國 立 清 華 大 學

碩士論文

錫鉍合金線材熔融積層製造之截面輪廓變化與拉伸應力研究

Study on the relationship between the tensile stress and the cross-section profile of fused Sn-Bi alloy filament deposition manufacturing

系 所 別：動力機械工程學系

組　　別：設計製造組

學號姓名：107033573 陳俊元(Chun-Yuan Chen)

指導教授：蔡宏營 博士(Dr. Hung-Yin Tsai)

中華民國 109 年 7 月

摘要

本研究設計的噴頭系統能在短時間內直接將低熔點錫鉍金屬線材用於一般的開源式列印機進行結構列印，針對噴頭加熱均勻性進行優化，不需外加熔融腔體，改善了鑄造或雷射金屬積層製造使用遠高於材料熔點溫度所造成的能源損失缺點，並且達到節省鑄造的模具開發、雷射設備成本或是後處理加工造成的材料浪費。

本研究首先透過計算流體力學軟體 COMSOL 進行模擬實驗結果的預測和實際進行錫鉍合金線材熔融積層製造實驗，以驗證數值模擬的準確性與可行性，減少實驗製程上的時間與人力成本，再利用不同參數下列印的錫鉍合金疊層拉伸樣本進行拉伸試驗，透過改變疊層高度與列印速度等參數，探討對截面輪廓與最佳拉伸機械性質的影響。

金屬積層製造的形貌與環境間的關係還有待研究。本研究旨在使用熔融式積層製造代替高能量源並通過模擬預測實驗結果，以降低實驗上所需的成本同時維持材料的機械性質。實驗與模擬在截面輪廓的趨勢接近一致，截面輪廓的寬度和高度皆隨進料速度提高而提升，寬度有較明顯的變化趨勢，接觸角則隨列印速度提升而增加。本研究提出的方法實現了在相對低溫製程下獲得金屬疊層，其拉伸應力受列印速度及疊層高度影響，在層高 0.85 mm 及列印速度 180 mm/min 的金屬疊層最大拉伸應力平均值為 54.9 MPa 相對於鑄造樣本只略低 7 %。

Abstract

In this study, the new designed nozzle system can be heated uniformly without chamber and directly use low melting point Sn-58Bi alloy filament to do structure printing on a general open-source 3D printer. During laser additive manufacturing or casting, the temperature use higher than the melting point of the material results in energy loss. The new system in this study not only solves the engery loss problem but also achieves the target of saving the equipment cost and material waste caused by machining.

In this study, Computational Fluid Dynamics software COMSOL is used to predict the results of fused metal filament deposition experiment in order to verify the accuracy and feasibility of simulation which can reduce the time and the cost of the experiment. Print the lamination at different layer height and printing speed to do tensile testing, and then analyze how the cross-section profile influences the maximum tensile stress.

The relationship between morphology of metal additive manufacturing and the environment is yet to be further studied. This study aims to replace high-energy sources of laser additive manufacturing with fused deposition modeling, predict experimental results by simulation, reduce the cost and maintain the tensile stress. The cross-section profiles of the experiment and simulation are similar, and the width and height increase with feed rate. The width improves significantly, and contact angle increases with the printing speed. The method in this study can use low temperature to obtain metal lamination which was affected by layer height and printing speed. The tensile stress of metal laminations is 54.9 MPa at layer height 0.85 mm and printing speed 180 mm/min and is only 7 % lower than casting samples.