MACHINE LEARNING-BASED PREDICTIVE APPROACHES FOR DESIGNING HOT CRACK FREE WELDMENTS

A THESIS

Submitted by

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in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

FACULTY OF MECHANICAL ENGINEERING

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JUNE 2023

ABSTRACT

Hot cracking, also known as solidification cracking, poses a significant challenge in welding AA7075, stainless steel 310, and Inconel 625 alloys, limiting their applications in industries like automotive and aerospace due to high cracking sensitivity. This study aims to address these issues by employing ultrasonic vibration during welding to eliminate hot cracking and enhance joint strength. The focus is on conventional TIG welding, incorporating ultrasonic vibration, and filler materials, and optimizing welding parameters for Houldcroft weldability test specimens. The goal is to identify optimal parameters to mitigate hot cracking and improve joint strength. Additionally, the study aims to develop predictive models using machine learning algorithms for hot cracking sensitivity and microhardness.

The literature review underscores the significance of ultrasonic-assisted TIG welding in various manufacturing sectors, especially for hot cracking susceptible materials like AA7075, Inconel 625, and stainless steel 310 alloys. While some reports suggest that certain solid-state welding processes can mitigate fusion welding challenges, concerns such as joint softening, mechanical property deterioration, and process complexities hinder their widespread adoption. The use of appropriate filler material is explored to locally alter weld chemistry and reduce hot cracking sensitivity, although this may come at the expense of joint strength. Recent literature suggests that external vibratory fields, such as mechanical and ultrasonic vibrations, can significantly alleviate hot cracking sensitivity by promoting the formation of fine-grained structures in the weld metal.

While various studies have explored traditional TIG welding aspects, there is a gap in utilizing statistical analysis for ultrasonic-assisted TIG welding. This research aims to fill this gap by modifying TIG welding for hot cracking susceptible materials and investigating both conventional and ultrasonic-assisted methods, with and without fillers. The Houldcroft test specimens are employed to measure welded joints' hot cracking sensitivity and microhardness. Response

Surface Methodology (RSM) and RSM - Genetic Algorithms (GA) are used for optimization.

In Chapter 4, weldability tests on AA7075 alloy with ultrasonic vibration and filler material ER5356 are conducted. The RSM approach analyzes the effects of welding parameters on hot crack susceptibility and microhardness, with GA optimization identifying optimal process parameters. Tensile strength analysis validates the optimized parameters, confirming the significant reduction in hot crack susceptibility and improved mechanical properties. Machine learning algorithms are used to develop prediction models, with the random forest regression model showing superior performance. Sensitivity analysis highlights ultrasonic vibration as a crucial parameter.

Chapter 5 focuses on Inconel 625 specimens using ultrasonic vibration and ERNiCrMo-3 filler metal. Similar methodologies are employed, revealing that ultrasonic vibration and filler material significantly improve mechanical properties. Predictive models using machine learning again favor the random forest regression model, emphasizing the importance of ultrasonic vibration and filler material.

Chapter 6 describes welding 310 stainless steel specimens with and without ultrasonic vibration and ERSS310 filler material. RSM analysis, GA optimization, and machine learning models show that ultrasonic vibration and filler enhance mechanical properties, with sensitivity analysis emphasizing the importance of ultrasonic vibration.

Overall, the study, through RSM-GA optimization and machine learning models, presents a promising solution for creating crack-free welded joints in AA7075, Inconel 625, and stainless steel 310 alloys. The incorporation of ultrasonic vibration in traditional TIG welding emerges as a crucial factor in reducing hot cracks and strengthening joints, offering valuable insights for industries relying on these alloys for safety and structural integrity.