Analysing the Welding Process and Post Weld Heat Treatment

Case study

During planned inspections of a steam penetration, the dome end is cut-off to access the steam chest to carry out inspections and internal repairs. As a result, the dome end requires re-welding to the existing steam header in situ. Subsequent inspections of the weld are necessary to confirm the integrity of the weld. In order to justify a reduction in the frequency of these inspections improved estimates of the welding residual stresses were required.

The problem

During the welding process, welding residual stresses are introduced in the welding zone. This arises from differential expansion during the heating and the subsequent shrinkage of the surrounding material during the cooling of the welding process due to the high heat flux.

The welding residual stress will enhance creep deformation whilst under high temperature operation and consequently exacerbates accumulation of creep damage and the potential for reheat crack initiation. This may lead to shorter life of the weld under creep-fatigue loading.

The welding residual stresses need to be stress relieved through post weld heat treatment (PWHT) and in this particular case the new welds are PWHT on-site but are not fully solution heat treated.

Hence accurate calculation of welding residual stresses induced during the welding process is necessary to underwrite continued operation.

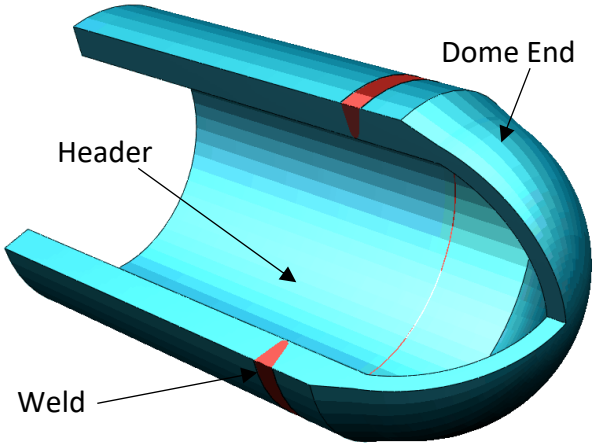

Figure 1 3D Model of the weld and surrounding components

The solution

The proposed welding procedure and PWHT have been simulated to determine the welding residual stress state in the new weld before and after the PWHT process.

Quasi-steady state transient heat transfer and stress analyses were carried out to simulate the high heat flux condition during the welding process where also the application of each of the weld passes was simulated.

A non-linear elastic plastic stress analysis was subsequently performed to determine the accumulation of welding residual stresses throughout the welding process.

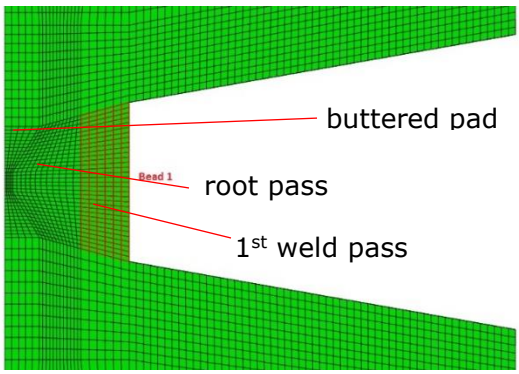

Figure 2 Construction of weld root

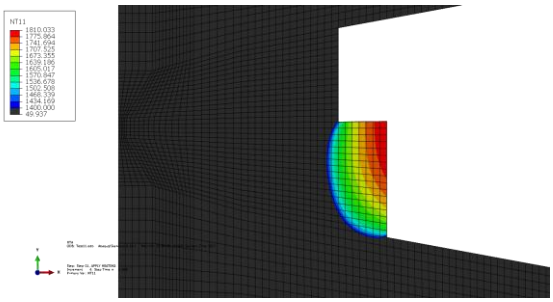

Figure 3 Nodal temperatures in an individual weld pass (°C)

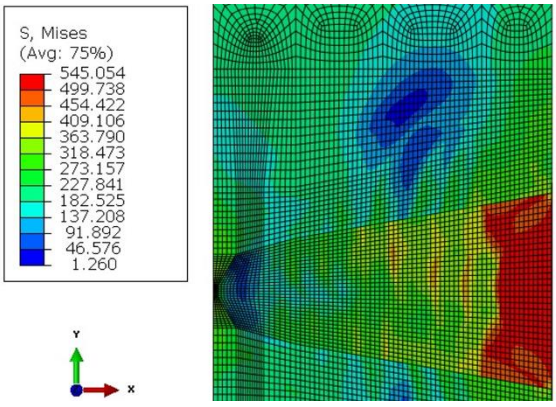

Figure 4 Mises Stress as welded condition (MPa)

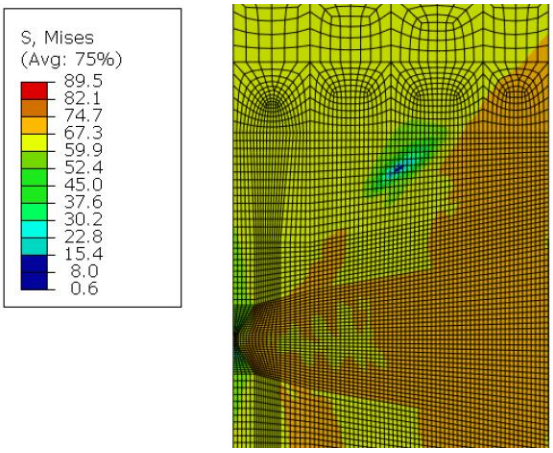

Figure 5 Mises Stress after PWHT (MPa)

The accumulation of creep damage was assessed using heat transfer and visco-plastic creep analyses to predict the creep damage accumulation and to estimate the elastic follow-up factor which can be used in subsequent integrity assessments.

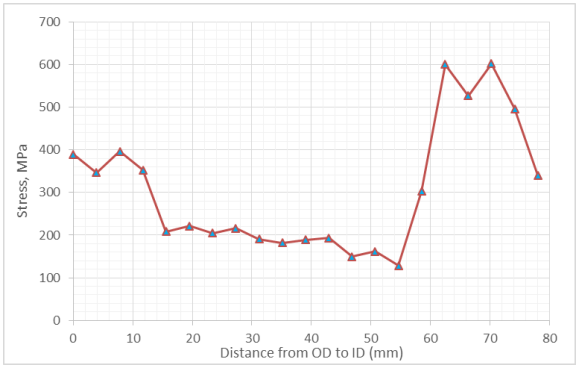

Figure 6 Plot of Mises Stress in as welded condition (MPa)

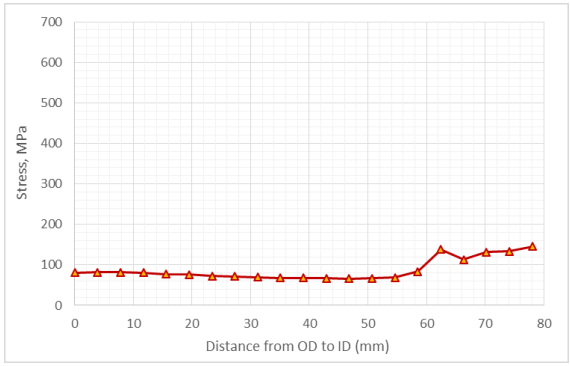

Figure 7 Plot of Mises Stress after PWHT (MPa)

The outcome

It was shown that PWHT reduced the welding residual stress to an acceptable level, such that reheat cracking would not occur during subsequent operation. The total creep and fatigue damage in the weld remains below a level likely to result in defect initiation.

This information was used as part of a safety case to determine the inspection frequency required to underwrite continued operation of the plant.

Other applications

This study was used in a safety case to justify a reduced frequency of weld inspection post repair.

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