When the material fails: Failure analysis at ALTER | HTV

If material failure occurs in a product, the reason for the failure is usually instinctively investigated, to be able to avoid this product failure in the future. At the Institute for Material Analysis at ALTER | HTV, our analytical experts have a comprehensive portfolio of methods at their disposal that enables them to intensively pursue the question of the reason for the failure. ALTER | HTV shows an excerpt of its possibilities and their use in an example of analysis of a failure on an everyday product to demonstrate its capabilities. The origin of the failure is worked out in the course of this investigation.

1. Description of the error pattern

In the investigated case, a mechanical deformation of a bottle has led to tearing of the material. As a result, the function of the product is no longer given and the bottle is leaking.

In a failure analysis, it is important not to change the area of the failure so as not to obliterate or alter possible traces. Therefore, a sequential approach is indicated, in which the first step is the description of the macroscopic defect pattern. For ALTER | HTV, this step is usually done with state-of-the-art optical digital microscopy.

Figure 1: Defective product after mechanical impact (damage area, red)

The failure pattern clearly shows a preferred area in which the deformation propagates (cf. Figure 1). A detailed examination showed that the material failure and the preferred direction of deformation follow a hidden weld seam. Based on this finding the further procedure was aligned and the corresponding analysis methods were selected

2. Detailed analysis – Why did the bottle fail?

Since more detailed examinations are not possible without dissecting the damaged area out of the bottle, the crack and part of the undamaged weld seam were cut out of the damaged product. A metallographic section was made of the extracted weld to be able to examine the microstructure of the weld and the workpiece. The damaged area was directly microscoped without further measures. Initially, optical digital microscopy and later scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDX) were used for the examinations. This ensures that no detail has been overlooked.

The optical microscopy shows that the execution of the weld seam appears to be defective in several places (cf. Figure 2). The weld showed hard defined areas, both at the location of the fracture and at other locations, indicating the presence of weld undercuts. Areas of significant weld overlap, pores within the weld and traces of corrosion were also documented.

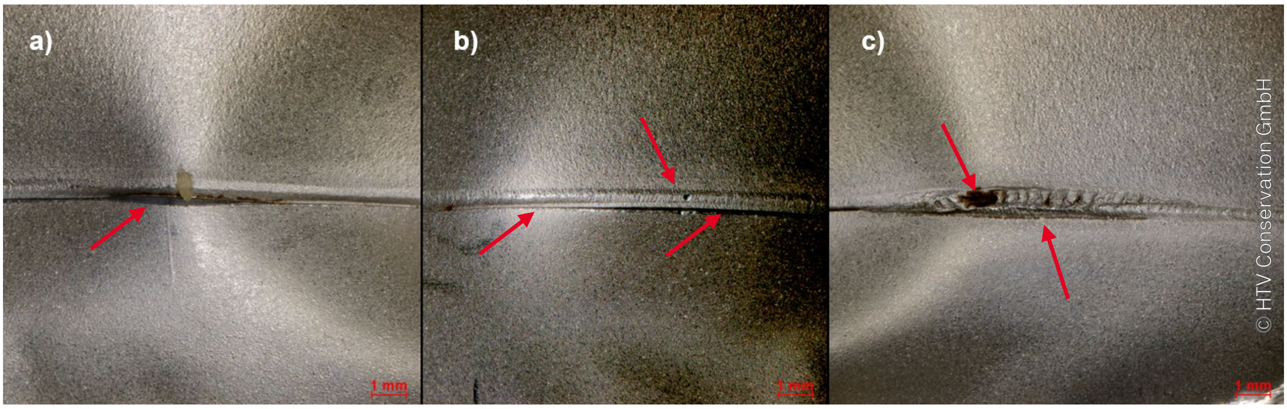

Figure 2: Light microscopy of the weld seam with damage area a), weld seam with pore and undercut b) and overlap with corrosion trace c) – conspicuous features are marked in red

An examination under the scanning electron microscope underlined the findings (cf. Figure 3 f.) and showed a clear undercut as well as a weld overlap. A typical dendritic structure was found within the weld. The fracture surface, which makes the fracture mechanism accessible, was also microscoped in detail (cf. Figure 5). This shows a fracture surface whose structure indicates a ductile fracture. Thus, failure of the weld due to force alone is unlikely. Rather, the geometry of the weld was a weak point that led to the fracture under load.

