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Dimensional and Geometrical Quality Enhancement in Additively Manufactured Parts: Systematic Framework and A Case Study

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Abstract: In order to compete with traditional manufacturing processes, Additive Manufacturing (AM) should be capable of producing medium to large batches at industrial-degree quality and competitive cost-per-unit. This paper proposes a systematic framework approach to the problem of fulfilling dimensional and geometric requirements for medium batch sizes of AM parts, which has been structured as a three-step optimization methodology. Firstly, specific work characteristics are analyzed so that information is arranged according to an Operation Space (factors that could have an influence upon quality) and a Verification Space (formed by quality indicators and requirements). Standard process configuration leads to characterization of the standard achievable quality. Secondly, controllable factors are analyzed to determine their relative influence upon quality indicators and the optimal process configuration. Thirdly, optimization of part dimensional and/or geometric definition at the design level is performed in order to improve part quality and meet quality requirements. To evaluate the usefulness of the proposed framework under quasi-industrial condition, a case study is presented here which is focused on the dimensional and geometric optimization of surgical-steel tibia resection guides manufactured by Laser-Power Bed Fusion (L-PBF). The results show that the proposed approach allows for part quality improvement to a degree that matches the initial requirements.

Keywords: additive manufacturing; quality enhancement; process parameters; design optimization

1. Introduction

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 fabrication methodologies" according to ISO 17296-1 [1] and ASTM 2792-12 [2]. This definition encompasses a wide variety of processes used to manufacture three-dimensional objects by means of vertical stacking of bi-dimensional layers. Most of the technologies involved have gained maturity in recent years. This has allowed AM applications to evolve from prototype manufacturing to small-batch-size production. Nevertheless, according to Gartner´s hype cycle, consistent adoption of AM in manufacturing operations will still take 5 to 10 years of development [3]. There are many factors that influence AM's difficulties to match the requirements of medium and high batch-size production. Some are related to working volumes and production rates of machines at the current state of development. Others reflect the difficulty of producing parts with similar mechanical behavior to those obtained by traditional manufacturing processes. Finally, dimensional and geometric quality deficiencies of AM parts have also been highlighted as common disadvantages [4,5], which explains their relevance as research subjects during the last decade [6–10]. Quality improvement is a *sine qua non* condition