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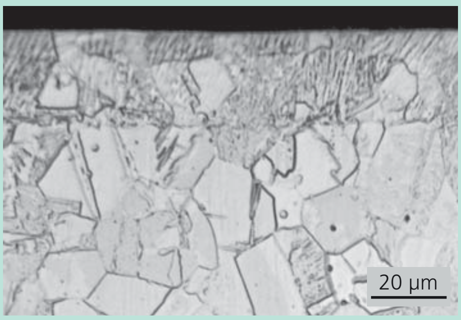
INFLUENCE OF THE LASER BEAM CUTTING ON FATIGUE STRENGTH

THE TASK

The laser beam cutting is a highly efficient process, which is based on efficient use of materials, cutting speeds, the flexibility and the minimal material deformations in the cutting region. However, with increasing metal sheet thickness a significant relief forms on the cut surfaces. The heat deposition into the material also causes microstructural changes in surface-near regions (Fig. 2). If the cutting parameters are not optimized, a part of the melt is not ejected by the shielding gas and solidifies to form macroscopic burrs.

These issues limit the use of the process to components, which are subjected to static and/or cyclic load conditions and have to fulfill safety relevant functions. The micro- and macroscopic grooves and burrs on the sidewalls of the cut cause local stress peaks and affect the classic fatigue resistance as much as the original state of the material. Currently there are no experimental data which allow for a reliable prediction as to what influence the surface relief and burr formation has on the cyclic strength of the material. Research work at the Fraunhofer IWS Dresden tries to address this gap.

Heat affected zone at the cutting edge



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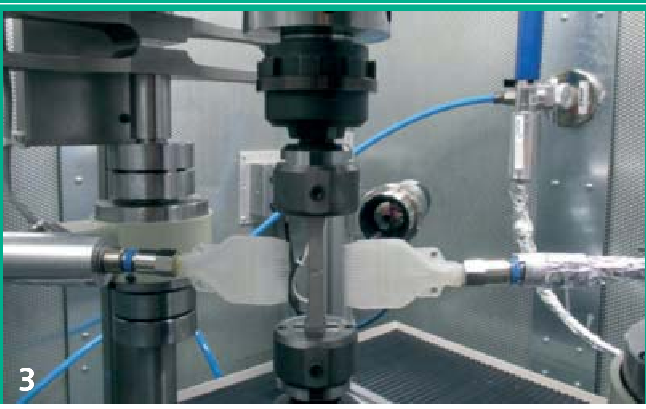
OUR SOLUTION

The influence of the laser cutting process on the fatigue behavior of sheet metal was studied with sheets of various cut qualities made from the metastable austenitic stainless steel material 1.4301. Laser beam cutting is a cost- and time efficient process to machine this material. The geometric and metallurgical changes at the cutting edges are affected by the formation of high melting point oxide phases on the surfaces. These properties of the oxide phases depend on the particular composition of the steel alloy. To improve the fatigue behavior by process optimization requires to understand the interdependencies between geometric non-uniformities (burr formation), hardness gradient (due to heat deposition and microstructural transformations) and the effects of the surface quality.

A particular challenge for understanding the fatigue behavior of laser cut samples lies in the comparatively large scatter of the experimental data. This can be related mostly to the irregularly roughened surface structure of the cutting edges. At the Fraunhofer IWS this problem is addressed by analyzing a sufficiently large number of samples. However, this is only possible if one has high frequency fatigue test stands such as those available at the IWS.



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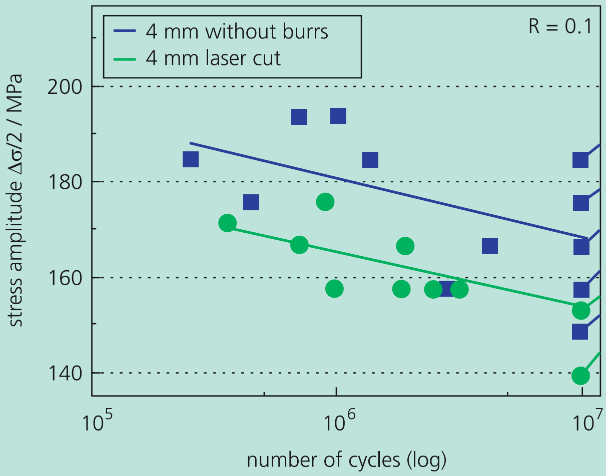
RESULTS

The surface roughness of the cutting edge changes with the metal sheet thickness. This directly translates to a different fatigue behavior. The fatigue test experiments were performed under cyclic tension-tension stresses. Here the fractured surfaces usually allow for an unambiguous conclusion about the causes of the crack initiating features. Laser cut metal sheets of 2 to 6 mm thickness showed a fatigue strength in the range from 154 to 166 MPa for a load cycle limit of $N = 10^7$ at 50 percent failure probability. The cracks generally initiated from the burrs (Fig. 5), their geometry often resembles a technical crack right from the beginning.

To simulate a process optimization, an additional experiment was performed, in which the burr was removed after cutting a 4 mm sheet. Now the remaining factors that could influence the fatigue behavior were the surface relief and the heat affected zone. This step led to an increased fatigue strength by 10 percent (Fig. 4).

Fatigue strength of laser cut fatigue test specimen from 1.4301 material with and without burrs



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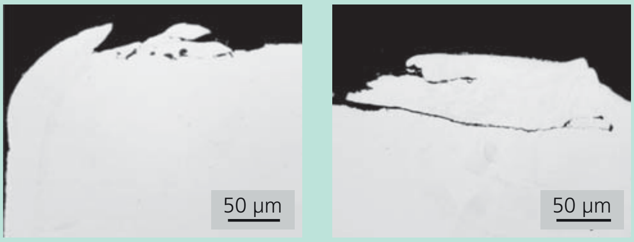
A novel Suisse high frequency fatigue tester was used for the first time to obtain the here presented data for the fatigue strength of 1.4301 steel sheets representing the properties of laser cut sheet edges. This machine is a resonance pulsator, the so called Gigaforte, which can test with frequencies of about 1000 Hertz.

Burrs at the cutting edge



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This test stand concept is not yet commercially available, but it allows for a significant reduction in testing time due to the high testing frequency. Up to 100 million load cycles can be reached within 1 to 2 days. So far such reduced experiment times were only possible with ultrasonic fatigue testing (also available at IWS), which is limited to certain sample shapes.

1 Laser melt cutting

3 1000 Hz resonance pulsator test stand

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