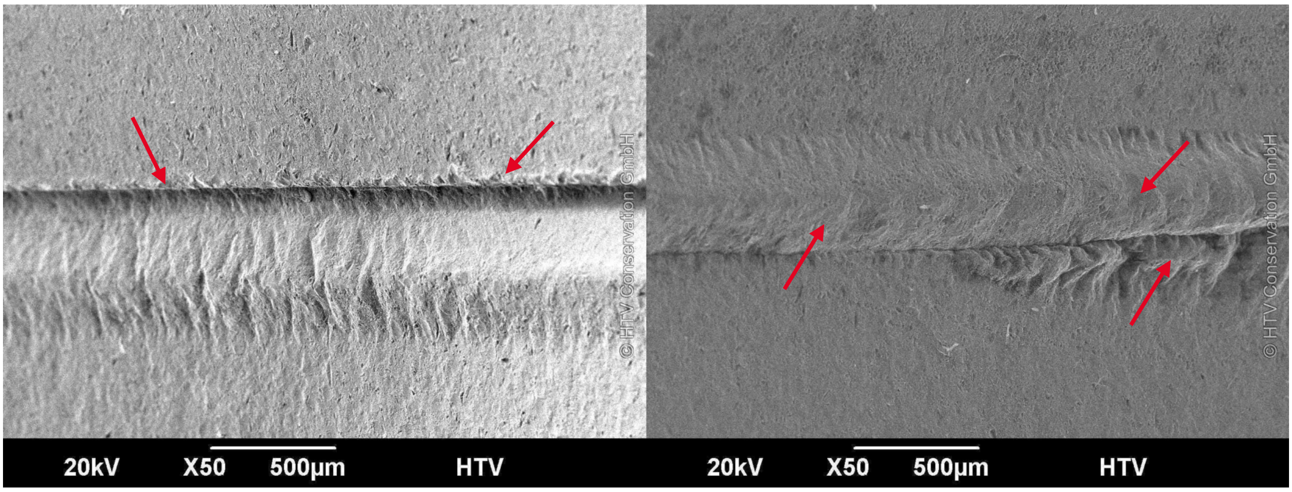

Figure 3: Scanning electron micrograph of the weld seam with undercut a) and overlap b) (conspicuities are marked red)

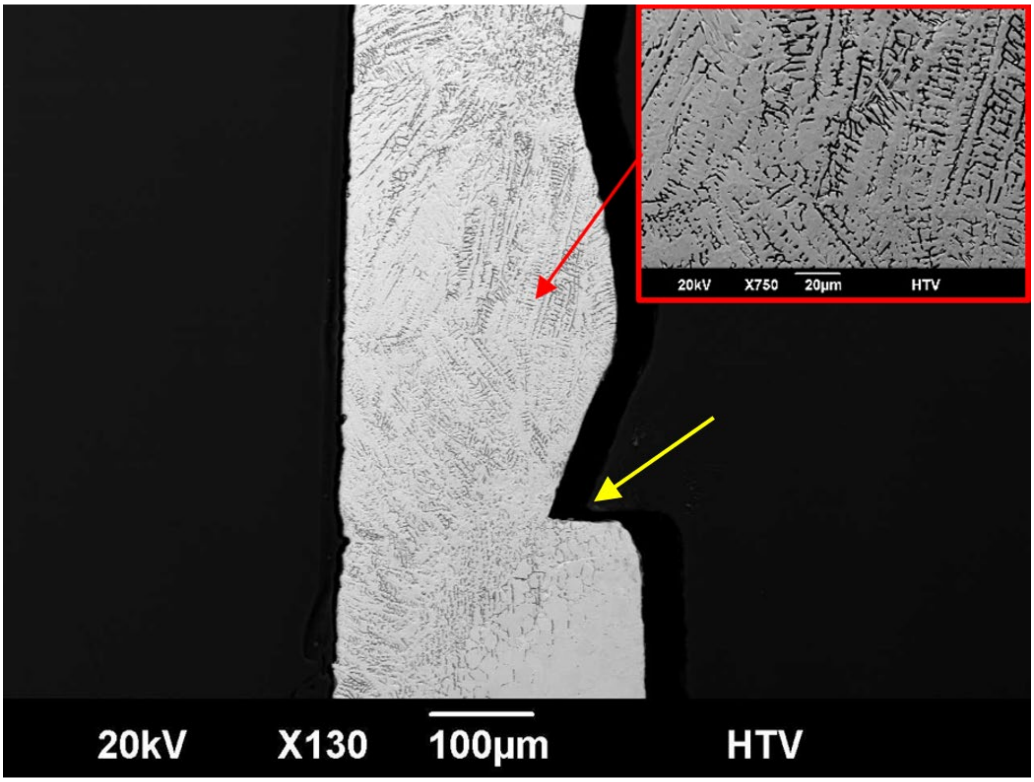

Figure 4: Weld seam in micrograph with undercut (yellow) and dendritic structure (red)

