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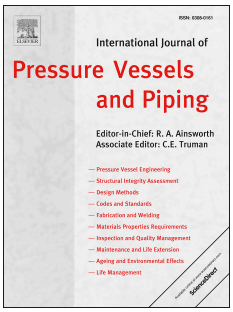

The NeT Task Group 4 residual stress measurement and analysis round robin on a three-pass slot-welded plate specimen

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PII: S0308-0161(16)30142-9

DOI: 10.1016/j.ijpvp.2017.09.003

Reference: IPVP 3648

To appear in: *International Journal of Pressure Vessels and Piping*

Received Date: 1 April 2016

Revised Date: 26 September 2017

Accepted Date: 29 September 2017

Please cite this article as: Smith MC, Smith AC, Ohms C, Wimpory R, The NeT Task Group 4 residual stress measurement and analysis round robin on a three-pass slot-welded plate specimen, *International Journal of Pressure Vessels and Piping* (2017), doi: 10.1016/j.ijpvp.2017.09.003.

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The NeT Task Group 4 residual stress measurement and analysis round robin on a three-pass slot-welded plate specimen

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ABSTRACT

Accurate prediction and measurement of residual stresses in welds is an important part of assuring their short and long-term structural performance in high value, safety critical engineering components and structures. However, both measurements and predictions of weld residual stresses often exhibit high levels of variability that are not widely appreciated. The mission of the European Network on Neutron Techniques Standardization for Structural Integrity (NeT) is to develop experimental and numerical techniques and standards for the reliable characterisation of residual stresses in structural welds.

The NeT Task Group 4 project examined residual stresses in a three-pass slot-welded plate specimen fabricated from AISI 316L(N) austenitic stainless steel plate. Several nominally identical specimens were fabricated under closely controlled conditions, with detailed records kept of the manufacturing history, weld process parameters, transient temperatures during welding, and the resulting geometric distortions. Comprehensive stress-strain material property characterisation was then undertaken, extending to the isothermal cyclic tests necessary to calibrate the mixed isotropic-kinematic material hardening models required for accurate weld residual stress prediction. Parallel residual stress measurement and simulation round robins were performed by a large number of participants from around the world.

Residual stresses were measured using neutron and high energy synchrotron diffraction, surface X-ray diffraction, surface and deep hole drilling, the contour method, and ultrasonics. Neutron diffraction measurements were made at eight different instruments. The diffraction measurements database alone is large enough to generate reliable mean profiles, to identify clear outliers, and to establish that there is no statistically significant difference in the residual stress field in the specimens used for the non-destructive measurements. Net Task Group 4 gives a unique insight into the real-world variability of diffraction-based residual stress measurements, and forms a reliable foundation against which to benchmark other measurement methods.

NeT Task Group 4 is also a unique test bed for the development and validation of weld residual stress simulation techniques in austenitic stainless steel. Its combination of extensive materials characterization, accurately characterized welding temperature transients, and reliable residual stress and distortion measurements is currently unrivalled. About thirty finite element simulations were submitted to the network over the course of the project, giving insights into the required accuracy of welding thermal solutions, the mechanical solution accuracy achievable using optimized material constitutive models, and the level of acceptable error in finite element residual stress simulation results for use in structural integrity assessments of high integrity engineering components.

KEYWORDS

Welding, Weld modelling, Residual stress measurement, Finite element modelling, Materials characterisation

1 INTRODUCTION

Residual stresses are those left in a stationary body in the absence of any external load or internal thermal gradient [1]. They are caused by the generation of misfit strains through localised plastic deformation. The welding process is a common source of residual stress, due to the large localised

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