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激光功率/焊接速度对 SiC_p/2A14 接头显微组织演变与力学性能的影响

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颗粒碳化硅增强铝基复合材料（SiC_p/Al 复合材料）因其优异的比强度、比模量、热稳定性，广泛应用于航天器机翼蒙皮、战斗机腹鳍、制动装置等高性能构件。然而，SiC_p/Al 复合材料中的 SiC 陶瓷增强相与 Al 基体之间物理与化学特性差异巨大，激光焊接过程不可避免的改变 SiC 组成、分布及其与 Al 基体界面特性，且 SiC 与 Al 基体反应大量生成的 Al_4C_3 脆性相严重恶化了接头强度并降低了服役安全性。因此，在这项工作中采用激光自熔焊接技术制备了 10vol%SiC_p/2A14 复合材料对接头。采用高速摄像，Flow 3D，SEM 等监测与表征手段系统研究了相同热输入下不同激光功率/焊接速度组合对 SiC_p/2A14 焊接头显微组织与力学性能的影响。结果表明，在焊透 4mm 厚 SiCp/2A14 复合材料所需的 60J/mm 线能量下，4kW-67mm/s 与 8kW-133mm/s 的焊接工艺参数强烈影响焊缝几何形状，SiC 颗粒反应与迁移行为和力学性能。随着激光功率/焊接速率的增加，焊缝几何形状由 V 形演变为 I 形，其实质过程为闭合型匙孔模式演变为开放型匙孔模式。开放型匙孔有效改善了 SiC 颗粒迁移行为，并增加了熔池凝固速率，降低了 $3SiC+4Al=Al_4C_3+3Si$ 反应时间，显著降低了 Al_4C_3 脆性相的体积分数。本研究揭示了激光焊接 SiC_p/Al 复合材料的工艺特性以及 SiC 颗粒的迁移与反应行为，为激光焊接技术制备高性能铝基复合材料接头提供了新思路。

SiC particles reinforced aluminum matrix composites (SiC_p/Al composites) are widely used in aircraft wing skin, aircraft fins, brake devices and other high-performance components because of their excellent specific strength, specific modulus and thermal stability. However, the physical properties of SiC ceramic in SiC_p/Al composites are very different from that of Al matrix. The laser welding process inevitably changes the composition, distribution and contact mode of SiC and Al matrix, and the Al_4C_3 brittle phase generated by the reaction between SiC and Al matrix seriously restricts the strength and service safety of the joint. The effects of different laser power/welding speed combination on the microstructure and mechanical properties of SiC_p/2A14 welded joint under the same heat input were systematically studied by means of high-speed imaging, Flow 3D, SEM and other monitoring and characterization methods. The results show that the welding parameters of 4kW-67mm/s and 8kW-133mm/s strongly affect the weld geometry, reaction and migration behavior of SiC particles and mechanical properties under the 60J/mm /mm wire energy required for the welding penetration of 4mm thick SiC_p/2A14 composites. With the increase of laser power/welding rate, the weld geometry changes from V shape to I shape, and the actual process is from closed keyhole mode to open keyhole mode. The open keyhole effectively improved the migration behavior of SiC particles, increased the solidification rate of molten pool, reduced the reaction time of $3SiC+4Al=Al_4C_3+3Si$, and significantly reduced the volume fraction of Al_4C_3 brittle phase. This study revealed the process characteristics of laser welding SiC_p/Al composites and the migration and reaction behavior of SiC particles, which provided a new idea for the preparation of high performance aluminum matrix composite joints by laser welding technology.

关键词：激光焊接；SiC_p/2A14 复合材料；显微组织；力学性能

参考文献

[1] Mingyang Z., Chunming W., Gaoyang M., and Qiubao Ouyang., In situ study on fracture behaviors of SiC/2A14Al composite joint: Co-construction of microstructure and mechanical properties via laser welding, Compo. B, **238, 109882 (2022)**.

[2] Mingyang Z., Chunming W., Gaoyang M., Ping J., Xiong Z., and Xiuhui Y., Laser beam oscillation welded SiC_p/2xxx Al alloy: Microstructure, phase interface and mechanical properties, Mater. Sci. Eng A, **820, 141482 (2021)**.

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