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Conoscopic Holography feasibility for form error in-situ monitoring in Additive Manufacturing

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Abstract: The lack of standardization and the low quality of parts produced by Additive Manufacturing requires in certain cases the use of in-situ monitoring techniques based on the use of different types of sensors, each of which has advantages and disadvantages depending on the type and nature of the signatures to be analyzed. Therefore, in this work the feasibility of Conoscopic Holography (CH) technology is analyzed for in-situ monitoring of form errors that take place during the creation of each layer in an AM process. The results obtained using this sensor are compared to those of a Coordinate Measuring Machine used as ground truth. The CH sensor is also compared to a Contact Image Sensor in terms of metrological performance, proving the former to be more suitable and versatile for monitoring this type of errors.

Keywords: Conoscopic Holography, Contact Image Sensor, Additive Manufacturing, layer form error, in-situ monitoring

1. INTRODUCTION

Additive manufacturing (AM) has undergone a major development since its beginning in the 80s. Today, there exist numerous techniques that make it possible to obtain components of different materials with a high degree of complexity and customization without an excessive cost increment. This makes AM of great interest to leading sectors such as aerospace, automotive, medical, etc. Nevertheless, due to the novelty of most of these techniques and the subsequent lack of standardization, quality assurance of the AM parts becomes a key issue today, Tofail et al. (2018). This fact, together with the long manufacturing time required for high value-added parts and as well as the design possibilities provided by this technology, both regarding internal cavities and structures, has led researchers to focus their efforts on the development of different in-situ inspection techniques, which make it possible to analyze each manufactured layer and, therefore, the quality of the parts during the process.

Typically, these in-situ techniques are based on using different types of sensors, Everton et al. (2016), each of which showing different advantages and drawbacks. Charge-Coupled Devices (CCD) are cheap, compact and allow for obtaining high-definition images, but they usually show optical distortions in the captured information due to the type of lenses that they mount, Kannala et al. (2006). Non-contact triangulation laser sensors allow for obtaining high-quality metrological data but are expensive and require more complex digitizing and data-processing procedures, Vasconcelos et al. (2012). Contact Image Sensors (CIS) are compact, cheap and enable fast digitizing of broad surfaces, but problems arise when the contrast of the captured images is below a certain threshold, Blanco et al. (2021). Therefore, exploration of further types of sensors for geometrical errors detection layerwise in AM becomes of great interest nowadays.

A technology that can be applied for this purpose is Conoscopic Holography (CH), a type of incoherent light interferometric technique able to detect the distance between the sensor and the projected laser spot on a surface. For that, CH point-type sensors analyze the light reflected by the surface, which arrives to the sensor's linear CCD via a conoscope, Sirat et al. (2005). This technology can be used on a wide variety of materials, and its high-quality metrological performance was demonstrated, Zapico et al. (2018).

Accordingly, the feasibility of using a CH point-type sensor for AM layer contour error detection is analyzed in this work. For a set of circular geometries obtained by Fused Filament Fabrication (FFF), the performance of the CH sensor is assessed by comparing the measurement results to those obtained with a Coordinate Measuring Machine (CMM) used as ground truth. The CH sensor's performance is also compared with that of a CIS, another digitizing system commonly used by researchers for this error detection purpose.

2. MATERIALS

A point-type CH sensor (ConoPoint-10 by Optimet) equipped with a lens of 50 mm focal length was used in this work. The main specifications of this setup are shown in Table 1. To achieve a relative controlled movement between the sensor and the digitized surface, the CH sensor was integrated into a 3-axis machining center (MC), Zapico et al. (2019).

By using this integrated system, the circular area of the top layers of a set of FFF specimens were digitized. Each specimen consists of an inverted truncated cone standing on a base (Fig. 1). Specimens of three different heights h were used (i.e., 2, 4 and 8 mm).

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