A layerwise geometric error compensation procedure for additive manufacturing

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Abstract

Purpose – The purpose of this paper is to provide a new procedure for in-plane compensation of geometric errors that often appear in the layers deposited by an additive manufacturing (AM) process when building a part, regardless of the complexity of the layer geometry.

Design/methodology/approach – The procedure is based on comparing the real layer contours to the nominal ones extracted from the STL model of the part. Considering alignment and form deviations, the compensation algorithm generates new compensated contours that match the nominal ones as closely as possible. To assess the compensation effectiveness, two case studies were analysed. In the first case, the parts were not manufactured, but the distortions were simulated using a predictive model. In the second example, the test part was actually manufactured, and the distortions were measured on a coordinate measuring machine.

Findings – The geometric deviations detected in both case studies, as evaluated by various quality indicators, reduced significantly after applying the compensation procedure, meaning that the compensated and nominal contours were better matched both in shape and size.

Research limitations/implications – Although large contours showed deviations close to zero, dimensional overcompensation was observed when applied to small contours. The compensation procedure could be enhanced if the applied compensation factor took into account the contour size of the analysed layer and other geometric parameters that could have an influence.

Originality/value – The presented method of compensation is applicable to layers of any shape obtained in any AM process.

Keywords Additive manufacturing, Layerwise, Geometric deviations, Error compensation

Paper type Research paper

1. Introduction

Despite the competitive advantages of additive manufacturing (AM) (e.g. reduction of overall production time and cost), this technology has not yet reached a sufficient level of maturity for industrial application compared to other conventional manufacturing methods (Gibson *et al.*, 2010). The scarcity of standards regulating the implementation of AM, together with the limitations of tools and methodologies for quality assurance (e.g. structural, dimensional and geometric) in these manufacturing techniques, has prompted numerous research efforts to improve the capabilities of this technology (Tofail *et al.*, 2018).

Factors such as CAD to STL format conversion of a part, staircase effect due to the layered part construction, machine errors, other process parameters-related errors or those errors associated to material shrinkage during the process negatively influence the accuracy of manufactured parts. These and other errors have been recognised and analysed in numerous research papers (Bochmann *et al.*, 2015; Umaras and Tsuzuki, 2017), and several strategies have been proposed for their attenuation.

Among the lines of research focusing on geometric distortion compensation, those that address the problem by modifying the nominal geometry of the CAD model stand out (Noriega *et al.*, 2013; Xu *et al.*, 2017; Beltrán *et al.*, 2021; Zhang *et al.*, 2020; Navangul *et al.*, 2013). Within this strategy, Noriega *et al.* (2013) developed a predictive model based on artificial neural networks to predict dimensional errors in prismatic parts and compensate for them in the CAD models. Other works parameterise the CAD model to establish a correspondence between it and the surfaces of the manufactured part to determine and compensate for geometric deviations. Such is the case of Xu *et al.* (2017), who used markers distributed along the geometry to establish a correspondence between the manufactured part and the CAD model. Likewise, Beltrán *et al.* (2021) apply a similar methodology on cylindrical parts, parameterising the geometry based on generatrices and circular sections to compensate for the deviations actually measured with a coordinate measuring machine (CMM) on the part surface. Another example of parameterisation is proposed by Zhang *et al.* (2020) who, based on the deviations information obtained by a predictive model, perform the compensation of the CAD model by means of a NURBS-adjusted surface.

Other authors, such as Navangul *et al.* (2013), propose to modify the STL file to minimise the chordal errors with respect to the original CAD model and thus improve the accuracy of the manufactured part. Similarly, Zha and Anand (2015) applied a methodology to improve the mesh density in the STL model locally to minimise chordal errors in the most complex areas of the geometry. Other authors apply strategies that

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