Study of Thermal Gradient Effect for In-Process Ultrasonic Inspection of Fusion Welding

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Background, Motivation and Objective

Ultrasonic Non-destructive Evaluation (NDE) is a well-established inspection method in welding industry. Currently the manufacturing and inspection are two separate processes in the supply chain, which limits productivity and increases re-work. With the recent advances of robotic automation in welding, it is therefore advantageous to consider combining the NDE at the point of manufacturing. Among the many challenges associated with the deployment of in-process inspection of automated welding, this paper focuses on the heterogeneous temperature distribution within the weldment, and the resulting contribution to low signal to noise ratio and potential for poor defect localization in the resultant image.

Statement of Contribution/Methods

The sample under consideration is a 15mm thick steel specimen with a 60° single V-groove weld. In order to consider the thermal distribution in the weldment, and the associated spatial variation in elastic properties, a finite element (FE)-derived thermal distribution maps obtained from a weld model were corroborated experimentally using thermocouple measurements. The resultant map comprises various temperature zones across the specimen, which were then assigned appropriate material properties to represent the effect of temperature variation on wave propagation. The wave propagation model (PZFlex, OnScale, CA, USA) analyzed the performance of a 5 MHz, 64-element linear array coupled to an angled high temperature wedge to perform shear wave inspection of lack of fusion defect at the weld root center. A control model was also built assuming a homogeneous steel medium at a uniform temperature.

Results/Discussion

With beam steering via an appropriate delay law, a 70° shear wave was generated in steel plate for weld root inspection. Preliminary results were obtained by utilizing a thermal map with temperature varying from 128 to 150°C. This particular map was created to represent the measured scenario 6 minutes after completion of the weld process. By contrast, the control model was assumed to be spatially isothermal at 150° C. Results show that with thermal distribution considered, the energy arrived at the defect was 40% lower, with negligible differences in time of flight when compared to the control. A challenging range of experimental scenarios with significant temperature variations will be presented to provide imaging correction information towards in-process inspection.

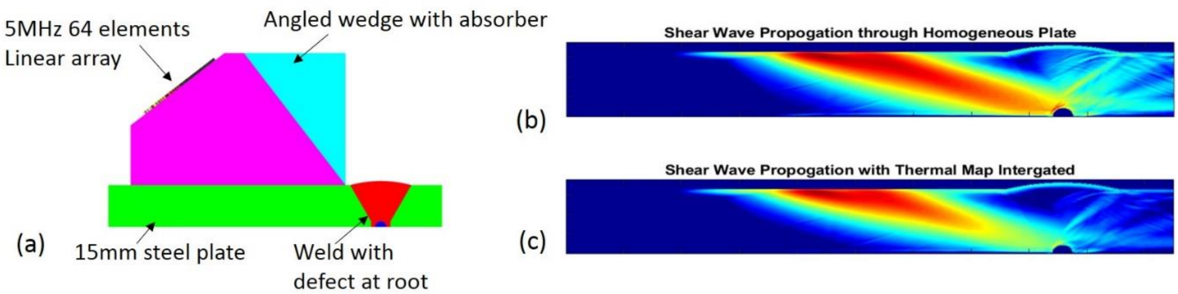

Figure.1 (a) The schematic diagram of FE model; (b) the shear beam profile within the steel weldment when considering the plate was homogenous under the temperature of 150°C; (c) when considering thermal distribution with temperature varies from 128 °C to 152 °C