser-MPNG technology developed at the Fraunhofer IWS offers great potential for joining nickel-based super alloys thanks to its technological specifics. In general, the technique is characterized by very low energies per unit length, which, in turn, reduces angular distortions and thermal damages of the joining parts' base material. The consumption of filler metal is drastically reduced, because the seams can be made in a very narrow manner, with gaps from 2 to 3 mm width and a minimal side opening angle of less than 2 °.

The welding technology was developed by means of the *removeld*®MPNG welding head prototype (Fig. 1). The modular structure of the welding head allows the configuration of the optical unit to be flexibly adapted to the materials to be welded and their specific properties. Thanks to the optical and mechanical design, components of maximum 250 mm wall thickness can be welded in the future.

Welding process engineering was consequently based on the profitability of the technique's application. Nickel-based super alloys were joined by using extremely bright fiber laser sources up to a power of 5 kW. An advantage of these lasers is the reasonable investment for equipment manufacturers. With these lasers, extremely small gap sizes during welding are feasible due to the low beam parameter product.

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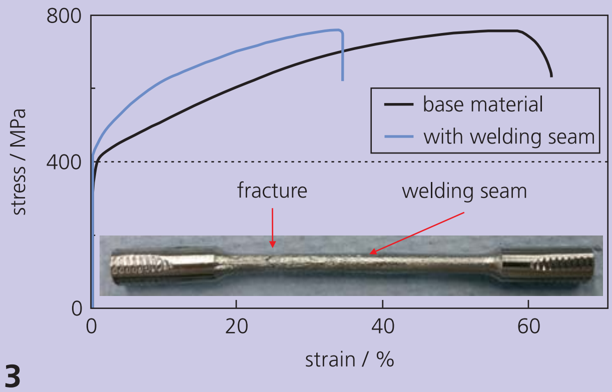
RESULTS

Welding tests on component-like cylindrical alloy 617occ samples after solution heat treatment (Fig. 2) have demonstrated that it is possible to generate sufficiently adhered welding seams free of cracks by laser MPNG and using a similar filler metal (Fig. 4). Using high-frequency beam oscillation minimizes the occurrence of pores and guarantees that the filler material is molten off reliably. As a result, quasi side-parallel welding seams of homogenous structure are formed.

Examinations of the mechanical welding seam strength values in a direction lateral to the welding direction showed – in comparison with the base metal – higher yield strength values and the same tensile strength values (Fig. 3). The samples with weld material failed throughout in the base material, but not in the weld material or the heat-affected zone. Melting losses of the alloying elements were not found in the weld material.

Strength characteristics of tensile test items made of base metal and test items with welding seam – in comparison



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The next goal of the project is to increase welding seam depth incrementally beyond 100 mm to maximum 200 mm. These studies were accompanied by the determination of the creep and fatigue characteristics of the welds created, as well as the development and implementation of an inline-capable non-destructive testing procedure.

The results introduced were gained by the research-oriented, strategic alliance of the Fraunhofer institutes IWS, IWM and IKTS. They include excerpts from the project entitled "Laser-multi-pass-narrow-gap welding applied to key components of future energy-efficient and resource-saving high-temperature processes", funded internally by the Fraunhofer-Gesellschaft.

1 Welding head (prototype) removeld®MPNG

2 Component-like cylindrical sample of 50 mm wall thickness

4 Microscope detailed image of the welds of a welding seam, alloy 617occ

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