THERMAL STABILITY OF MECAHNICAL SURFACE TREATMENT INDUCED RESIDUAL STRESS IN AUSTENITIC STAINLESS STEEL BY NEUTRON AND SYNCHROTRON DIFFRACTION

A.D Evans[1], M. Turski[2], S. Clitheroe[2], J. Kelleher[2] and P.J. Withers[2]

[1]European Synchrotron Research Facility (ESRF), 6 rue Jules Horowitz, Grenoble, 38043, France
[2] School of Materials, University of Manchester, Manchester, UK

The fatigue and stress corrosion cracking behaviour of engineering materials have been shown to be significantly improved through the application of optimized mechanical surface treatments. These processes tend to generate significant compressive residual stresses in the near surface layers of material following localized plastic deformation of the surface of the treated material. In the case of mechanical surface treatments such as laser shock peening and ultrasonic impact treatment (UIT) among others, the compressive residual stress layer can extend to a depth in the order of millimeters beneath the surface, with balancing tensile stresses extending deeper still. These typical depths are of an order of magnitude greater than conventional shot peening. The presented study is a part of a wider ranging project to understand the stress corrosion cracking benefits gained by mechanical surface treatment of welded stainless steel structures operating at elevated temperatures. The presented results characterize the magnitudes and depth of compressive residual stresses generated in 304 austenitic stainless steel plates using monochromatic neutron diffraction using oscillating radial collimator optics to suppress spurious strains. The samples were treated with both high and low intensity variations of shot peening (SP), laser shock peening (LSP) and ultrasonic impact treatment (UIT). Ex-situ measurements followed in order to characterize the thermal relaxation the as-treated residual stresses exposed to typical operating temperatures (350°C) and higher operating temperature (550°C). Subsequent monochromatic synchrotron diffraction measurements on thin slices electro-discharge machined from the samples were performed to characterize the reduction of plastic work following thermal relaxation by correlating the peak widths of the surface treated slices to samples strained to known levels of plastic strain. These measurements aimed to assess empirically the influence of plastic deformation on the extent of thermal relaxation observed. By combining these complementary diffraction techniques, the thermal stability residual stresses can be characterized and an estimation of plastic work levels and their stability can be assessed.