Chapter 8
A Particle Swarm Optimization Approach for Minimizing GD&T Error in Additive Manufactured Parts:
PSO Based GD&T Minimization

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ABSTRACT

This paper presents a particle swarm optimization (PSO) approach to improve the geometrical accuracy of additive manufacturing (AM) parts by minimizing geometrical dimensioning and tolerancing (GD&T) error. Four AM process parameters viz. Bed temperature, nozzle temperature, Infill, layer thickness are taken as input while circularity and flatness error in ABS part are taken as response. A mathematical model is developed for circularity and flatness error individually using regression technique in terms of process parameters as design variables. For the optimum search of the AM process parameter values, minimization of circularity and flatness are formulated as multi-objective, multi-variable optimization problem which is optimized using particle swarm optimization (PSO) algorithm and hence improving the geometrical accuracy of the ABS part.

INTRODUCTION

In recent times, due to emergence of advance manufacturing technologies, the market situation has become extremely competitive and volatile. To sustain in such competitive market, it is imperative to not only produce low cost product but also with high quality and shorter development time. To achieve the

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aforesaid objectives in flexible manufacturing industries, they are forced to use advanced manufacturing tools and machines such as Rapid prototyping (RP).

Almost all the RP systems work on the principle of deposition of material in the form of thin cross-sectional layers. Each layer is built upon the previous layers until the complete 3D model is developed (Suresh & Narayana, 2016). Additive manufacturing (AM) is a rapid growing tool that belongs to RP technologies. Due to its ability to develop complex engineering parts and fast product development, it is gaining wide acceptance among different applications like biomedical (Pathak & Singh, 2016), automobile (Wiedemann & Jantzen, 1999), construction (Buswell, Soar, Gibb, & Thorpe, 2007) and many more. Although RP has shown competence in fast product development but its full- fledged use is hindered by limited materials available in market (Levy, Schindel, & Kruth, 2003; Pilipović, Raos, & Šercer, 2009). To improve its sustainability in market, its performance needs to be improved.

One way of improving the performance of any process is by suitably adjusting and optimizing its process parameters so that improved quality products may be fabricated (Kibria, Doloi, & Bhattacharyya, 2014; Molla & Manna, 2013; Silva Filho, Abrão, Paiva, & Ferreira, 2012; Balraj & Krishna, 2014). Many studies have been conducted to determine the optimum process parameters for RP using different conventional optimization techniques. Ahn et al. (2002) and Khan et al. (2005) applied design of experiment (DOE) approach to determine the influence of process parameters like raster angle, air gap and layer thickness on AM response. Thirumurthulu et al. (2004) used GA to determine the optimum part orientation in AM to minimize surface roughness and build time. Chockalingam et al. (2006) optimized stereolithography (SL) process parameters to achieve maximum part strength. Raghunath and Pandey (2007) applied Taguchi method to improve the accuracy of SLS parts through shrinkage. Sood et al. (2009) applied gray relational analysis to minimize the dimensional accuracy of AM parts. Sood et al. (2010) and (2012) studied the effect of process parameters on mechanical properties using RSM and sliding wear of the AM models. Phatak and Pande (2012) used GA to determine the optimum part orientation for improved part quality by minimizing the build time and material used. Guralla and Regalla (2014) used NSGA algorithm for optimization of part strength and volumetric shrinkage in the AM parts.

All the aforesaid studies suggest that researchers have correlates AM process parameters with the dimensional accuracy, surface roughness, strength, shrinkage improvement, mechanical properties and wear analysis in a part produced by AM. However, the correlation between process parameters and Geometric dimensioning and Tolerancing (GD&T) errors have not found yet for AM based parts. The current work thus bridges this gap and by establishing an empirical relationship between process parameters and GD&T error in parts manufactured by AM using regression analysis. Further, the analytical model is unified as multi-objective and optimized using PSO. So the current paper motivation is that industries want AM parts to be aesthetically appealing and at the same time to be functional for its sustainability. The minimized circularity and flatness error will help the AM parts to be functionally reliable and would make it more sustainable for engineering applications.

MATERIALS AND METHODS

The quality and accuracy of any part produced using AM process typically depends on its process parameters. This study considered four important process parameters bed temperature (A), nozzle temperature (B), Infill (C), layer thickness (D) to study their effects on circularity and flatness. The factors and their levels under which tests were carried out are given in Table 1. They are defined as follows: