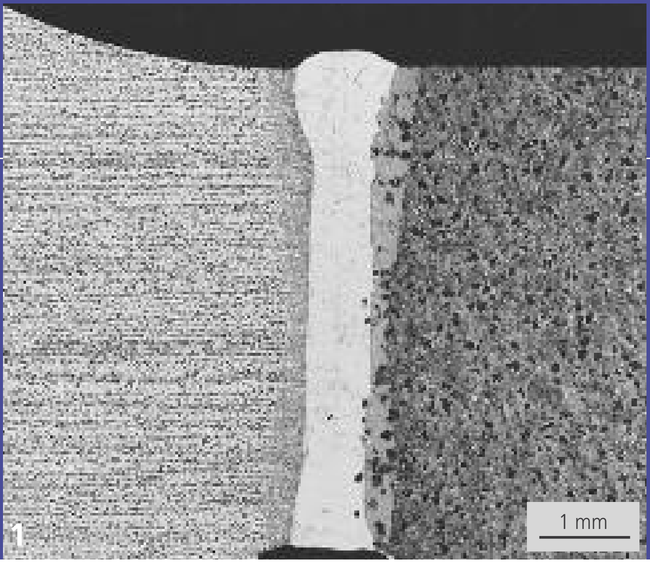

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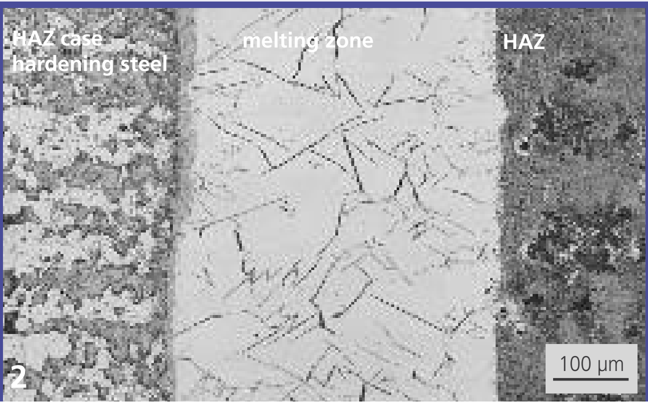

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# LASER BEAM WELDING OF HIGHLY LOADED COMPONENTS MADE FROM BLACKHEART MALLEABLE CAST IRON

## THE TASK

For more than 15 years mixed joints from case hardened steel and cast iron have increasingly become the worldwide standard for automotive transmissions. Previously the joints, especially in differential transmissions, were very complex screwed and riveted connections, which were more difficult to fabricate and also heavier.

However, the general industry pressure on costs and quality continues. Highly cyclic loading resilient globular cast iron (GJS) is more and more often replaced by blackheart malleable cast iron (GJMB) with its specific cost advantages. GJMB is easier to cast and to machine due to a sulfur content of 0.17 %, which is 8-10 times higher than in GJS. However, that sulfur content is challenging in terms of hot-crack formation during conventional $CO_2$ laser welding using nickel containing wire filler. Such hot-cracks are due to low melting point iron sulfides and have to be avoided.

Another important aspect when welding cast materials is the general desire to reduce manufacturing costs. This is possible due to further developed laser sources, but also based on stable, energy efficient and resource sparing welding processes. It is also possible to save costs by optimizing component designs. However, detailed design specifications are scarce for axially and torsionally loaded joints. Thus to obtain them is the subject of current Fraunhofer IWS research.

## OUR SOLUTION

Fraunhofer IWS engineers together with partners from the automotive industry have developed a very competent and reliable laser welding process for the crack-free joining of blackheart malleable cast iron (GJMB) with case hardened steel (Fig. 3).

The process is performed with a modern disk laser of advantageous beam quality. The resulting seam flanks are mostly parallel (Fig. 1). Laser power, welding speed and relative welding position are adjusted to achieve mixing ratios in the melting zone, which lead to cooling and solidification conditions that effectively suppress the formation of hot-cracks. The mixing ratio is adjusted via the relative beam position with respect to the weld gap. A special beam guiding optics achieves a reliable adjustment with the precision of a few hundreds of a millimeter.

The very high welding speeds have another useful side effect. Due to the speed no crack sensitive microstructure, such as extremely hard ledeburite, can form in the heat-affected zone of the cast material. There is also very little energy deposited into the welded parts. This causes few thermal transient stresses and deformations. An additional nickel containing wire or sheet material is not required anymore. This substantially adds to the cost savings.

## RESULTS

The welding process was tested for a number of GJMB and case hardened steel sample parts. It was possible to achieve high quality GJS/GJMB welds with nearly parallel seam flanks


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while using substantially reduced laser powers and energy inputs compared to previous processes. Nickel additives were not necessary.
The melting zone consists of the desired retained austenitic structure with its advantageous ductile properties (Fig. 3). Only very few hot-cracks form in spite of the very high sulfur content in GJMB. Their form is drastically reduced compared to conventional laser welding processes. Ledeburite can only be found in small quantities in the form of islands in the heat-affected zone.

The results also show that mixed joints involving case hardened steel and GJMB or GJS can be welded with mostly similar parameters when using disk lasers. A typical laser welding task for a differential gear box involves a welding diameter of about 150 mm and a welding depth of about 5.0 mm. When using the disk laser the energy input is only about 25% and thus substantially lower compared to previously established $CO_2$ laser welding processes with filler material.

The cyclic load carrying capacity of disk laser welded parts was evaluated at Fraunhofer IWS using a servo hydraulic axial-torsional testing machine (Fig. 4). The purpose was to obtain design specifications for component optimization. The test specimens were loaded according to von Mises' distortion energy stress hypothesis. The typical loading case for a weld seam in a differential gearbox is a combination of bending and torsion.

A GJMB/case hardened steel mixed joint is achieved as high load carrying capacities as GJS/case hardened steel joints when welded with disk lasers. The results significantly exceeded those of GJS/case hardened steel joints typical in the automotive industry, which are welded with conventional $CO_2$ lasers and filler material.

Currently the systems are tested for vibrational fatigue strength. Preliminary results are already giving hope that there will be additional cost savings potential through adjusting the weld penetration depth to the required loads.

*1 Welded mixed joint from GJMB/case hardened steel (overview)*

*2 Weld material structure of the mixed joint from GJMB/case hardened steel*

*3 Laser welding of a test sample made from GJMB/case hardened steel*

*4 Long-term vibrational fatigue testing of a test specimen in a servo hydraulic axial-torsional testing machine*

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