Current challenges of precision manufacturing through powder bed fusion – laser beam

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Abstract

Additive manufacturing (AM) technologies enable manufacturing complex designs compared to traditional manufacturing methods. There is an enormous opportunity to explore this technology which aids its evolution process to acceptable manufacturing methods. This work focuses on the dimensional tolerances of AM parts. In particular, small features typically required in applications such as waveguides, filters, and antennas applicable for telecommunication services in the millimeter-wave frequency range are considered. In this study, the objective is to design, manufacture and test (i) a radio frequency (RF) waveguide resonator with small features and (ii) a test artefact featuring a variety of small features ranging from canonical shapes to complex shapes exploited in the RF resonator. Precision parts are manufactured using powder bed fusion-laser beam/metal (PBF-LB/M), and geometrical deviations of their small features are measured and compared between parts printed at different positions on the build plate. The geometrical deviations of the fine features are characterized using a scanning electron microscope (SEM). Also, resonance frequencies and Q-values of the RF resonators are measured. It is found that the manufactured parts have a surface roughness subject to orientation and strategies with powder particles fused to the small features. Geometrical accuracy in the range of tens of micrometers and RF resonance frequency with a small spread between samples but systematic deviation from the nominal value were measured.

1. Introduction

With the advancements in technology over the years, cutting-edge manufacturing processes have emerged for the development of intricate shaped components [1]. One of these processes is additive manufacturing (AM) technology, based on a 3-dimensional computer-aided design (CAD) model by applying material layer upon layer to build the component according to ISO/ASTM 52900. Various types of potential AM technologies are established for a highly growing number of applications in variant areas like medical, aerospace, computer industry, and engineering [2], [3]. Of the many advantages that AM technology exhibit is the reduction of material consumption and geometrical freedom of the final 3D build component contrary to the conventional manufacturing methods [4], [5]. Of particular interest to achieve geometrically complex metallic parts combined with a high degree of design freedom, the powder bed fusion–laser beam (PBF-LB) has enabled in unlocking the limitations in design by surpassing conventional manufacturing technologies [6]. PBF-LB is a single-stage process that typically uses powder in a size range of 20-50 μm. Today, PBF-LB is sufficiently mature to provide