激光立体成形 Ti-Al-Mo 合金成分-组织相关性研究

武文璐[1]，赵可馨[1]，邱莹[1]，张凤英[1*]

[1] 长安大学材料科学与工程学院，西安市长安中路 65 号，710064

*Email: zhangfengying@chd.edu.cn

摘要：研发高性能专用钛合金是激光增材制造钛合金在高端装备领域发展和应用的关键。然而现有合金设计方法效率低，难以建立钛合金成分-显微组织的定量关联。本研究利用激光立体成形高效制备系列成分钛合金的技术优势，制备60组不同成分的Ti-Al-Mo合金试样，结合显微组织观察和图像处理方法，获得不同成分Ti-Al-Mo合金的显微组织参数(晶内初生α板条宽度, W_α 及α相体积分数, F_α)，通过BP(Back Propagation)神经网络模型的建立，获得激光立体成形Ti-xAl-yMo ($2.0\leq x\leq 7.5$, $2.0\leq y\leq 9.0$)合金成分-显微组织的定量关系。结果表明：Al含量一定时，W_α 随Mo含量的升高而下降。在Al含量相对较低时(2.0-4.5 wt.%)，呈现先缓慢下降、然后快速下降、进而缓慢下降的非线性趋势，而Al含量相对较高时(5.0-7.5 wt.%)，呈现近似线性下降趋势。Al含量一定时，α相体积分数随Mo含量的增加并未呈现连续下降的趋势，而是在某些成分范围内出现反常增高的现象，这表明在激光立体成形条件下，Mo元素的合理添加可实现α板条细化和α相体积分数提升的协同作用效果。分析这种现象的产生是由于激光往复热循环作用下，部分合金保留较高含量初生α相的同时，β转变基体上析出大量次生α相导致的[1-2]。BP神经网络模型的预测结果与典型成分合金的实验观察结果吻合较好。

关键词：激光增材制造；Ti-Al-Mo合金；BP神经网络；显微组织

Relationship between composition and microstructure of laser solid forming Ti-Al-Mo alloys

Wenlu Wu[1], Kexin Zhao[1], Ying Qiu[1], Fengying Zhang[1*]

[1] School of Materials Science and Engineering, Chang'an Univeristiy, No. 65, Chang'an Middle Road, Xi'an, 710064

*Email: zhangfengying@chd.edu.cn

ABSTRACT： The research and development of high-performance special titanium alloy materials is the key to the development and application of laser additive manufacturing titanium alloys in the field of high-end equipment. However, current alloy design methods are inefficient, and the quantitative correlations between titanium alloy composition and microstructure are difficult to be established. In this study, 60 sets of Ti-Al-Mo alloy samples of different compositions were prepared using laser solid forming (LSF). Microstructure parameters(width of α lath, W_α, and volume fraction of α phase, F_α) of Ti-Al-Mo alloys with different compositions were obtained by combining microstructure observation and image processing methods. In addition, combined with the establishment of BP neural network model, the quantitative relationship between the composition of the LSF Ti-xAl-yMo ($2.0\leq x\leq 7.5$, $2.0\leq y\leq 9.0$) alloys and the microstructure was obtained. The results showed that W_α decreases with the increase of the Mo content when the Al content is fixed. At a relatively low Al content (2.0-4.5 wt.%), W_α exhibits a nonlinear decrease of slow, then fast, and then a slow decline. It is interesting to note that when the Al content is fixed,

W_α does not show a continuous downward trend with the increase of Mo content, but abnormally increases within the range of certain components. This indicates that under the LSF condition, the appropriate addition of Mo element can achieve the synergistic effect of refining α lath and improving the volume fraction of the α phase. It is an interesting result that F_α increases with increasing Mo content in a specific composition range because Mo is a kind of β stable element. The analysis of this phenomenon is due to the precipitation of a large number of secondary α phases on the β-transformation matrix while retaining a higher content of the primary α phase under the action of laser reciprocating thermal cycle during LSF[1-2]. The predictions from the BP model agreed well with some typical Ti-Al-Mo alloy experimental observations.

KEYWORDS：laser additive manufacturing; Ti-Al-Mo alloys; BP neural network; microstructure

参考文献

[1] Zhang F Y, Chen H, Xu Y K, Zhang X M. Influence of Mo content on microstructure and microhardness of laser solid formed Ti-6Al-Mo system alloys[J]. RARE METAL MAT ENG, **2013**, **42(7)**: 1332.

[2] Zhang F Y, Yang M, Clare A. T, Lin X M, Tan H, Chen Y N. Microstructure and mechanical properties of Ti-2Al alloyed with Mo formed in laser additive manufacture [J]. J ALLOY COMPD, **2017**, **727**: 821.

*第一作者（报告人）联系方式：武文璐、18392841613、1766326684@qq.com