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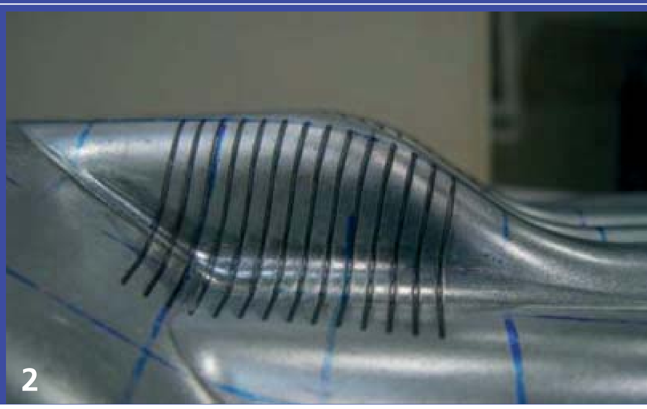

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LASER-STRENGTHENED STEEL SHEET STRUCTURES – NOW WITHSTANDING HIGH CYCLIC LOADS!

THE TASK

Current laws drastically limit the permissible CO_2 emissions of automobiles. This forces the manufacturers to develop light-weight bodywork construction technologies to reduce the vehicle weight without compromising safety. Components get ever more complex and need to be stronger. Conventional construction principles were based on using homogeneous high strength materials. This approach will not be sufficient in the future.

An innovative approach has been developed to use lasers to locally strengthen steel crash structures used in vehicle bodies. The method tailors the workpiece hardness and strength at selected locations to adjust the material properties for the expected load distribution. Clear improvements of static and dynamic crash performances of steel sheet components were already demonstrated. However, in addition to static and impact loads, automotive chassis and body components are also exposed to cyclic mechanical fatigue loading.

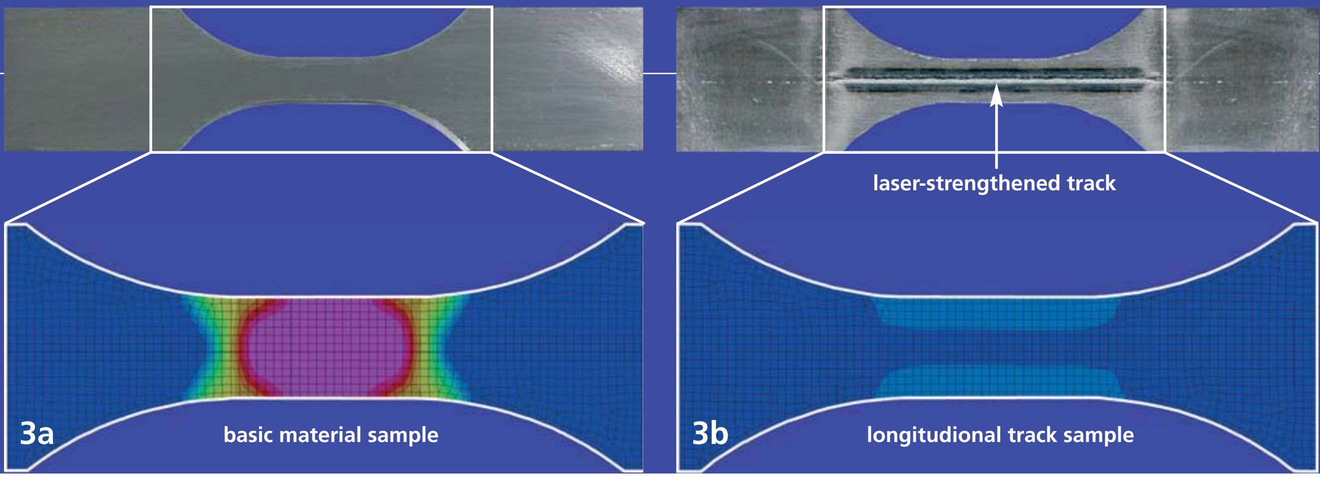
The task was to investigate the influence of the laser-strengthened structures on the fatigue strength of automotive sheet materials. The comparison included the basic sheet material and laser-strengthened sheets. The aim was to estimate the effect of the process and to derive conclusions for future component designs.

