Virtual-point-based geometric error compensation model for additive manufacturing machines

Pablo Zapico, Fernando Peña, Gonzalo Valiño, José Carlos Rico, Víctor Meana and Sabino Mateos
Department of Construction and Manufacturing Engineering, University of Oviedo, Oviedo, Spain

Abstract

Purpose – The lack of geometric and dimensional accuracy of parts produced by additive manufacturing (AM) is directly related to the machine, material and process used. This paper aims to propose a method for the analysis and compensation of machine-related geometric errors applicable to any AM machine, regardless of the manufacturing process and technology used.

Design/methodology/approach – For this purpose, an error calculation model inspired by those used in computerized numerical control machines and coordinate measuring machines was developed. The error functions of the model were determined from the position deviations of a set of virtual points that are not sensitive to material and process errors. These points were obtained from the measurement of an *ad hoc* designed and manufactured master artefact. To validate the model, off-line compensation was applied to both the original designed artefact and an example part.

Findings – The geometric deviations in both cases were significantly smaller than those found before applying the geometric compensation. Dimensional enhancements were also achieved on the example part by using a correction parameter available in the three-dimensional printing software, whose value was adjusted from the measurement of the geometrically compensated master artefact.

Research limitations/implications – The errors that persist in the part derive from both material and process. Compensation for these type of errors requires a detailed analysis of the influencing parameters, which will be the subject of future research.

Originality/value – The use of the virtual-point-based error model increases the quality of additively manufactured parts and can be used in any AM system.

Keywords Additive manufacturing, Geometric error compensation, Machine error model, Virtual point

Paper type Research paper

1. Introduction

A remarkable evolution has taken place from rapid prototyping (RP) techniques born in the 1980s to today's additive manufacturing (AM) processes. This progress has had impact from prototyping to obtaining fully functional, highly complex parts in a wide variety of materials, with a customised design and without a significant cost increase (Campbell *et al.*, 2012; ISO 17296–2:2015, 2015). For this reason, AM techniques have attracted particular interest in leading sectors such as medical, aerospace, automotive and military (Javaid and Haleem, 2018; Najmon *et al.*, 2019). However, the lack of specific consolidated regulations, as well as the low quality of parts obtained in certain cases, still greatly limit their industrial applicability (Moroni *et al.*, 2020).

A relevant aspect to measure the quality of mechanical components has to do with their geometric and dimensional accuracy in combination with their surface finish characteristics. In parts obtained by AM, the lack of geometric and dimensional accuracy derives mainly from three possible error sources (Abdelrahman *et al.*, 2017; Hartmann *et al.*, 2019; Vanaei *et al.*, 2020; Omairi and Ismail, 2021):

1 Process parameters: although process parameters greatly depend on the characteristics of the AM technology considered (ISO 17296-2:2015, 2015), some of them are common to almost all processes and materials, such as layer thickness, consolidation zone width, hatch distance, infill density, scanning strategy, scanning velocity or even the amount of energy necessary to prepare and transform the material (Sood *et al.*, 2009; Foster *et al.*, 2015; Fang *et al.*, 2017; Klassen *et al.*, 2017; Elkaseer *et al.*, 2020; Oliveira *et al.*, 2020; Haghshenas Gorgani *et al.*, 2021; Mohamed *et al.*, 2021).

2 Material properties: although they also depend partially on the considered technology, some properties affect to most of the processes, such as density, surface tension, thermal conductivity, moisture absorption or melting temperature (Sutton *et al.*, 2016; Vock *et al.*, 2019; Yuasa *et al.*, 2021; Fico *et al.*, 2022; Shanmugam *et al.*, 2021).

The current issue and full text archive of this journal is available on Emerald Insight at: **https://www.emerald.com/insight/1355-2546.htm**

Rapid Prototyping Journal
29/4 (2023) 837–849

[DOI 10.1108/RPJ-02-2022-0052]

Funding: This work was supported by the Spanish Ministry of Science, Innovation and Universities and by FEDER (DPI2017-83068-P).

Received 16 February 2022
Revised 1 July 2022
13 September 2022
Accepted 6 October 2022