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A Review of Process Optimization for Additive Manufacturing Based on Machine Learning

Xiaoya Zhai and Falai Chen*

School of Mathematical Sciences, University of Science and Technology of China, Hefei, Anhui 230026, China

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Dedicated to the memory of Professor Zhongci Shi

Abstract. Additive manufacturing (AM), also known as 3D printing, has emerged as a groundbreaking technology that has transformed the manufacturing industry. Its ability to produce intricate and customized parts with remarkable speed and reduced material waste has revolutionized traditional manufacturing approaches. However, the AM process itself is a complex and multifaceted undertaking, with various parameters that can significantly influence the quality and efficiency of the printed parts. To address this challenge, researchers have explored the integration of machine learning (ML) techniques to optimize the AM process. This paper presents a comprehensive review of process optimization for additive manufacturing based on machine learning, highlighting the recent advancements, methodologies, and challenges in this field.

AMS subject classifications: 68V99, 90C90
Key words: Additive manufacturing, 3D printing, machine learning, process optimization.

1 Introduction

Additive manufacturing (AM), has emerged as a transformative technology that has revolutionized the field of manufacturing. Unlike traditional subtractive manufacturing methods that involve removing material from a solid block to create a desired

*Corresponding author.
Emails: xiaoya93@mail.ustc.edu.cn (X. Zhai), chenfl@ustc.edu.cn (F. Chen)

shape, additive manufacturing builds objects layer by layer, adding material to form the final product. This innovative approach enables the production of complex and customized parts with unprecedented design freedom.

The process of additive manufacturing typically begins with the creation of a digital model using computer-aided design (CAD) software. The model is then sliced into thin layers, and the AM system precisely deposits or solidifies the material layer by layer, following the instructions provided by the digital model. The materials used in additive manufacturing vary widely, ranging from polymers and metals to ceramics and composites, allowing for a broad range of applications across industries.

There are several types of 3D printing technologies, each with its own unique approach and characteristics. Here are some of the commonly used types of 3D printing:

(1) Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF): FDM/FFF is one of the most widely adopted technologies. It involves the extrusion of thermoplastic filaments through a heated nozzle. The material is deposited layer by layer, and as it cools down, it solidifies, forming the desired object. FDM/FFF is known for its simplicity, affordability, and versatility, making it suitable for both personal and professional use.

(2) Stereolithography (SLA): SLA utilizes a liquid photopolymer resin that hardens when exposed to specific wavelengths of light. The resin is contained in a reservoir, and a movable platform gradually lifts the object out of the resin bath as each layer is cured by a UV light source. SLA is known for its ability to produce high-resolution, detailed parts with smooth surface finishes, making it popular in industries such as jewelry and prototyping.

(3) Selective Laser Sintering (SLS): SLS involves using a laser to selectively fuse powdered materials, typically polymers or metals, to create the desired object. The powdered material is spread in a thin layer, and the laser sinters the particles together based on the 3D model's cross-section. SLS allows for the production of complex geometries and functional parts, making it suitable for prototyping, manufacturing end-use parts, and low-volume production.

(4) Digital Light Processing (DLP): DLP technology is similar to SLA, but instead of a laser, it uses a digital light projector to cure each layer of liquid photopolymer resin. The projector shines UV light onto the entire layer simultaneously, enabling faster printing speeds compared to SLA. DLP is known for its high-resolution prints and is commonly used in dental applications, jewelry making, and rapid prototyping.