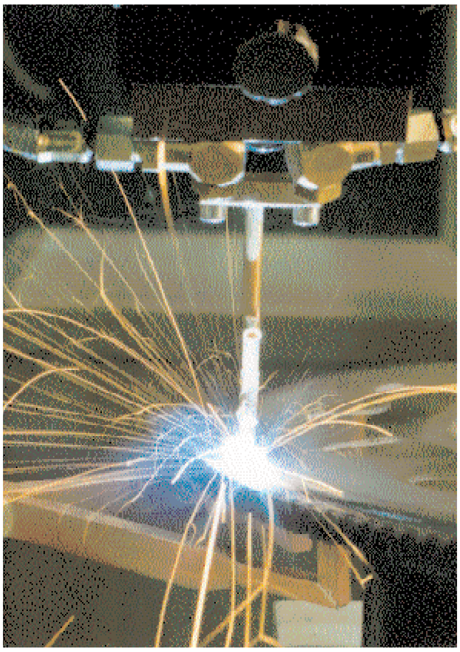

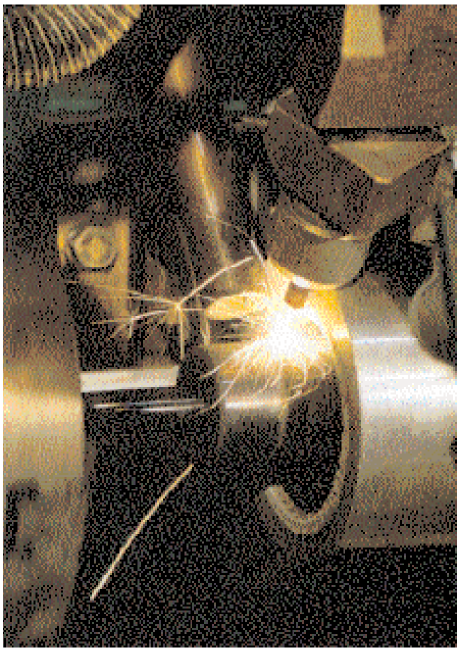

Induction assisted laser materials processing

Fraunhofer Institut Werkstoff- und Strahltechnik

Laser beam plus induction -
The combined technologies overcome application barriers

Issue

The wide variety of potential applications of laser for welding and surface enhancement is the result, above all, of the high power density obtainable in a laser beam. This high power density, on one hand, allows high feed rates and short processing times which help to reduce the heat input into the part, and it also produces fine grained solidification and transformation microstructures. On the other hand, laser processing is usually associated with high temperature gradients, the formation of undesirable phases and significant thermal stresses. Latter ones generate high residual tensile stress which may result in cracks limiting the industrial applicability of laser processing.

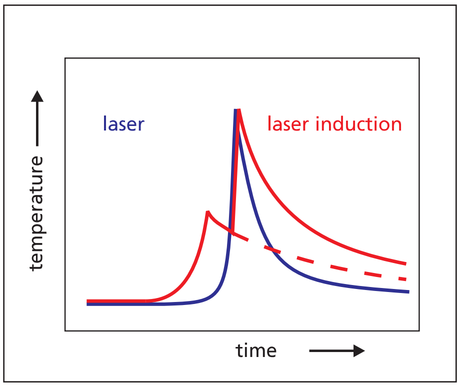

Fig. 1: Effect of induction heating on the temperature-time cycle during laser processing

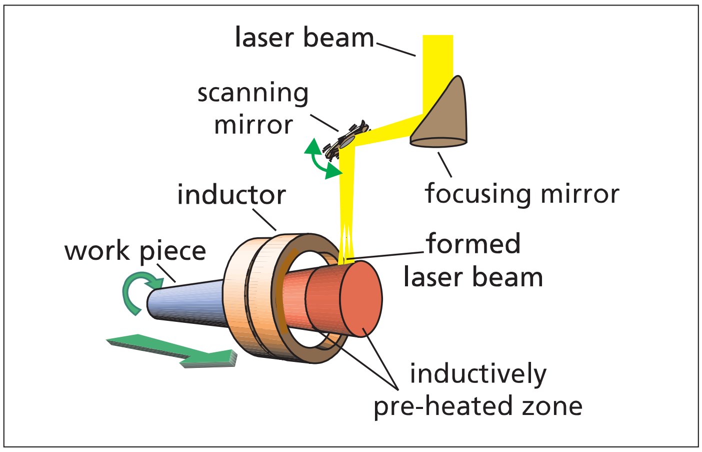

Fig. 2: Schematic for induction assisted laser processing

Solution

To prevent these undesirable side effects which occur between 150 °C (300 °F) and 650 °C (1200 °F), an additional heating source like induction heating is needed. The sole objective of this heating source is to reduce the temperature gradient within the critical temperature range. Induction heating is an elegant technology for this purpose that is easily controllable and can be favorably integrated in laser processing machines.

