

沉积策略对高功率激光-电弧复合增材制造实体的影响规律

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摘要：激光-电弧复合增材制造 (LHAM) 能够通过两种热源的相互作用增强电弧高速稳定性，解决电弧增材制造中大电流熔池失稳问题，从而同时提升沉积效率和成形精度^[1,2]。但在大型构件的实际制造中，除了薄壁结构，更应考虑具有一定厚度的实体结构。因为实体零件通常需要进行多层多道搭接沉积才能完成，在从二维到三维的转变过程中，沉积策略的变化会导致热循环和热积累效应更为复杂，并使得组织性能产生新变化。因此，本文基于 100 mm×100 mm×70 mm 的长方实体，研究了沉积策略对 LHAM 成形、组织和性能的影响规律。发现采用同一层面内不熄弧连续往复沉积策略可有效避免频繁起/熄弧导致的工艺过程不连续问题，获得和设计图形一致的实体零件。和薄壁墙相比，实体零件中的多重大电流热积累效应会形成更强的固溶热处理作用，导致晶体凝固由 FA 模式转变为 A 模式，晶粒内部的铁素体基本消失。沉积策略不影响实体不同截面的显微组织组成，都表现为：XOY 面为等轴晶；YOZ 面为柱状晶或胞状晶；XOZ 面则为细长胞状晶。但采用 90°连续沉积策略因为散热条件更随机，能获得综合性能更好的 LHAM 实体零件：和薄壁墙相比，单丝沉积效率由 942 cm³/h 提升至 1036 cm³/h，抗拉强度略低 4%，但延伸率可提高 10% 以上，均满足 ASTM A 479 标准。

Abstract: Laser-arc hybrid additive manufacturing (LHAM) can stabilize the arc by laser-arc interaction, and solve the problem of melt pool instability of wire arc additive manufacturing at big current or high speed, and then improve deposition efficiency and forming accuracy at the same time ^[1,2]. However, the thick-walled structures are in dominant than that of thin-walled structures in fabrication of entities, microstructures and mechanical properties will vary with deposition strategies when the entities are fabricated by multi-layer and multi-pass processes. This paper therefore investigates the effects of deposition strategies on the formation, microstructure and tensile properties of 100 mm×100 mm×70 mm rectangular LHAM entities. It is found that the continuous reciprocating deposition strategy without extinguishing in the same layer can effectively avoid the discontinuous process caused by repeat arcing/extinguishing, and obtain an entity that matches the design. The effect of solution heat treatment for entities manufactured with multiple high current is stronger than that of thin-walled parts, resulting in the transformation of crystal solidification from FA mode to A mode, and the ferrites inside the grains disappear basically. The deposition strategies do not affect the microstructures of different cross-sections of the entities: the grains in the XOY, YOZ and XOZ planes are equiaxed, columnar/cellular and elongated cellular, respectively. However, the entity fabricated with 90° continuous deposition strategy can obtain a

better performance due to a more random heat dissipation. Compared with the thin-walled part, the single-wire deposition efficiency is further improved from 942 cm³/h to 1036 cm³/h, the ultimate tensile strength is slightly reduced by 4%, and the elongation is increased by over 10%, meeting the ASTM A 479 standard.

关键词: 复合增材制造; 沉积策略; 实体; 组织性能

Keywords: Hybrid additive manufacturing, Deposition strategy, Entity, Microstructure and properties

参考文献

- [1] Gong M., Meng Y., Zhang S., Zhang Y., Zeng X., Gao M.*, Laser-arc hybrid additive manufacturing of stainless steel with beam oscillation. *Addit. Manuf.*, **33**, 101180 (2020)
 - [2] Gong M., Zhang S., Lu Y., Wang D.*, Gao M.*, Effects of laser power on texture evolution and mechanical properties of laser-arc hybrid additive manufacturing. *Addit. Manuf.*, **46**, 102201 (2021)
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