Abstract

Laser based powder bed fusion of polymers (PBF-LB/P) is increasingly adopted for the production of functional polymer parts. Still, it lags behind injection molded benchmarks in terms of repeatability, mechanical performance, material choices, surface quality, and cost. This work aims to address the knowledge gap linking material properties to final part performance.

The quality of parts varies across PBF-LB/P systems and materials. Process parameter variability, coupled with different material and system combinations, leads to an unclear picture of what can be achieved reliably. The material–process–quality relationship for PBF-LB/P process is researched, and key powder properties and process factors that govern part quality are selected as the basis for investigation. New powder materials are tailored to achieve more desirable powder properties, and along with commercial powders, both are used to investigate the key properties that affect the final part quality.

Before investigating the key factors influencing the process parameters, the baseline part quality was defined based on parts manufactured using the commercial system utilized in this research project. Special attention was given to defining realistic expectations for the surface quality of the parts produced, due to the complexity of the process, heterogeneity of the surface texture, and the influence of post-processing.

Four different investigations were conducted to develop an in-depth understanding of the material properties and their impact on the final part performance. Firstly, the size and shape of the powder particles were investigated in two separate studies to determine their influence on the final part quality. Secondly, the influence of powder particle dynamics during the process was correlated to the final part performance in two separate investigations. Finally, the base (inherent) material properties, along with the powder properties, were collectively correlated with the final part properties to establish a hierarchical understanding of the material properties' influence on part performance. This study presents a materials-forward approach to improving PBF-LB/P part quality, suggesting material properties to tailor and screen for, to enable faster iteration and a more reliable transfer from screening to production.

The material–process–quality insights presented here support setting realistic and actionable specifications that enable efficient materials Research and Development (R&D) cycles, thereby narrowing the gap between expectations and part performance.