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Towards Real-Time Ultrasound Driven Inspection and Control of GTA Welding Processes for High-Value Manufacturing

Nina E. Sweeney[1,2*], Charles N. MacLeod[1], Ewan Nicolson[1], Dave Lines[1], Simon Parke[2], Stephen G. Pierce[1]

[1]*Centre for Ultrasonic Engineering (CUE), Department of Electronic & Electrical Engineering, University of Strathclyde, Glasgow, G1 1XQ, UK*

[2]*Peak NDT Ltd, Jubilee Business Park, 1 Enterprise Way, Derby, DE21 4BB, UK*

* nina.sweeney@strath.ac.uk

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Many industrial sectors, such as nuclear and defence, employ high-integrity welding processes for the manufacture of safety-critical, high-value components. Non-Destructive Evaluation (NDE) techniques are used to ensure the strength and safety of these components both before they reach service and throughout their service-life. Often these welded components are composed of thick-sections which necessitate the use of a multiple-pass weld deposition strategy. As a result of the traditional inspection approach occurring only after the deposition of all weld runs, defects which have been introduced in early weld runs remain undetected and buried until the final inspection. This greatly complicates the re-work procedure, increases material wastage and the associated costs as well as delaying early correction of improper process parameters.

With the nuclear sector being called upon to play a significant role in the delivery of low-carbon energy production there has been an increasing drive to reduce manufacturing costs. The development and deployment of innovative in-process inspection and control strategies is one method being explored to help achieve this. Through in-process inspection and monitoring of the welding process, it is possible to detect the formation of defects at the earliest possible point to enable quicker, more efficient, and more cost-effective correction and repair.

As the most critical weld run within any multi-pass weld is the root pass, it is vital that this be monitored precisely to ensure integrity of the welded joint. Here, the feasibility of using single element and phased array ultrasonic approaches to interrogate and analyse the molten weld pool during robotic deposition of a Gas Tungsten Arc Welding (GTAW) root pass of a common multi-pass weld joint (90 degree included bevel angle, 1.5 mm root face height and 3.2mm root gap) is explored.

Through processing and analysis of the received shear and longitudinal ultrasonic waves, this technique is shown to be capable of screening root pass width and height and joint fusion, critically indicating lack-of root fusion. This capability directly informs in-process inspection and monitoring and enables the potential for closed-loop control with the opportunity to correct for any defects as they are formed. The concept of utilising a similar strategy for upper passes within multi-pass welds is introduced. Along with the wildly varying wave propagation path and associated impedance variations, the challenges encountered during discrimination of the solid lower and upper molten passes are presented along with suitable signal processing techniques to counteract for these.