Technical Solution

The world's first multi-purpose machine that combines laser and induction heating is located at the Fraunhofer Institute for Material and Beam Technology in Dresden. This laser-induction machine is used to develop new techniques in the area of induction assisted laser beam welding, cladding and hardening. It can also be utilized to develop specific applications for individual customers.

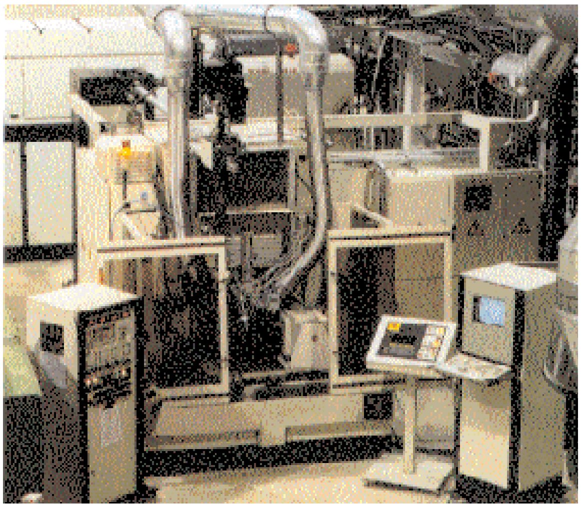

Fig. 3: Multi-purpose laser-induction processing center LIHM 1000; Manufacturer: EFD Induktionserwaermung Fritz Duesseldorf GmbH, Freiburg, Germany

Laser beam plus induction –
The new techniques

Induction assisted laser beam welding

Process: Laser beam welding is the preferred method for various joining applications due to a low heat input and fast welding speeds. Until recently, however, and with only a few exemptions, laser beam welding of ferrous materials has been limited to low and medium carbon steels. Carbon contents greater than 0.25 % in carbon steels and 0.2 % in alloyed steels cause cracking in the fusion or heat affected zone due to a hardening of the weld during cooling which prevents the material from relaxing. The concept of induction assisted laser beam welding is based on the rather elementary insight that the cracking in these cases can be avoided if the cooling rate is lower than the critical value which is depending on the specific steel composition. Induction heating by its nature can be very favorably incorporated in the laser process and achieve the necessary lowering of the cooling rate.

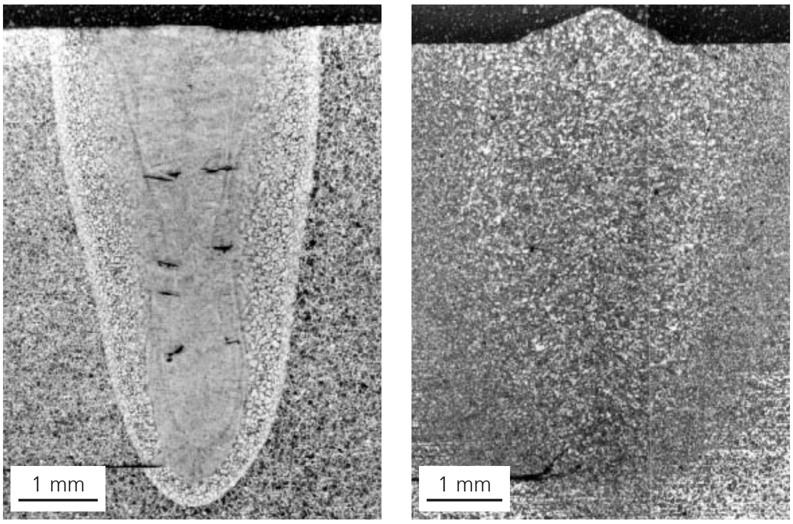

Fig. 4: Laser weld joint of C45 / C45 (AISI 1043):
Left: Cracks after conventional laser beam welding,
Right: No cracks after induction assisted laser beam welding

