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激光选区熔化成形 Inconel 718 合金拉伸及疲劳性能尺寸效应

万宏远[1,2]，张广平[2*]，陈玮[1]

[1] 中国航空制造技术研究院 高能束流加工技术重点实验室，北京，100024
[2] 中国科学院金属研究所 沈阳材料科学国家研究中心，沈阳，110016

*Email: gpzhang@imr.ac.cn

摘要：复杂形状增材制造合金部件由于存在组织不均匀性和几何尺寸限制等问题，使得采用传统标准样件进行力学性能认证变得困难，因此如何正确评价增材制造合金部件真实力学性能是当前需要解决的关键科学问题之一。本研究以激光选区熔化成形（Selective Laser Melting, SLM）Inconel 718 合金为研究对象，系统考察了厚度在 0.1 至 1 毫米范围内合金试样的室温拉伸及疲劳性能，定义了能够反映 SLM 成形合金组织结构特点的“组织结构单元”，发现随试样厚度与“组织结构单元”尺寸比值（t/d）减小至 1 以下时，应变局部化行为的转变是导致试样发生过早颈缩且拉伸塑性显著下降的主要原因。研究初步建立了适用于预测 SLM 成形小微样件疲劳极限的概率统计模型，并提出了小微样件用于室温力学性能测试评价的可靠性判据：$t/d \geq 4$，该判据能够为建立基于小微样件的增材制造材料认证标准提供理论指导。

关键词：激光选区熔化，Inconel 718，尺寸效应，力学性能，材料认证

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*万宏远，18640455621，easonwhyimr@outlook.com

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Size effects of tensile and fatigue properties of selective laser melted Inconel 718

Hongyuan Wan[1,2], Guangping Zhang[2*], Wei Chen[1]

[1] *Key Laboratory of Power Beam Processing, AVIC Manufacturing Technology Institute, Beijing 100024, China*

[2] *Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China*

*Email: gpzhang@imr.ac.cn

Abstract: Combined with the topology optimization, additive manufacturing can be used to fabricate metal parts with complex shapes. However, due to the geometrical variations and microstructure heterogeneities of the additively manufactured metal parts, new standards with the use of miniature specimens are required for the evaluation of the spatial distribution of mechanical properties throughout the parts. Here, we conduct a systematic investigation on tensile and fatigue properties of selective laser melted Inconel 718 specimens with different thicknesses ranging from 0.1 mm to 1 mm. A “microstructure unit” that can well reflect the microstructure characteristic of selective laser melted materials is defined. The results reveal that premature necking with a dramatic drop in uniform elongation occurs if the ratio (t/d) of specimen thickness (t) to the "microstructure unit" size (d) is less than one. Premature necking is mainly attributed to the transition of strain localization behavior. We also propose a probabilistic statistical model for fatigue limit prediction based on the available fatigue data. It is recommended that the criterion of $t/d \geq 4$ should be satisfied to ensure that the yield strength, the uniform elongation, and the fatigue limit determined by the miniature specimens are comparable with those determined by standard specimens. The findings may provide a guide to the establishment of miniature specimen-based standards toward the qualification of additively manufactured metal parts.

Keywords: Selective laser melting, Inconel 718, Size effect, Mechanical properties, Materials evaluation