

CHAPTER 7 THERMAL ANALYSIS OF OSCILLATION LASER WELDING FOR DISSIMILAR ALLOYS

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7.1 INTRODUCTION

The steel-aluminium hybrid bodies have garnered widespread attention as a solution to the challenges of carbon emissions and fuel efficiency in the automobile industry. This is primarily due to the low density of aluminium, its high strength-to-weight ratio, superior deformability, excellent corrosion resistance, and recyclability. However, the significant disparities in physical and chemical properties, encompassing factors such as melting point, thermal conductivity, and the constrained solubility between steel and aluminium alloy, inevitably facilitate the formation of Iron-aluminum (Fe-Al) intermetallic compounds (IMCs) at the interface. The inherent hardness and brittleness of Fe-Al IMCs are critical factors leading to microcracks formation, resulting in a significant reduction in mechanical properties and lifespan of steel-aluminium hybrid bodies (Kotadia et al., 2022).

Oscillation laser welding has attracted significant interest in the field of mechanical manufacturing due to its ability to enhance weld quality by homogenizing IMCs through the agitation of the molten pool. The bonding width and the quality of weld formation have been verified by

using oscillation laser (Wang et al., 2019). The finite element model has been confirmed as an effective method to simulate oscillation in laser welding (Xu et al., 2004). In this Chapter, oscillation laser welding was performed on dissimilar galvanized steel sheet and aluminum alloy sheet.

7.2 OSCILLATION LASER WELDING OF FE/AL ALLOY

The scheme of oscillation laser welding for Fe/Al alloys is illustrated in Figure 7.1. Li et al. (2022) confirmed that the circular oscillation mode was the most effective compared to other modes. Therefore, this study employs a counterclockwise circular oscillation mode, with the laser spot trajectory depicted. The combination of circular motion and linear motion in the welding direction results in a helical trajectory. This technique widens the welding seam and significantly reduces the temperature gradient and porosity by agitating the weld pool. Oscillation laser welding involves two key parameters: oscillation amplitude and oscillation frequency. To better study the effect of these oscillation parameters on the performance of Fe/Al dissimilar joint and its corresponding temperature characteristics, finite element analysis was employed.

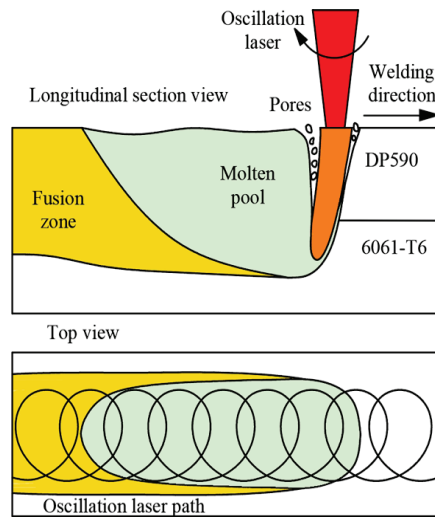


Figure 7.1 The scheme of oscillation laser welding for Fe/Al alloys
(Source: Guo et al., 2023)

7.3 FINITE ELEMENT MODEL

During the process of laser welding dissimilar steel and aluminium alloys, an instantaneous non-uniform temperature field is generated, resulting in significantly higher temperatures within the weld seam compared to the surrounding area. To thoroughly understand the temperature distribution of the weldment and the effects of oscillation amplitude and frequency on the temperature field during oscillation laser welding, a finite element method (FEM) model was developed. Thermal analysis of laser welding was performed to validate the computational model by comparing the molten pool morphology and thermal cycle curves. This FEM model provides a foundational framework for studying the thermal characteristics at the interface (referring to Figure 7.2).

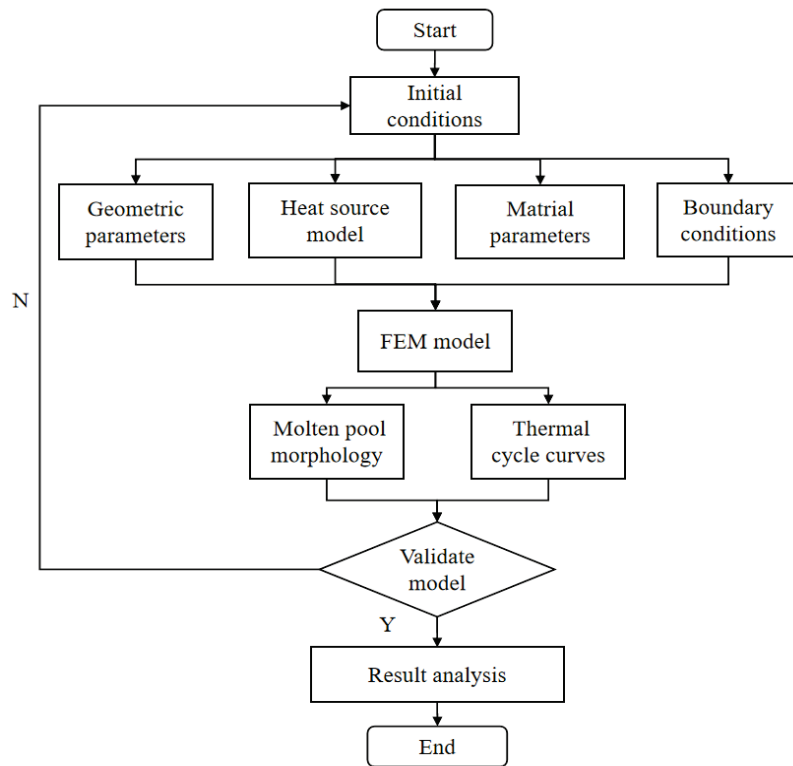


Figure 7.2 Finite element method process for oscillation laser welding