Advantages: Compared with preheating in a furnace, the induction assisted laser beam welding is distinguished by the following features:

- Simultaneous heating and welding
- Lower energy consumption
- Easy part handling
- Simplified machine design in case of automated systems
- Lower heat input
- No annealing of previously hardened part areas
- Lower capital investment

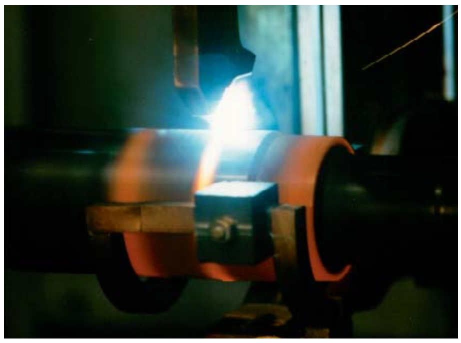

Fig. 5: Laser beam welding with inductive preheating

Fig. 6: Induction assisted laser beam welding in production in the automotive industry: Welding of drive shafts at Ford Motor Co., Cologne, Germany

Applications: Induction heating allows the laser beam welding of a significantly enlarged spectrum of steels including high carbon and case hardening steels, cold work tool steel as well as selective types of cast iron. In conjunction with other techniques it provides entirely new opportunities for the design and manufacture of components.

Laser beam plus induction –
The new techniques

Induction assisted laser beam surface remelting

Process: The ledeburidic microstructure produced on cast iron parts by surface melting and subsequent self quenching is distinguished by excellent resistance against abrasive or lubricated wear. The to-date most commonly used technology, TIG-remelting, produces a comparably coarse microstructure, a rather rough surface and a low asperity with respect to the part contour. The rare industrial installations of laser or electron beam remelting utilize furnace preheating in order to prevent the parts from cracking. This through-heating in a furnace, however, keeps the hardness in the remelted layer from reaching its highest possible level, produces only marginally improved wear properties over TIG-remelting and involves a difficult part handling.

The induction assisted laser surface remelting overcomes these disadvantages by being able to achieve a peak temperature and a temperature gradient just adequate to prevent cracking but that, at the same time, allow sufficient cooling rate to produce a fine grained microstructure with superior wear resistance.

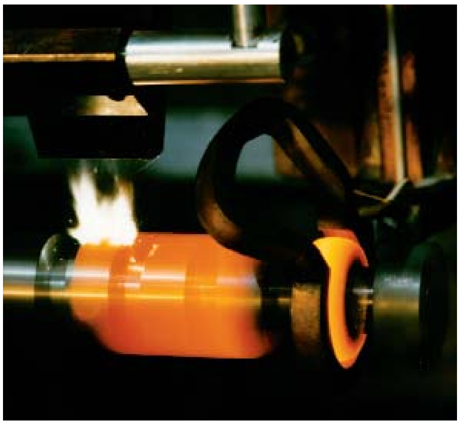

Fig. 7: Induction assisted laser beam surface remelting of a gray cast iron part

Advantages:
- Improved resistance against abrasive and lubricated wear
- Increased hardness in the melted surface layer of 100 HV and more
- Increased hardness in the heat affected zone of 250 HV and more
- Case (melting) depth of 0.1 - 1 mm
- Favorable residual stress state
- Shorter cycle times
- Reduced finishing requirements due to improved asperity

