Application of Low Plasticity Burnishing to Mitigate SCC of Nuclear Components

EPRI 2010 International Pressurized Water Reactor Conference and Exhibition
Colorado Springs, CO
June 28 – July 1, 2010

Doug Hornbach and Jeremy Scheel
Lambda Technologies
Cincinnati, OH 45227, USA

Brian Hall
Areva NP
Lynchburg, VA 24506, USA

Initial 40 year licensing periods of the 104 commercial light water reactors (LWR) operating in the United States will begin to expire in the next 15 to 20 years. Nuclear power plants will be required to apply for extended licenses to continue operation and avoid a lapse in continuous energy production. A license extension will increase the power plants operating life from 40 to 60 years. There are many technical considerations, including the repair and replacement of aging reactor components, which must be addressed to minimize risk and provide safe and reliable reactor operation through this extended period.

Energy security concerns, and the effort to reduce CO_2 emissions, are prompting the U.S. Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE) to seek new technologies that extend reactor life to well beyond initial 40-year license. In order to safely, efficiently, and economically extend the operational life of LWR systems to 60 years, all critical components such as piping, vessels, and the weldments connecting them, must be able to function reliably. To this end, material degradation problems affecting critical components of reactor systems, such as stress corrosion cracking (SCC), and fatigue, must be addressed. Methods of controlling or mitigating SCC, and increasing fatigue strength, are necessary to achieve low risk life extension of LWR systems. Current inspection and maintenance of these systems to prevent failures due to SCC is costly. Inspection, maintenance and replacement costs for aging reactor systems will continually increase as the operational life is extended.

Welding, machining, and fit-up of reactor components can produce high levels of tensile residual stresses greatly increasing susceptibility to SCC. A surface treatment is needed that can consistently produce deep compressive residual stresses in austenitic and Ni based alloy weldments in order to prevent SCC and increase the reliability and longevity of reactor systems. Post-weld surface enhancement processing via low plasticity burnishing (LPB) can be used to

introduce engineered compression, low cold working and a smooth surface finish in critical regions thereby mitigating SCC. LPB has been developed as a rapid and inexpensive surface enhancement method adaptable to existing CNC machine tools, robots or customized delivery platforms.

Both 304L and 316L SS welded mockups were examined to determine the influence of LPB on the residual stress and SCC behavior. SCC and residual stress test results comparing LPB treated and un-treated samples are presented. Test results conclusively demonstrate that LPB eliminates SCC in 304L and 316L weldments. Residual stress measurements reveal the compressive residual stresses introduced by LPB are stable at temperatures and applied strains representing worst-case reactor conditions. Furthermore, the surface finish following LPB was 10X smoother than the as-received plate material, providing an ideal surface finish for non-destructive examination (NDE).