ISSN 2706-655X Vol. 7, Issue 2: 62-66, DOI: 10.25236/IJFET.2025.070209

Research Progress on Laser Welding Technology of Copper Aluminum Dissimilar Materials for New Energy Vehicle Batteries

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Abstract: *With the rapid development of the new energy vehicle industry, the laser welding technology of copper-aluminium dissimilar materials has received wide attention in battery manufacturing. This paper reviews the current study status of laser welding technology for Cu-Al dissimilar materials, focusing on the analysis of thermal behaviour, molten pool morphology, performance metrics of welded joints and the application of numerical simulation during the welding process. By summarising the research progress at home and abroad, the application prospect and future research direction of this technology in new energy vehicle battery manufacturing are discussed.*

Keywords: *New energy vehicles, Copper-aluminium dissimilar materials, Laser welding, Thermal behaviour, Numerical simulation*

1. Introduction

The rapid development of new energy vehicles has put forward higher requirements for battery manufacturing technology. Copper and aluminum are often used in battery systems caused by their excellent conductivity and low cost. However, there are many challenges in welding copper and aluminium dissimilar materials, for example, there are significant differences in physical and chemical properties, and brittle intermetallic compounds are more likely to form. Laser welding technology provides a new solution for joining copper and aluminium dissimilar materials with its advantages of high energy density and precise control of heat input. This paper surveys the research developments of laser welding technology for copper and aluminium dissimilar materials, focusing on the thermal behaviour during the welding procedure and its effect on the welding quality.

2. Current Status of Research on Laser Welding Technology for Copper and Aluminium Dissimilar Materials

2.1. Thermal behaviour of the weld interface

The caloric behaviour of the weld boundary of copper-aluminium dissimilar materials is a key factor affecting weld quality. Studies have shown that factors, namely, laser power and welding speed have a significant effect on weld formation and microstructure formation. Wu Yan et al[1] significantly improved the weld formation of copper pole lugs and aluminium alloy busbar by adjusting the laser power and welding speed (shown in Figure 1). Yu Haojie et al[2] probed the effects of laser power and scanning speed on the morphology and temperature field of the molten pool through finite element simulation, which provided a theoretical reference for copper-aluminium welding.

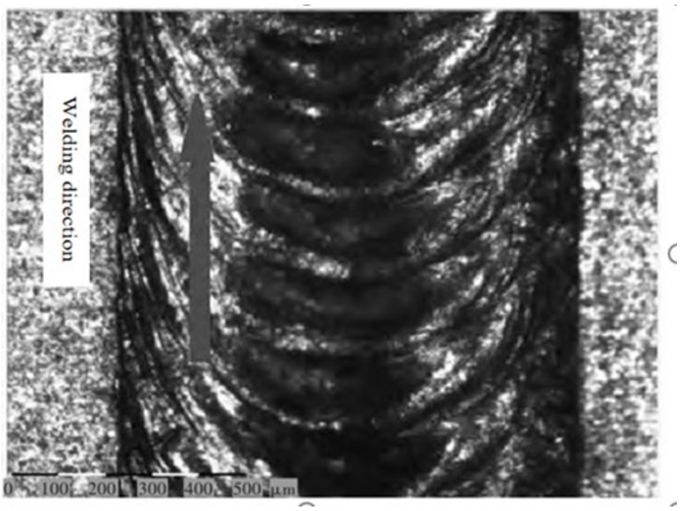

Figure 1: Surface morphology of Cu-Al welding joint[1].

2.2. Melt pool morphology and welding quality

The molten pool morphology directly affects the microstructure and mechanical properties of welded joints. Peng Jin et al[3] studied the impact of filler material on the molten pool morphology and flow behaviour by establishing a three-dimensional transient laser welding heat-flow coupling model, and found that the filler material is not conducive to the stability of the keyhole, which can easily lead to the production of porosity and inclusions.Zhou et al[4] examined the result of the alternating field on the molten pool morphology of laser filler welding of aluminium alloys, and the results showed that the oscillating magnetic field can significantly increase the depth of melting of the molten pool and penetration ability (as shown in Figure 2).

