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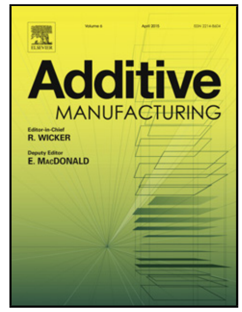

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Computed tomography metrological examination of additive manufactured acetabular hip prosthesis cups

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Abstract

Additive Manufacturing (AM) is uniquely suitable for healthcare applications due to its design flexibility and cost effectiveness for creating complex geometries. Successful arthroplasty requires integration of the prosthetic implant with the bone to replace the damaged joint. Bone-mimetic biomaterials are utilised due to their mechanical properties and porous structure that allows bone ingrowth and implant fixation. The predictability of predetermined interconnected porous structures produced by AM ensures the required shape, size and properties that are suitable for tissue ingrowth and prevention of the implant loosening. The quality of the manufacturing process needs to be established before the utilisation of the parts in healthcare. This paper demonstrates a novel examination method of acetabular hip prosthesis cups based on X-ray Computed Tomography (CT) and image processing. The method was developed based on an innovative hip prosthesis acetabular cup prototype with a prescribed non-uniform lattice structure forming struts over the surface, with the interconnected porosity encouraging bone adhesion. This non-destructive, non-contact examination method can provide information of the interconnectivity of the porous structure, the standard deviation of the size of the pores and struts, the local thickness of the lattice structure in its size and spatial distribution. In particular, this leads to easier identification of weak regions that could inhibit a successful bond with the bone.

Keywords: Computed Tomography, Additive Manufacturing, Image processing, Non-Destructive Testing, Metrological Application, Local thickness analysis, Hip prosthesis, Bone Ingrowth

1. Introduction

According to ASTM standard terminology [1], Additive Manufacturing (AM) is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. The continuing fast development of AM in the last four decades demonstrates the advantages of the technology. The reduction or even elimination of fixturing, cutting tools and minimal post processing, improves the product development cycle time. AM is the only manufacturing process that allows the build of complex geometries to reduce assembly requirements, increase the functionality of the product, and improve their energy footprint [2, 3, 4]. According to Gao et al. [5] the unique capabilities of AM include design flexibility, cost effective geometric complexity, assembly free designs, time and cost efficiency in production run for low part quantities. Due to the wide application spectrum of AM, it receives great interest from niche markets such as aerospace, medicine and biological systems [2, 3]. In particular the application of AM for healthcare/medical customised products based on the requirements of the patient is expected to improve population wellbeing [3].

The application of AM in the healthcare industry is relatively new with the first applications surfacing approximately a decade ago [6]. These applications are established with numerous examples in maxillofacial prosthesis, dentistry, surgical guides and orthopaedic implants such as total hip prosthesis [6, 7, 8, 9, 10, 11, 12, 13, 14]. AM can produce customised products based on the patients requirements and shape person-

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