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ORIGINAL PAPER

Torque rheometry and rheological analysis of powder–polymer mixture for aluminum powder injection molding

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Abstract Selection of desired powder–polymer mixture (feedstock) formulation is a key factor in manufacturing perfect parts via powder injection molding. In the present study, feedstock characteristics of an aluminum-based powder were investigated by torque rheometry and rheological analyses. Several binders containing various amounts of polypropylene (PP), paraffin wax (PW), and stearic acid (SA) were selected for torque mixing and viscosity evaluation. Then, feedstocks consisting of 54, 58, 62, and 66 vol. % solid contents were prepared with modified binder. Feedstock flow behaviors were investigated regarding the rheological parameters such as mixing torque, viscosity, flow behavior index, flow activation energy and moldability index. It was found that increasing solid loading from 54 to 62 vol. % led to improved rheological behavior. This improvement was not observed in high solid contents, i.e., 66 vol. %. Based on experimental results, the optimized binder composition (60PW,35PP,5SA vol. %) and the optimum powder loading (62 vol. %) were selected as the best formulations for injection of aluminum powder. These values are supported by critical powder volume concentration measurements deduced from the oil absorption method. The resulting aluminum molded green parts with no defects exhibited the straightforward injection molding process of selected feedstock.

Keywords Powder–polymer mixture · Binder · Al powder · Rheology · Torque rheometry

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Introduction

Aluminum and its alloys have great advantages for use as superior materials in advanced and high technology applications. Today, increased demands for high thermal and electrical conductivity [1], decreasing component weight [2], and excellent specific mechanical properties [3] lead to increasing Al product applications, especially in automotive, aerospace, electronic, and defense fields [4].

There are significant scientific and industrial potentials for the fabrication of aluminum alloys via powder metallurgy (PM) as a net-shape technique [5]. Among various powder-shaping methods, powder injection molding (PIM) is a unique candidate for manufacturing aluminum components with small sizes, delicate shapes, and complex geometries [6].

Feedstock preparation, molding, de-binding, and sintering are four main steps of PIM technology [7]. Fine powder particles and sacrificial thermoplastic polymers are compounded in adequate temperatures and suitable proportions. The resulting injectable paste-form mixture is termed feedstock. The binder is added between powder particles as the temporary flow-vehicle to obtain homogeneous powder packing during the injection step [8]. Homogeneous composition without separation/segregation and proper rheological behavior are key points in the feedstock preparation. This step is crucial since feedstock deficiencies cannot be corrected with subsequent processing adjustments [9].