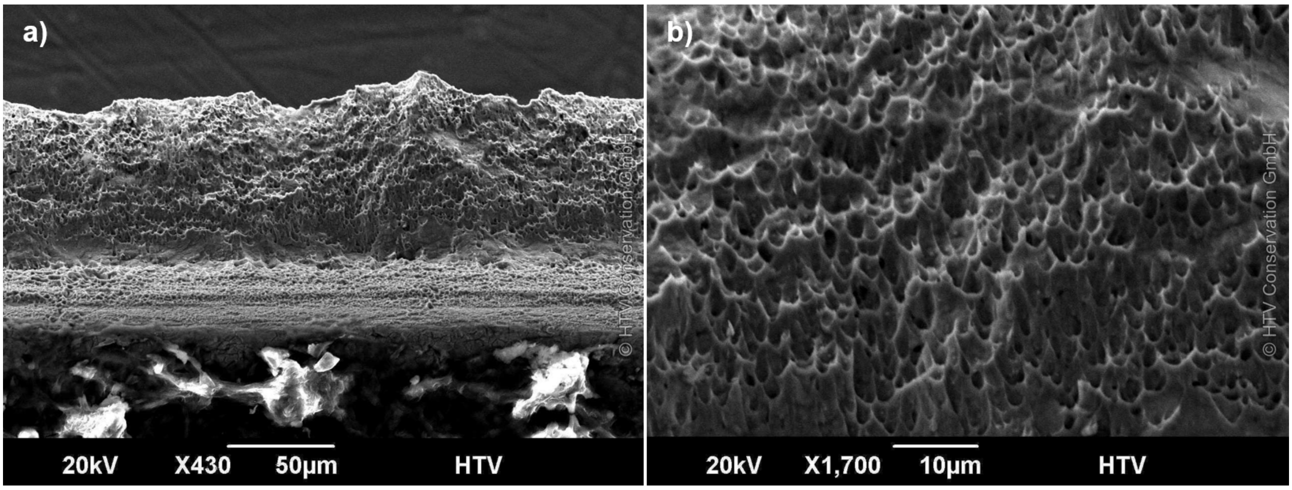

Figure 5: SEM image of the fracture surface with overview a) and detail b)

3. Confirmation of weld geometry as root cause of failure

In order to verify that the weld geometry can be identified as the cause of failure, further measurements were carried out. EDX measurements were carried out to check whether the material used for the weld seam corresponds to that of the workpiece or whether a different material was used, which would be problematic due to potentially deviating mechanical properties. Nanoindentation measurements were also carried out to determine whether there were any differences in hardness between the weld material and the workpiece that could have caused the weld to fail under load.

The measurements showed that the material for the weld seam does not have any differences in its elemental composition compared to the workpiece (cf. Figure 6) and thus material differences can be ruled out as a cause of failure. The hardness of the weld seam is also not considered to be noticeably different from the rest of the material (cf. Figure 7) and therefore cannot be considered as the cause of the failure. The weld geometry is therefore the only possible cause of damage. The penetration notch found along the weld seam exceeds the maximum depth acceptable by DIN EN ISO 5817 and acts with sufficient probability as a crack nucleus in the damage case shown here.

