Weld Defect Downscaling Recognition for Phased Array Ultrasonic Data Based on Semantic Segmentation

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Phased array ultrasonic testing (PAUT) is one of the most advanced ultrasonic inspection methods, providing inspection data in image sequences with increased resolution and coverage, consequently enhancing inspection efficiency. Due to the inherently abstract nature of ultrasound images, the analysis of PAUT weld data continues to rely on the expertise of experienced inspectors, particularly in the context of shipbuilding welds, which exhibit characteristics such as arbitrary lengths, varying thicknesses, and various weld methods, particularly when associated with hybrid laser-arc welding involving higher upper caps and narrower fill widths. This paper applies a semantic segmentation architecture to PAUT data for hybrid laser-arc welding to segment defects automatically. By incorporating PAUT imaging principles and scan processes, a PAUT image dataset is established, with data presented as a volume image and the downscaled target being binary images to recognize defect characteristics such as location, length, depth, and height. This dataset contains 196 defects collected from shipyards, encompassing three thicknesses and two scan angles. The proposed architecture for defect segmentation possesses three key properties: (1) It adopts an encoder-decoder architecture that enables direct localization and sizing defects. (2) It handles PAUT image sequences of arbitrary length, eliminating the need for horizontal scale normalization while preserving the integrity of defect shapes. (3) The architecture incorporates a specially designed size of the convolutional kernel to reduce the data's dimension in width, thereby significantly enhancing computational efficiency. The proposed architecture was validated in the aforementioned dataset to demonstrate the superiority of the proposed method in locating and sizing defects in PAUT weld data, offering a promising automated solution to a challenge in ultrasonic inspection methodologies.