Chapter 9

Enhancing Steel Performance Through Microwave-Based Cladding Solutions:

A Next-Generation Welding Method for Surface Engineering

Manish Sharma
https://orcid.org/0009-0006-4037-3217

Department of Mechanical Engineering, Chandigarh Group of Colleges Jhanjeri, Mohali, India

Shalom Akhai
https://orcid.org/0000-0002-7533-457X

Department of Mechanical Engineering, M.M. Engineering College, Maharishi Markandeshwar University, Haryana, India

Harvinder Singh
https://orcid.org/0000-0001-7304-7270

Department of Mechanical Engineering, Punjabi University, Patiala, India

ABSTRACT

Surface engineering plays a pivotal role in enhancing the performance, durability, and functionality of steel components across industries such as automotive, aerospace, energy, and manufacturing. Traditional welding and cladding techniques, while effective, often face limitations such as high thermal distortion, residual stresses, and limited material compatibility. Microwave-based cladding has emerged as a next-generation welding method, offering unique advantages in terms of energy

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efficiency, precision, and material versatility. This chapter explores the principles, advancements, and applications of microwave-based cladding solutions for enhancing steel performance. The chapter also discusses the challenges, future prospects, and potential of this innovative technology in surface engineering.

1. INTRODUCTION

The growing need for advanced surface engineering techniques to enhance steel performance under extreme conditions has led to the development of innovative welding technologies, with microwave-based cladding emerging as a significant breakthrough. This technique provides distinct advantages over conventional welding and cladding methods, such as rapid heating, superior energy efficiency, and improved metallurgical bonding. Traditional welding processes often result in excessive energy consumption, large heat-affected zones (HAZ), and compromised bonding integrity, whereas microwave-based cladding mitigates these drawbacks, making it a promising solution for various industrial applications (Vasudev et al., 2019; Thakur et al., 2024). Microwave cladding involves a carefully controlled sequence of steps to ensure optimal bonding and surface enhancement. The process begins with the pre-treatment of both the substrate and cladding material, ensuring proper adhesion and compatibility. Once prepared, the materials are subjected to microwave radiation, which induces localized melting and metallurgical bonding between the clad layer and the substrate. The rapid heating effect minimizes energy wastage and thermal distortion, significantly reducing the extent of the heat-affected zon (Singh et al., 2021). Following the bonding process, the clad surface undergoes post-processing treatments such as heat treatment, polishing, or surface modifications to refine the microstructure and enhance mechanical properties. Compared to traditional cladding techniques, microwave-based cladding offers numerous advantages, including lower energy consumption, improved bonding strength, and greater uniformity in microstructural characteristics. The fine-grained microstructure resulting from the rapid heating and cooling cycles minimizes defects such as porosity and phase segregation, contributing to enhanced material performance (Akhai et al., 2021; Kumar et al., 2024). The mechanical and functional properties of microwave-clad layers make this technique highly valuable for industrial applications. The rapid solidification process increases hardness and wear resistance, making it ideal for components exposed to high-friction environments. Additionally, the reduction in residual stresses improves fatigue strength, ensuring a longer service life for critical components operating under cyclic loading conditions. Another key benefit is superior corrosion resistance, as the controlled microstructure and strong metallurgical bonding enhance the material’s ability to withstand oxidation

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