ONE-STEP DISTORTION SIMULATION OF PULSED LASER WELDING WITH MULTI-PHYSICS INFORMATION

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Abstract
The pulsed laser welding technique involves complex physical mechanisms, which demand a multi-physics welding simulation for reliable computational analysis. Although the multi-physics simulation provides high accuracy in detailed welding information, it is difficult to apply in practice, as it requires vast computational resources for systematic analysis. We propose a highly efficient and reliable simulation technique based on multi-physics analysis and mechanical analysis. The developed technique is used to efficiently and reliably simulate a complete model of a nuclear fuel spacer grid by introducing a virtual welding distortion that exports the thermo-mechanical information. This study has the potential to develop the computational analysis and optimization of a sequence of pulse laser welding in a nuclear fuel spacer grid.

Key Words: Pulsed Laser Welding, Multi-Physics Analysis, Welding Distortion, Nuclear Fuel Spacer Grid, Finite Element Analysis

1. INTRODUCTION

Conventional welding methods, such as arc welding, are widely used for joining metal specimens with a high-strength bond. However, the accumulated thermal energy and temperature gradients result in large welding distortions and residual stress in the specimens. To prevent this side-effect of the welding assembly process, several welding techniques have been proposed, such as laser spot, friction stir, and magnetic pulse welding. Laser spot welding is appropriate for minimizing the thermal distortion and residual stress. A laser heat source focuses a large amount of energy in a small area, and the pulsed welding requires less energy than continuous welding in joining components. Thus, pulsed welding generates a narrow heat-affected zone (HAZ) that is closely related to the welding distortion. Pulsed laser welding consists of several overlapping welding spots that are repeatedly heated rapidly and cooled down over a period of seconds.

Each spot welding technique involves complex physical mechanisms, such as keyholes. These physical mechanisms are closely related to the parameters of pulse welding, such as the peak power, duration, and frequency of the pulses. Thus, there have been many attempts to parameterize the laser spot welding technique and to analyse the effect of each parameter on the welding distortion. Ghosh predicted the dimensions of the HAZ arising from submerged arc welding and optimized the input parameters, such as power and speed, in order to get better bead quality and minimum HAZ width [1]. Bukvic studied the fatigue failure at the HAZ of a bi-material welded joint [2]. Weckman et al. analysed the relationships between the parameters of laser spot welding, such as the pulse duration and power density, and different diameters and depths of the welding spot [3]. Tzeng investigated the effects of the welding parameters, including the mean power, pulse energy, and the traverse speed, on the dimensions of the welding spot and the weldability [4]. Fuerschbach and Eisler predicted the size of a welding spot from the experimentally measured pulse energy and duration [5]. Tadamalle studied the influence of the transverse speed and peak power on the geometry of


