Measurement verification f the stress reduction on a water vessel by shape modification of a welded part

by Heinz Joas

Shortly before finalizing inspection, a problem was found on the internal wall of a feed water tank at a power station. Cracks with a maximum depth of 4 mm (0.16 in) were found in welded mounting brackets alter a three-year operating period. The tank is 50 m (164 ft) long with a diameter of 4 m (13 ft). All the cracks on the welded parts were ground away and the brackets non-destructively tested again. Metallographic examination showed that the cause of failure was strain-induced crack corrosion. This could be traced to cracks arising in the magnetite coating applied as corrosion protection to the area in question. The cracks were formed on the inside of the tank wall.

The welded brackets acted as local clamps preventing deformation in the container wall which is relatively thin and easily elastically deformable. This in turn leads to stress concentrations in the joint regions. These increased stresses exceed the local strain capabilities of the magnetite coating and induce cracks in it. At the points of these cracks corrosion then causes deeper cracks in the tank wall. With regard to other power station units, it was important to be able to assess the degree to which the stresses arising from the design and from the mechanical and thermal operational loads were significant factors causing the damage. Therefore, strain measurements with strain gages, together with temperature measurements, were carried out at critical points over a few months of operation.

Since the design of the brackets in the regions where they joined the tank wall already pointed to the formation of significant stress concentration at this point, this part was immediately geometrically optimized on a prototype basis. In the cross-sectional transition, which was the most susceptible part, larger radii were ground into the brackets. The success of this modification in shape was tested in a 1:1 model test during the shutdown period. As shown in **Fig. 1**, the relevant area of the tank wall with the welded bracket was copied true in detail and fitted with strain gages on both sides at the various transition points. The uniaxial load was then provided by a tensile testing machine as can be seen in the right part of **Fig. 1**. The strains that occurred on the original and on the optimized cross-sectional transitions were measured with strain gages, the positions of which can be seen in the left part of the figure. In the center part of the figure the reductions in the stress concentration are shown which were obtained due to the shape optimization and changes in operational practice. Just by changing the geometrical shape a reduction in the stress concentration of about 50 % was achieved. Reductions in the stress brought about by a modification in operation are also shown.

The combination of the change of design and the change in operation reduced the local strains to 20 % of their original value. They were then acceptable for the magnetite coating. Regular testing in the last few years of operation has shown that no more cracks have occurred. This confirms the success of the applied remedial measures.

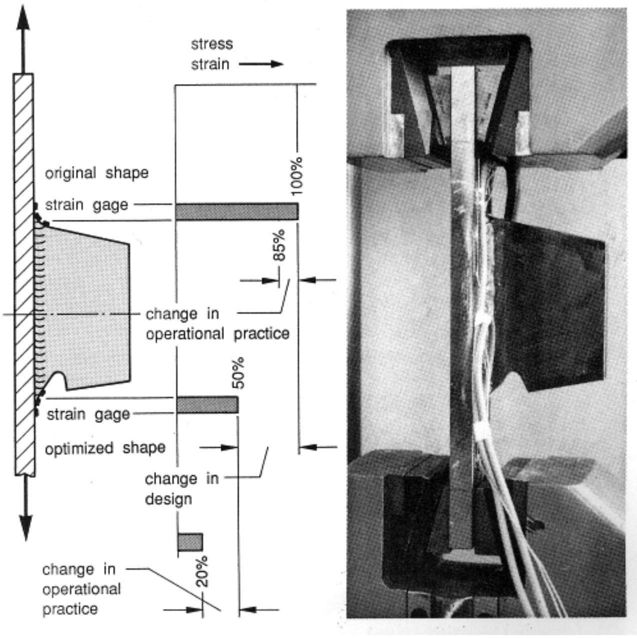

Fig. 1: Shape optimization on the transition region between the welded bracket and the tank wall;

left: original and optimized shape of the transition part and strain-gage measuring points

center: diagram showing the reduction in stress due to the modified shape and the change in operational practice
right: comparison of the stress concentrations in the differently shaped transition regions by strain-gage measurement in a tensile test in a testing machine.

Dipl.-Ing. Heinz Joas conducts field studies in practical stress analysis at the Technical Control Board (TÜV Bayern), Munich, FRG.