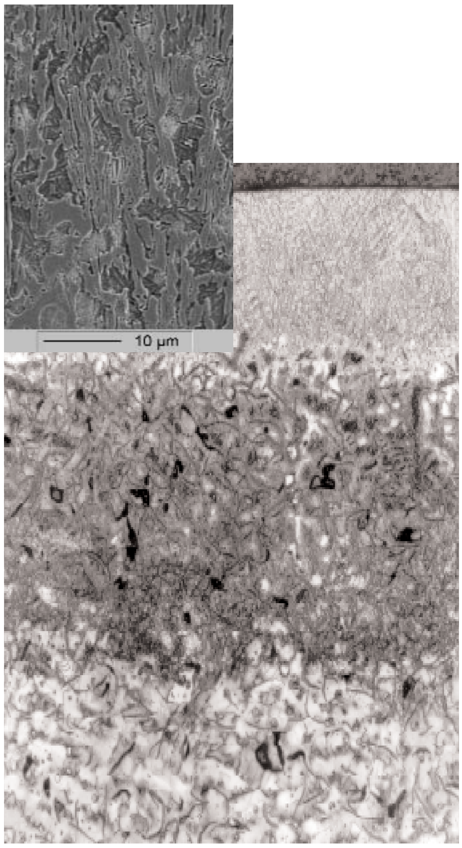

Fig. 8: Micrograph of a gray cast iron surface processed by induction assisted laser beam remelting
Top: Ledeburidic fusion zone
Center: Bainitic heat affected zone
Bottom: Unaffected (as cast) state

PIP: Ledeburidic structure at high magnification

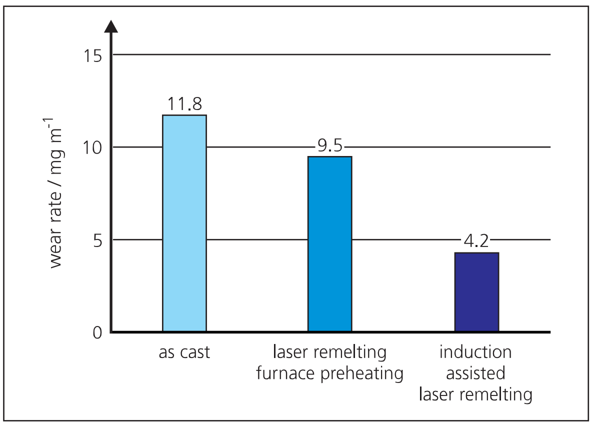

Fig. 9: Improving of abrasive wear performance of gray cast iron by induction assisted laser surface remelting (Parameters: SiC 45 µm, 10 m, 1 MPa)

Applications: The induction assisted laser surface remelting significantly enhances the performance of heavy-duty parts made from cast iron, such as camshafts and cam disks, rocker arms, race ways and guides, gates and diffuser or deflector plates, etc. The application of the technology on tool steel is possible.

Laser beam plus induction –
The new techniques

Induction assisted laser beam cladding

Process: Laser applied coatings are distinguished by superior wear performance compared with conventional weld overlays. Yet, the excellent wear performance often heavily weighs on the coating's ductility which, in conjunction with a high cooling rate, causes cracking. In addition, the coating rate in sqin/min or g/min is rather limited. Inductive preheating can eliminate both issues at once. Utilizing inductive heating, cold work steel can be laser clad with no cracks, and the coating rate can be multiplied while the main advantage of the process, namely the low dilution, is maintained.

Advantages:
- Crack-free cladding of high carbon and alloyed steels, e.g., 42CrMo4 (AISI 4137), C45 (AISI 1043), 40Mn4 (AISI 1039), 90MnCrV8 (AISI O2)
- Crack-free cladding with brittle coating materials
- Producing martensite in the HAZ of hardenable steels
- Increase coating rate by factor 10
- Simplified part handling

Fig. 10: Cold work steel 90MnCrV8 (O2) crack-free coated with NiCrBSi alloy Deloro 60

Induction assisted laser beam transformation hardening

Process: Induction case hardening is a widespread technology with high acceptance in industry. Induction hardening of thin sections, hidden surfaces, small holes or concave elements of small radius, however, cannot be done without great difficulty. Laser hardening, in contrast, can often handle those jobs but is simply not economical. The combination of both technologies, induction heating and laser hardening, opens up a range of difficult parts for quick and economical case hardening.