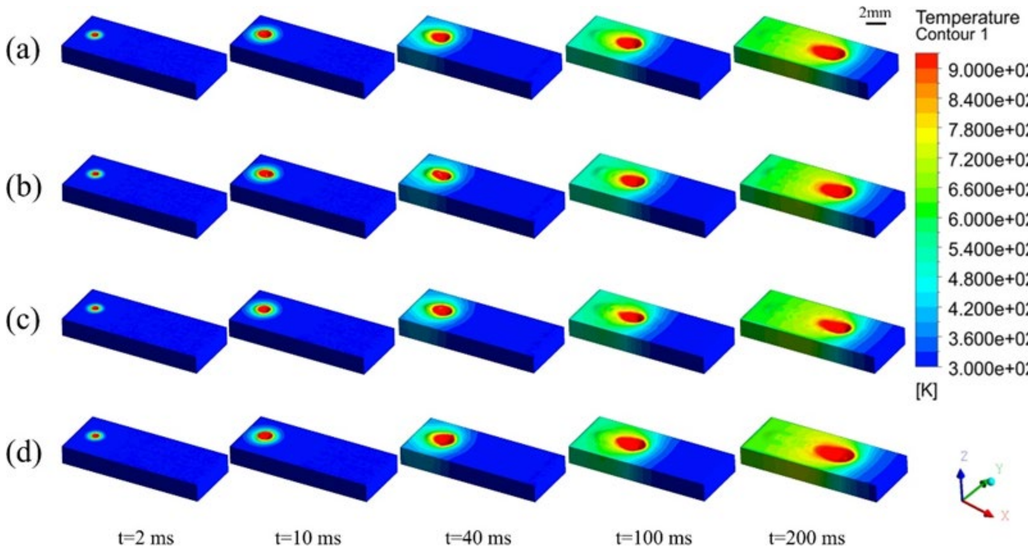

Figure 2: Evolution of surface moltenpool morphology at different magnetic field frequencies:(a)nomagneticfield;(b);50Hz(c);100Hz(d)150Hz[4].

2.3. Mechanical properties and failure analysis of welded joints

The mechanical attributes of welded joints are important indicators for evaluating the quality of welding.Zuo et al[5] studied the properties of the interlayer and its fracture behaviour of continuous Nd:YAG laser welded copper/aluminium metal joints, and found that the microstructure and thickness of the interlayer had a significant effect on the mechanical properties of welded joints. Hao Xiaohu et al[6] optimised the welding parameters and significantly improved the mechanical properties of aluminium/copper joints by blue-red composite laser welding technique (shown in Figure 3).

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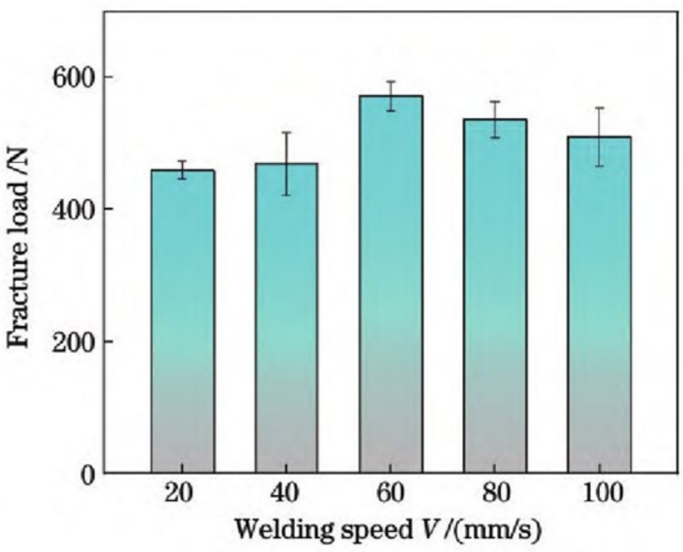

Figure 3: Fracture load of Al/Cu blue-red composite laser welded joint versus welding speed[6].

3. Application of Numerical Simulation to the Study of Welding Thermal Behaviour

3.1 Numerical Modelling of Melt Pool Flow and Temperature Field

Numerical simulation provides an important tool for the study of thermal behaviour during laser welding.Shanmugam et al[7] successfully predicted the melt width and depth of melt of laser welded 304 stainless steel sheet by establishing a 3D conical Gaussian heat source model. Ouyang Zhiyong et al[8] created a finite element simulation framework using ANSYS software and analysed the relationship between the welding temperature field and the melt pool depth (shown in Figure 4).

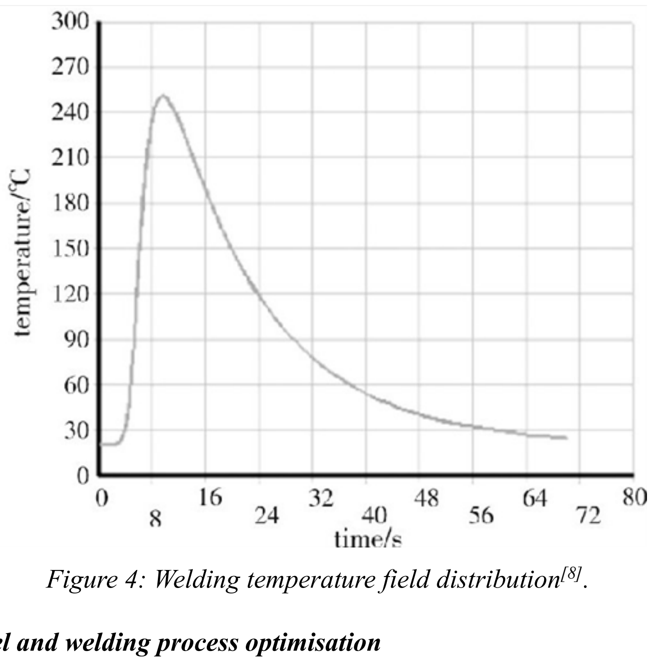

Figure 4: Welding temperature field distribution[8].

