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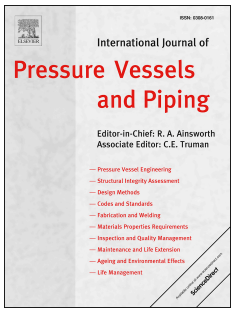

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Investigating Optimal Cutting Configurations for the Contour Method of Weld Residual Stress Measurement

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Abstract

The present work examines optimal cutting configurations for the measurement of weld residual stresses (WRS) using the contour method. The accuracy of a conventional, single-cut configuration that employs rigid clamping is compared with novel, double-embedded cutting configurations that rely on specimen self-constraint during cutting. Numerical analyses examine the redistribution of WRS and the development of cutting-induced plasticity (CIP) in a three-pass austenitic slot weld (NeT TG4) during the cutting procedure for each configuration. Stress intensity factor (SIF) analyses are first used as a screening tool; these analyses characterise lower stress intensities near the cutting surface when double-embedded cutting configurations are used, relative to SIF profiles from a single-cut process. The lower stress intensities indicate the development of CIP – which will ultimately affect back-calculated WRS – is less likely to occur when using an embedded configuration. The improvements observed for embedded cutting approaches are confirmed using three-dimensional finite element (FE) cutting simulations. The simulations reveal significant localised plasticity that forms in the material ligaments located between the pilot holes and the outer edges of the specimen. This plasticity is caused by WRS redistribution during the cutting process. The compressive plasticity in these material ligaments is shown to reduce the overall tensile WRS near the weld region before this region is sectioned, thereby significantly reducing the amount of CIP when cutting through the weld region at a later stage of the cutting procedure. Further improvements to the embedded cutting configuration are observed when the equilibrating compressive stresses in material ligaments are removed entirely (via sectioning) prior to sectioning of the high WRS region in the vicinity of the weld. All numerical results are validated against a series of WRS measurements performed using the contour method on a set of NeT TG4 benchmark weld specimens.

Keywords: Contour method; Finite element modelling; Residual stress; Welding.