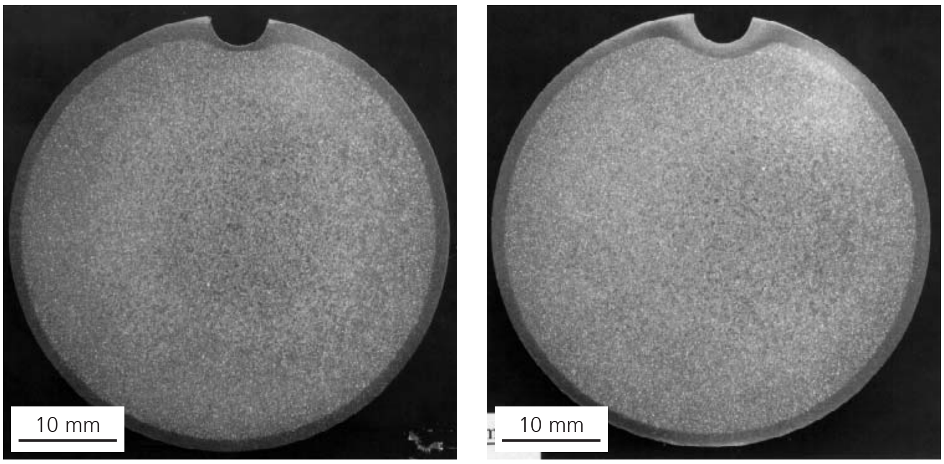

Fig. 11: Cross-section of case hardened shaft with a keyway
Left: Induction hardened
Right: Induction assisted laser beam hardened

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Laser beam plus induction - The way solving your problems

Equipment

The LIHM 1000 for induction assisted laser processing:

- 5 axis CNC machine with Siemens-controller 840 D
- 6 kW CO_2 laser RS 860 HF
- 20 kW CO_2 laser SR 200
- 80 kW RF Induction generator PSU 80/10
- X-Y-Z envelope 720 mm · 330 mm · 400 mm (28" · 13" · 16")
- High pressure quenching unit 120 l min^{-1} (250 SCFH)
- On-line temperature control for induction heating
- Seam tracking sensor

Partnerships

Fraunhofer Institut Werkstoff- und Strahltechnik IWS

The Fraunhofer Institute for Material and Beam Technology maintains partnerships with these companies to be able to provide complete production solutions to its customers:

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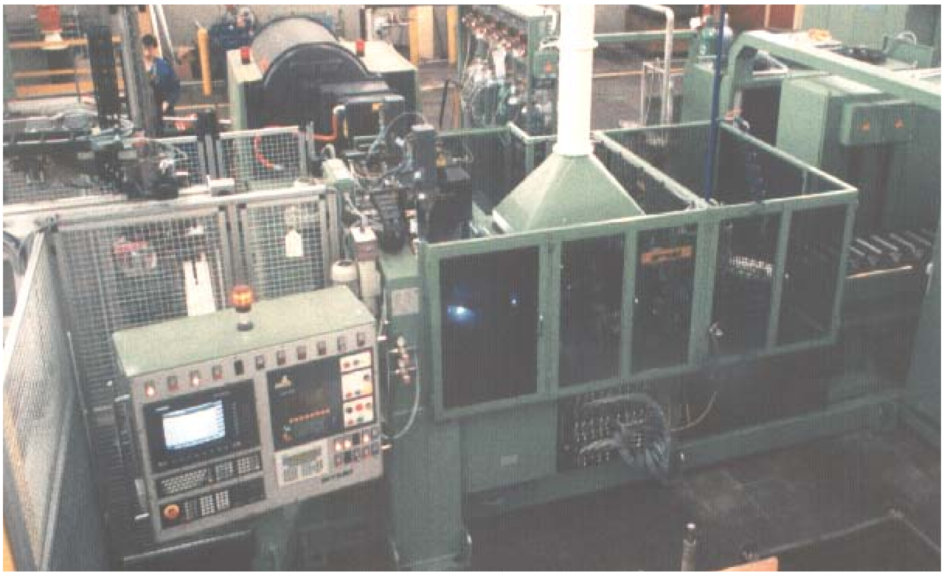

Fig. 12: Machine system for the induction assisted laser beam welding of drive shafts, Installation at Ford Motor Co., Cologne, Germany, Manufacturer: Arnold GmbH & Co. KG, Ravensburg, Germany

Services

Fraunhofer provides applied development for industrial customers on a contractual basis. Our services include:

- Feasibility studies
- Process development for induction assisted laser beam welding and surface enhancement
- Focused development projects on joining of 'non-weldable' materials
- Extensive material and part testing
- Prototype and pilot production
- Design and engineering of machines and machine components
- System engineering in cooperation with leading manufacturers of lasers, induction generators and handling systems

Title figures

Left: Induction assisted laser beam welding of a gear ring disk
Center: Induction assisted laser beam hardening of a shaft with keyway
Right: Induction assisted laser beam cladding of journal made of alloyed steel

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