Addressing Powder Morphology and Filament Properties for Extending PIM Feedstocks to Fabricate Green and Sintered Alumina Parts via Ceramic Fused Filament Fabrication (CF^3)

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ABSTRACT

In this work, a hybrid ceramic fused filament fabrication (CF^3) 3D printing process that combines fused filament fabrication (FFF) and sintering processes was used to fabricate highly dense alumina specimens. Spherical and irregular alumina powders were used to prepare highly loaded powder-filled polymer feedstock filaments to determine how powder morphology and filament properties affect 3D printing and the ensuing properties. Rheological and material properties of extruded filaments, 3D printed green, and sintered alumina specimens were studied. Feedstock viscosity was measured by varying temperature and shear rate and correlated with standard powder injection molding (PIM) feedstocks. Further, filament integrity was predicted and experimentally determined to identify how printability and mechanical properties of CF^3 3D printed specimens scale from green to sintered state. It is expected that such a method will enable the transition of PIM feedstocks for manufacturing ceramic components via CF^3.

1 Introduction

Fused Filament Fabrication (FFF) could potentially replace injection molding as the shaping step, especially competing with processes similar to powder injection molding (PIM). New feedstock materials are being developed every day that can be printed using conventional FFF equipment. Ceramic processing, in particular, has been conventionally performed using techniques that involve ceramic powder pressing followed by high-temperature sintering and machining, if required [1–6]. However, machining ceramics to complex shapes is challenging and causes a significant amount of tool wear due to their inherent brittleness and high hardness [7]. Therefore, a need for advanced manufacturing technologies such as additive manufacturing (AM) to manufacture a variety of ceramic components was emphasized [8–12]. Of the multiple AM technologies capable of manufacturing complex ceramic parts, ceramic fused filament fabrication (CF^3) is the most economical process as the cost of the machine/equipment, feedstock materials, and overall processing is relatively lower than other AM processes [11,12].

Ceramic Fused Filament Fabrication (CF^3) is a hybrid additive manufacturing technique that combines FFF for green part fabrication, thermal processing for debinding and sintering, and the fundamentals of powder processing and sintering with powder injection molding (PIM). A powder binder mixture is blended and extruded into a filament, which is then passed through a heated nozzle and deposited onto a heated platform, following a predetermined path to complete a three-dimensional (3D) part. *Figure 1* shows a typical CF^3 process overview where homogeneous blends of Al_2O_3 powder-binder are made using an appropriate mixer (such as torque rheometer), which are then extruded to produce filaments for 3D printing. Subsequently, parts are then printed using typical desktop fused filament fabrication (FFF) 3D printers. Finally, the green parts are processed through debinding (solvent and thermal debinding) followed by high-temperature sintering to achieve dense, solid parts.