3.2 Heat source model and welding process optimisation

Optimisation of thermal source simulation is the key to improve the accuracy of numerical simulation.Zhou et al[9] accurately simulated the thermal effects of the laser welding process by modelling a combination of a Gaussian rotating body heat source and a conical heat source (shown in Figure 5).Raza et al[10] optimised the laser power and the welding speed by computational fluid dynamics (CFD) simulation to improve the quality of the welded joints.

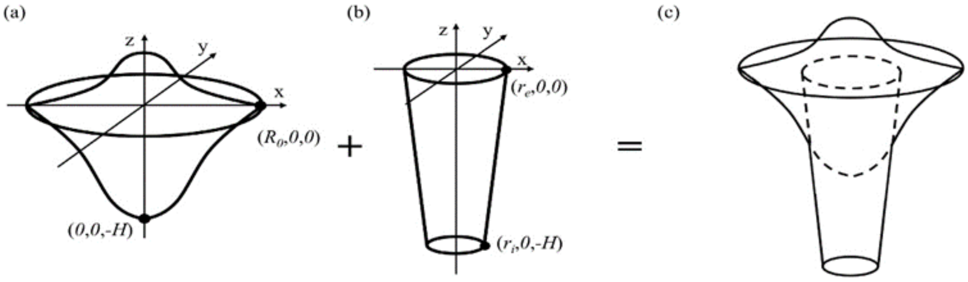

Figure 5: Framework of heat source:(a)Gaussian rotating body heat source;(b)Conical heat source;(c)combined heat source[9].

3.3 Numerical Modelling of Porosity and Crack Formation

Porosity and cracks are common defects in laser welding. Zhao Zhiyu et al[11] achieved the prediction of porosity and melt-through phenomena during the welding process by using machine vision technology.Lee et al[12] thoroughly investigated the formation mechanism of porosity by employing micro-targeted X-ray computed tomography (μXCT) and CFD simulation (shown in Figure 6).

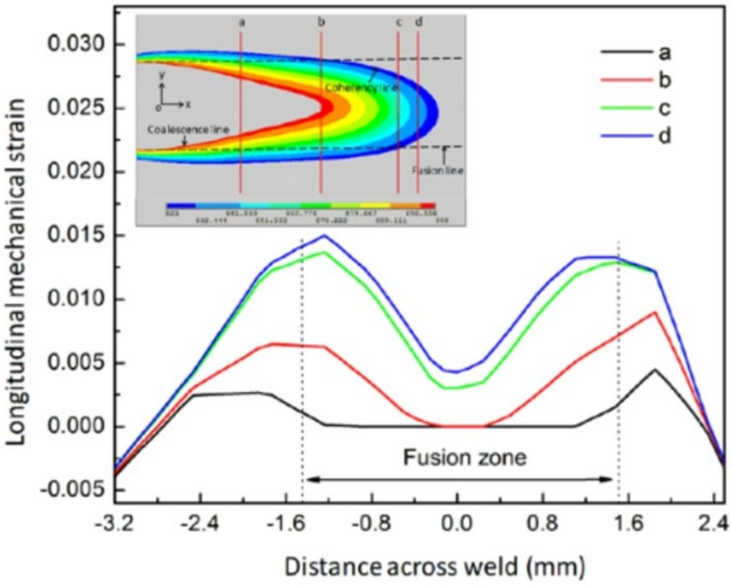

Figure 6: DCFD model predictions with stream lines for pore growth mechan is manalysis:(a)3D view,(b)longitudinal view,(c)horizontal view,(d)crosssection view[12].

4. Conclusion and Outlook

Copper-aluminium dissimilar material laser welding technology has an important application prospect in the manufacturing of new energy vehicle batteries. Current research focuses on the thermal behaviour of the welded interface, melt pool morphology, behavior of welded joints under mechanical loading and the application of numerical simulations. Despite the remarkable progress, some challenges remain, such as the control of welding defects and further optimisation of the welding process. Future research should further explore the optimisation of welding parameters, real-time monitoring related to welding process, and methods for evaluating the mechanical response of welded joints, in order to achieve more efficient and consistent copper laser joining and aluminium dissimilar materials.

Acknowledgements

The authors extend their gratitude to everyone who supported and contributed to this research.

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