Analysis of Residual Stresses in Stainless Steel Clad Piping used in Salt Plant and Methodology for Reducing the Tensile Residual Stress

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Summary

To understand and mitigate the chloride stress corrosion cracking (SCC) in austenitic stainless steel clad on the carbon steel (abbreviated as stainless-clad steel), three major researches were attempted. These are the analysis of cracked stainless-clad steel in a process plant, measurement of residual stresses in but-welded clad plates and development of two counter measures to combat SCC.

Analysis of cracked clad steel revealed that SCC was caused by the mutual action of chloride ion and higher tensile residual stresses induced by cladding and in-site welding operation. Most SCC was found to top its propagation just before the nickel layer inserted between the stainless steel and carbon steel. However, SCC at around the weld bond penetrated to the carbon steel due to the destruction of thin nickel layer, and resulted in severe rusting (Fe_2O_3). To combat SCC, we developed two methods to convert the tensile residual stresses to compressive ones, and measured the residual stresses using the hole drilling method (or the modified Kelsy method developed). Pneumatic shot peening of tough zirconia beads(Y_2O_3-ZrO_2) was found to be promising in its clean operation and resulting higher compressive residual stresses than -60 kgf/mm^2. Both the SCC and rusting over the flat surface were completely mitigated by this method. Second counter measure to mitigate the SCC at weld bond is the post weld cooling (PWC) in which stainless surface was cooled by tap water at an appropriate moment after the welding. It was experimentally demonstrated for a butt-welded clad plates that the welding-induced tensile residual stresses was converted to compressive residual stresses. PWC-treated weldment was demonstrated to be free from any SCC, and could be used as a countermeasure to SCC in stainless steel clad equipment.