Chapter 2
An Integrated Approach of Particle Swarm Optimization and Grey Relational Analysis in Multi-Response Optimization of Fused Deposition Modeling

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ABSTRACT

This study proposes an integrated approach combining grey relational analysis (GRA) and particle swarm optimization (PSO) to optimize process parameters for fused deposition modeling (FDM) 3D printing using polylactic acid (PLA) material. Experimental design based on definitive screening designs (DSD) is employed to identify optimal printing parameters, focusing on improving surface finish,

DOI: 10.4018/979-8-3693-3314-3.ch002

dimensional accuracy, and impact strength. A regression model, generated based on DSD, accurately predicts grey relational grades (GRG), facilitating efficient optimization. The model's effectiveness is validated through evaluation metrics and close agreement between actual and predicted GRG values. PSO further refines the optimization process by efficiently navigating the solution space towards superior printing parameters. A comparison between GRA and PSO reveals refinements in printing speed, indicating the more refined solutions by PSO. These findings highlight the effectiveness of the integrated approach in enhancing additive manufacturing performance.

INTRODUCTION

Fused Deposition Modeling (FDM) is a popular additive manufacturing technology used for 3D printing. It works by depositing layers of thermoplastic material, usually in the form of a filament, layer by layer to create a three-dimensional object. Common thermoplastics used in FDM include PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene Terephthalate Glycol), and others. Material selection depends on factors like strength, flexibility, and heat resistance (Abas et al., 2023; Jan et al., 2023; Rajan et al., 2022). FDM is widely used for prototyping, product development, and low-volume production due to its cost-effectiveness and versatility (Khan, Farooq, et al., 2023; Khan, Tariq, et al., 2023; Ullah et al., 2023).

Multi response optimization of process parameters in FDM is of paramount importance to ensure the production of high-quality, mechanically robust, and efficient 3D printed objects. The intricate nature of FDM involves numerous process parameters that, when fine-tuned, significantly impact the final output (Rasheed et al., 2023). Adjusting parameters such as layer height/lager thickness, extrusion temperature, infill density, and print speed directly influences print quality and mechanical properties. This optimization is crucial for minimizing defects like warping and curling, enhancing material and energy efficiency, and improving overall resource utilization (Patel et al., 2023). Multi-response optimization of FDM process parameters employs various methods to efficiently balance and enhance multiple performance criteria. One widely used approach is the application of optimization algorithms, including evolutionary algorithms, genetic algorithms (GA), and particle swarm optimization (Mellal et al., 2022; Yodo & Dey, 2023). These algorithms explore the parameter space, considering interactions between variables to identify the best compromise solutions. Response Surface Methodology (RSM) is another effective technique, involving statistical modeling to capture the relationships between process parameters and multiple responses. This enables the creation of predictive models that

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Halima Semaa, Safae Sossi Alaoui, Yousef Farhaoui, Brahim Aksasse, Ahmed Mousrijand Mohamed Ait Hou (2022). *International Journal of Applied Metaheuristic Computing (pp. 1-23).*

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