OUR SOLUTION

Laser-strengthening of metal sheets principally aims at using cost-effective low strength steel sheets with reduced wall thicknesses. These sheets are laser treated at locations with high loads. The focused laser beam is scanned across the surface at defined speed. The concentrated energy deposition heats or even melts and subsequently solidifies the track (Fig. 2). The subsequent cooling leads to martensitic hardening of such steels that are typically used in the automotive industry. This effect is used to locally strengthen the material. The tensile strength in the treated zones can be 2.5 higher compared to the base material.

How strengthened tracks affect the fatigue strength was researched jointly with the department for materials characterization and testing at the IWS. The test material (S355 J2+N) is typical for automotive chassis applications. A special test program was developed. The effects of shape (track orientation) and surface states were studied with respect to the achievable fatigue strengths and endurance limits.

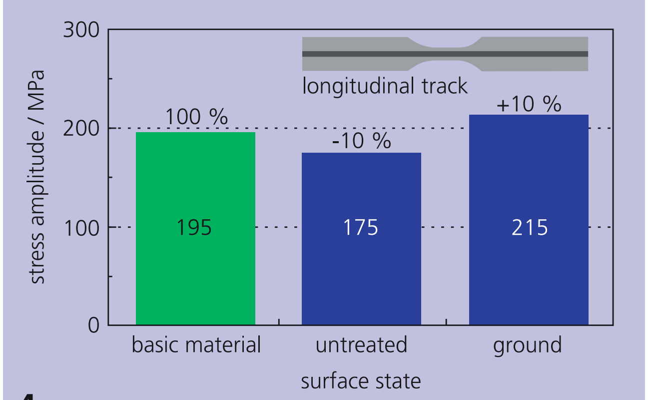
The experimental matrix includes the variations shown in Figure 4. One sample was ground down to remove the weld grooves and to reach a roughness of $R_Z \approx 6$ µm across the entire surface. FE simulations were performed (static nonlinear) to determine plastic deformation as a result of defined loads for various track orientations.



RESULTS

The FE calculations simulated a loading cycle by applying a static tensile load, which was subsequently relieved (1 cycle). As a result, the base material suffers plastic tensile deformation, which is homogeneously distributed (Fig. 3a). Applying the same load to material with longitudinal tracks, the results show no significant residual deformation in the area of the base material (Fig. 3b). The reason for this is the significantly higher yield strength of the laser-strengthened track. This longitudinally oriented tensile band reduces residual deformations so that one can also expect improved fatigue strength.

Results of fatigue strength tests for a cycle number of $N = 2 \times 10^6$



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Untreated (not ground) samples with tracks oriented in parallel to the direction of the loading force experience crack initiation at the edge of the track grooves. At the same loading conditions, the support due to the track reduces the maximum elongation and nearly compensates the detrimental effect of the groove. The fatigue strength only slightly reduces compared to the base material (Fig. 4, blue, untreated).

Ground down samples showed a tendency to improve the fatigue strength (Fig. 4, blue, lapped). The sampling size for these experiments is low. However, principle differences in the levels of fatigue strength and endurance limit became apparent.

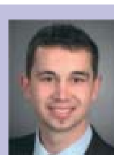
The experiments proved that laser-strengthened tracks are useful for applications, in which the parts are exposed to cyclic loads in addition to static and impact loads. The technology significantly improves the resilience of chassis components especially in situations of impact misuse. The experiments allowed the identification of strategies as to how to apply the technology while maintaining the fatigue strength of the base material. Even further improvements are expected from process optimization, which perhaps renders an additional grinding process obsolete.

1 *Chassis component made from welded sheets*

2 *Laser strengthened steel sheet structure*

3 *Comparison of plastic strain of untreated (a) and laser streng-thened (b) fatigue test samples (same scale of strain)*

CONTACT



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