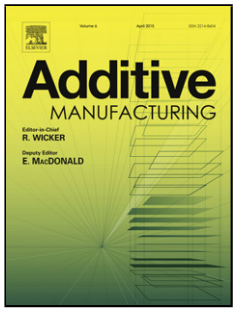

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Dual Process Monitoring of Metal-Based Additive Manufacturing Using Tensor Decomposition of Thermal Image Streams

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Abstract:

Additive manufacturing (AM) processes are subject to lower stability compared to their traditional counterparts. The process inconsistency leads to anomalies in the build, which hinders AM's broader adoption to critical structural component manufacturing. Therefore, it is crucial to detect any process change/anomaly in a timely and accurate manner for potential corrective operations. Real-time thermal image streams captured from AM processes are regarded as most informative signatures of the process stability. Existing state-of-the-art studies on thermal image streams focus merely on *in situ* sensing, feature extraction, and their relationship with process setup parameters and material properties. The objective of this paper is to develop a statistical process control (SPC) approach to detect process changes as soon as it occurs based on predefined distribution of the monitoring statistics. There are two major challenges: 1) complex spatial interdependence exists in the thermal images and current engineering knowledge is not sufficient to describe all the variability, and 2) the thermal images suffer from a large data volume, a low signal-to-noise ratio, and an ill structure with missing data. To tackle these challenges, multilinear principal component analysis (MPCA) approach is used to extract low dimensional features and residuals. Subsequently, an online dual control charting system is proposed by leveraging multivariate T^2 and Q control charts to detect changes in extracted low dimensional features and residuals, respectively. A real-world case study of thin wall fabrication using a Laser Engineered Net Shaping (LENS) process is used to illustrate the effectiveness of the proposed approach, and the accuracy of process anomaly detection is validated based on X-ray computed tomography information collected from the final build offline.

Keywords: Additive manufacturing, dual control chart, MPCA, process monitoring, tensor.

1 Introduction

The recent decades have witnessed a rapid growth in metal additive manufacturing (AM) processes for functional parts production within many industrial sectors (such as aerospace, tooling, and biomedical applications [1]). Ranging from customized to large-scale manufacturing,

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