2022 第十五届全国激光加工学术会议
15th National Conference on Laser Processing
2022年10月 | 武汉

大厚度铝合金窄间隙扫描激光焊接气孔形成及抑制研究

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摘要：如何降低并抑制气孔是铝合金窄间隙激光焊接领域的重要挑战，目前还没有稳定可靠的解决方案，尤其是对于综合性能更好但焊接难度更大的异种铝合金。为此，本文开展了AA6061和AA2024异种铝合金窄间隙扫描激光焊接研究，发现了窄间隙激光焊接中侧壁柱状晶生长截留气泡现象，及其和激光扫描之间的相互作用对焊缝气孔形成与抑制的影响机理。X射线无损检测结果表明，随着扫描频率（f）的增加，气孔由在焊缝中心的密集链状分布（气孔率10.6%）逐渐转变为偏聚于AA2024一侧的零星分布（气孔率0.2%），并在f≥400 Hz时被完全抑制。基于搅拌雷诺数（Re）归一化计算，发现窄间隙扫描激光焊接消除气孔所需的Re为1369，是常规开放空间扫描激光焊接的1.39倍以上，表明其需要更强的扫描搅拌效应来捕获并促进气泡逸出，从而消除气孔。分析认为，当f介于200~300 Hz之间时，侧壁柱状晶生长对气泡的截留效应是气孔形成和偏聚的主要因素。当f≥400 Hz以后，激光扫描搅拌范围增加到足以通过破碎柱状晶生长来完全抑制其截留气泡，从而有效消除了气孔。基于优化的激光扫描参量，完成了80 mm和110 mm铝合金超厚板的焊接，气孔率满足ISO 13919中B级焊缝标准。

关键词：窄间隙；厚板；扫描激光焊接；铝合金；气孔

Abstract: How to reduce and suppress pores is one of the important challenges in narrow gap laser welding of aluminum alloys, but there is no reliable solution, especially for dissimilar aluminum alloys with better comprehensive properties but difficult to weld. Here, the narrow gap oscillating laser welding (O-NGLW) of AA6061 and AA2024 dissimilar aluminum alloys was carried out. The phenomenon of the bubbles intercepted by the sidewall columnar grain growth and the effect of the interaction between it and laser oscillation on pore formation and suppression were found. The X-ray nondestructive testing results showed that with the increase of the oscillation frequency (f), the pores gradually changed from a dense chain distribution at the weld center (10.6% porosity) to a scattered segregation at AA2024 side (0.2% porosity), and then completely suppressed when f ≥ 400 Hz. Based on the normalized stirring Reynolds number (Re), it was found that the Re required for O-NGLW to suppress pores was 1369, more than 1.39 times that of the regular oscillating laser welding without narrow gap, indicating that a stronger oscillation stirring effect was needed to capture bubbles and make them escape. The analysis suggested that the effect of columnar grain growth on bubble interception (ECGGBI) was the main reason for the formation and segregation of pores when 300 ≥ f ≥ 200 Hz. After f ≥ 400 Hz, the stirring range induced by laser oscillation was increased enough to completely suppress ECGGBI by fragmenting the growth of columnar grains, thus pores were effectively eliminated. Finally, the 80mm-thick and 110mm-thick aluminum alloy plates were welded with the optimized oscillation parameters, and the porosity of the welds conformed to the level B in standard ISO 13919.

Keywords: Narrow gap; Thick plate; Oscillating laser welding; Aluminum alloy; Pore

参考文献

[1] Zhang C., Yu Y., Chen C., Zeng X., and Gao M., Suppressing porosity of a laser keyhole welded Al-6Mg alloy via beam oscillation, Journal of Materials Processing Technology, 278, 116382 (2020).

[2] Wang L., Liu Y., Yang C., and Gao M., Study of porosity suppression in oscillating laser-MIG hybrid welding of AA6082 aluminum alloy, Journal of Materials Processing Technology, 292, 117053 (2021).

[3] Shi L., Li X., Jiang L., and Gao M., Numerical study of keyhole-induced porosity suppression mechanism in laser welding with beam oscillation, Science and Technology of Welding and Joining, 26(5), 349-355 (2021).

[4] Wang L., Gao M., Zhang C., and Zeng X., Effect of beam oscillating pattern on weld characterization of laser welding of AA6061-T6 aluminum alloy, Materials & Design, 108, 707-717 (2016).

[5] Wang L., Gao M., and Hao Z., A pathway to mitigate macrosegregation of laser-arc hybrid Al-Si welds through beam oscillation, International Journal of Heat and Mass Transfer, 151, 119467 (2020).

[6] Gao M., Kawahito Y., and Kajii S., Observation and understanding in laser welding of pure titanium at subatmospheric pressure, Optics Express, 25(12), 13539-13548 (2017).

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