激光立体成形 Ti-15Mo 合金显微组织调控及力学性能研究

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摘要：亚稳 β 钛合金在航空航天、生物医疗等领域具有重要应用意义。本研究以典型亚稳 β 合金 Ti-15Mo 为对象，开展了激光立体成形 Ti-15Mo 合金的显微组织调控及力学性能研究。面向激光立体成形钛合金等轴细晶调控难题，以粘结包覆 Ti-15Mo 复合粉末为原料，利用高熔点不完全熔化 Mo 颗粒的异质形核作用，实现了全细小等轴晶+类等轴晶的 Ti-15Mo 合金制备。在此基础上，结合 EBSD (Electron backscatter diffraction)、XRD (X-ray diffractometer)和 TEM (Transmission electron microscope)对 Ti-15Mo 合金晶内显微组织进行分析表征，结果发现激光立体成形往复热循环导致的热、应力耦合作用下，Ti-15Mo 合金晶内形成亚晶界和高硬度的亚稳 ω 相。对合金典型力学性能进行评价，结果表明激光立体成形 Ti-15Mo 合金兼具优良的室温拉伸和压缩性能。其屈服强度、抗拉强度较锻件标准分别显著提高了 51.4%和 28.7%，同时由于拉伸过程中{332}<113>孪晶的产生，使合金在显著提高强度的同时仍保持良好的塑性，延伸率达到 20.2%[1]。压缩性能测试结果表明，Ti-15Mo 合金的抗压强度达到 1764 MPa，压缩弹性模量为 28.4 GPa[2]。结合显微组织对合金断裂行为的影响分析，细小等轴晶、晶内亚稳 ω 相以及亚结构的形成使得合金强度显著提高，而变形过程中诱发的 TWIP (Twinning-induced plasticity)效应使得该合金兼具良好的塑性。本研究为实现激光立体成形亚稳 β 钛合金宏微观组织调控及性能优化奠定了基础。

关键词：激光增材制造，Ti-15Mo，粘结包覆法，显微组织，力学性能

Microstructure control and mechanical properties evaluation of laser solid forming Ti-15Mo alloy

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Abstract: Metastable β titanium alloys have important application significance in aerospace, biomedical and other fields. In this work, the microstructure and mechanical properties of typical metastable β alloy Ti-15Mo formed by laser solid forming (LSF) were studied. To solve the problem of fine equiaxed grain control in LSF titanium alloy, using satellited Ti-15Mo powder as raw material, full fine equiaxed grains + near-equiaxed grains are obtained in the Ti-15Mo alloy because the heterogeneous nucleation of Mo particles with high melting point. On this basis, the intragranular microstructure of Ti-15Mo alloy was analyzed and characterized by EBSD (Electron backscatter diffraction)、XRD (X-ray diffractometer) and TEM (Transmission electron microscope). The results show that under the thermal and stress coupling caused by the reciprocating thermal cycles of LSF, the sub-grain boundaries and the metastable ω phase with high hardness are formed in the Ti-15Mo alloy. The typical mechanical properties of the alloy were evaluated. The results show that the LSF Ti-15Mo alloy has excellent tensile properties and compressive properties at room temperature. The yield and tensile strengths of the alloy increase significantly by 51.4%

and 28.7% compared with the forging standard, respectively. At the same time, due to the generation of {332}<113> twins in the tensile process, the alloy can still maintain good plasticity while improving the strength, and the elongation reaches 20.2%[1]. The compression results show that the compressive strength is 1764 MPa and the compressive elastic modulus is 28.4 GPa[2]. Combined with the analysis of the effect of microstructure on the fracture behavior of the alloy, the strength of the alloy is significantly improved by the formation of fine equiaxed grains, intragranular metastable ω phase and sub-structures, and the TWIP (Twinning-induced plasticity) effect induced during deformation contributes to the good plasticity. This work lays the foundation for the macro and micro-structure control and performance optimization of LSF metastable β titanium alloys.

Keywords: Laser additive manufacturing, Ti-15Mo, satelliting method, microstructure, mechanical property

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