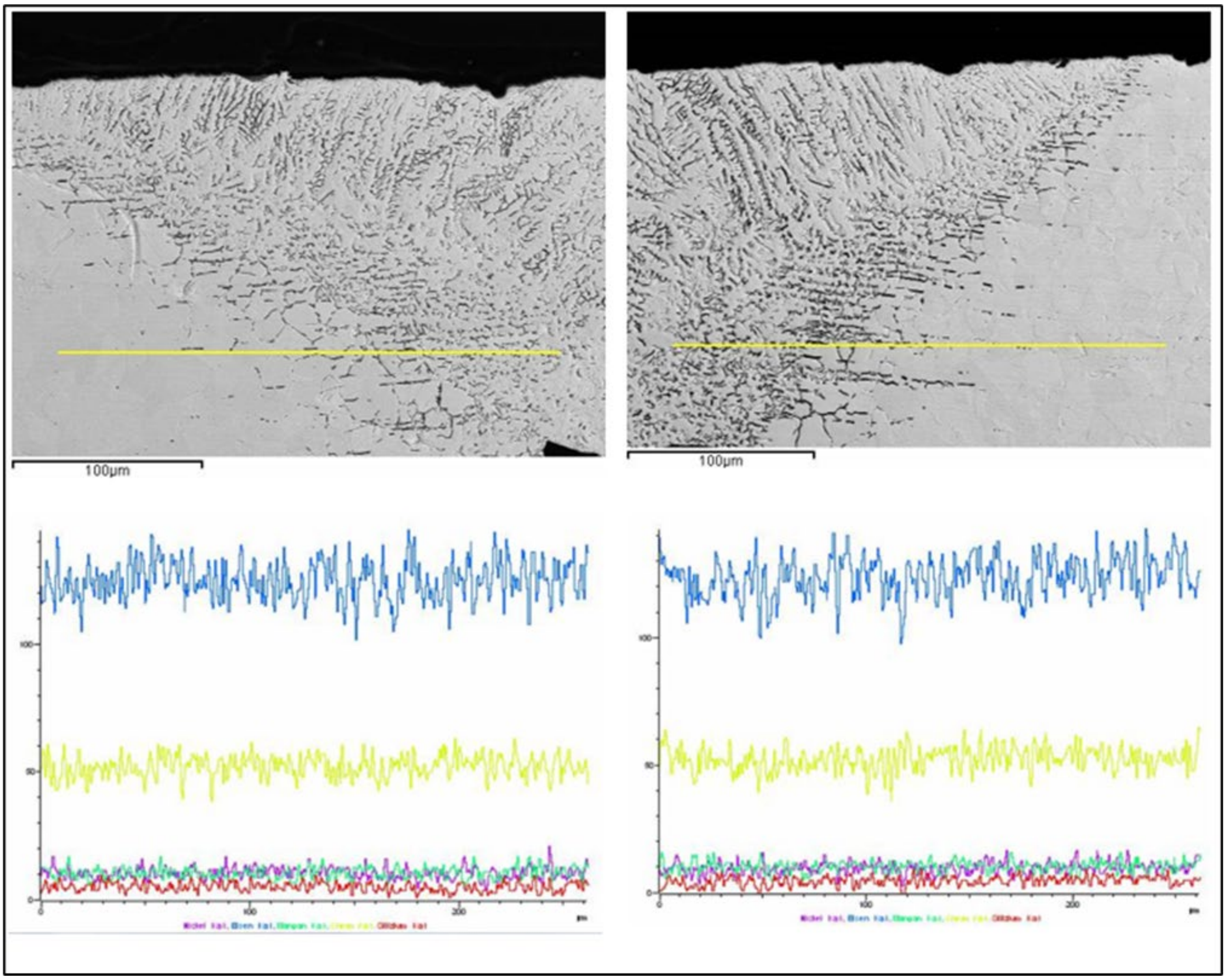

Figure 6: EDX line measurement on both sides of the weld. No changes can be detected along any line.

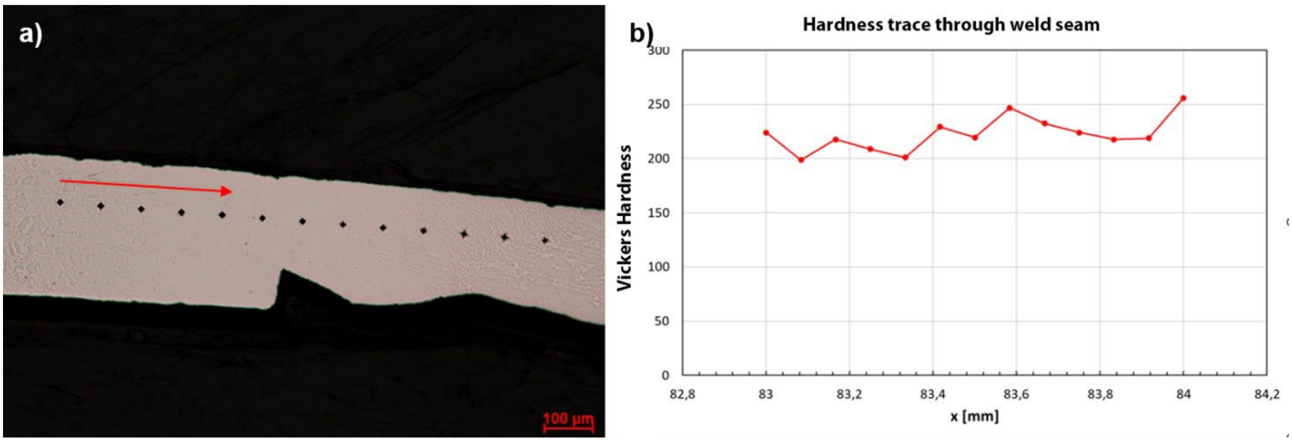

Figure 7: Impressions from nanoindentation along the weld a) and corresponding hardness values b)

4. Conclusion

Based on the structured application of the analytical methods available at the Institute for Material Analysis of ALTER | HTV, a deviation in the weld geometry was clearly proven step by step as the cause of failure in the case described above. ALTER | HTV has the most modern means at its disposal to be able to determine the cause in the event of failure of materials with different structures and geometries. This allows process corrections to be made that prevent future failures. With its Institute for Material Analysis, ALTER | HTV is a strong partner for the solution of your material problems.

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