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Effect of Particle Size in Feedstock Properties in Micro Powder Injection Molding

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Abstract

Small powder size is very useful in achieving detailed structures. STS 316 nanopowders with an average diameter of 100 nm and 5 μm were utilized to produce feedstock. The mixing behavior of the feedstock indicated that the nanoparticle feedstock produced the highest mixing torque at various powder loading compared to the micropowder feedstock. The nanoparticles feedstocks showed that elastic properties are dominant in flow behavior and high viscosity. Conversely the micropowders feedstocks, viscous properties are dominant in flow behavior and less viscosity. nanopowders feedstock perform lower flow activation energy than feedstock with bigger particles.

Keywords : STS 316 nanopowders, Micro powder Injection molding

1. Introduction

The fine particles required an appropriate binder system. The small particles provide some advantages: a) provide smaller structural details, higher aspect ratio and better shape retention of microstructure [3, 5], b) give fairly isotropic behavior [4], c) better surface finish. Inversely the small particles with, will promote higher viscosity behavior than conventional powder in micron sizes [6].

In this research we wanted to observe the comparison of two kinds of the feedstock properties which were produced by nanoparticles and microparticles.

2. Experimental and Results

Mixing. Powder and waxes based binder system were mixed in a *Brabender* Plastograph mixer. The speed rotation adopted was 60 rpms. Mixing temperature was determined above the binder melt temperature.Two kinds of feedstock A and B were prepared at 52 % powder fraction in volume. Feedstock A utilized STS 316 nanopowders with an average diameter of 100 nm (FSA) and feedstock B (FSB) used STS 316 micropowders with an average diameter of 5 microns. Oxide layer was produced on the STS 316 nanopowder surfaces. STS nanopowders were mixed with binder below 100^{0}C to prevent burning, after the nanopowder was covered by binder materials the mixing temperature can be increased to a desirable temperature.

Torque that is produced by FSA is five time higher than FSB at the same powder loading. Due to high surface area of the powder will increase the friction between each particle and to the binder.

Table 1. Mixing torque

Powder Loading	Mixing Torque (Nm)	
	FSA	FSB
35 %	0.9590	0.2780
40 %	1.1396	0.5106
45 %	2.7089	0.6703
52 %	4.2000	0.673

Feedstock characterization. A thermo gavimetry analyzer (TGA) was utilized to examine the thermal degradation of the binder system. The sample was heated from room temperature to 800 ^{0}C, with a heating rate of 10 K/min. The difference of degradation rate shown in TGA curve, it was bacause the binder system containing multi-component of waxes and polymer back bone. Thermoplastic binder started to degrade at 196 ^{0}C and ended completely at 500 ^{0}C. Therefore we suggested thermal treatment of this binder composition such at the mixing stage and the injection temperature must be applied below 196 ^{0}C. Thermal debinding temperature should be higher than 500 ^{0}C in order to remove all binder components. This result shows the same tendency as using microparticle.

A Different Scanning Calorimeter was employed to observe the melting point of the binder system. The samples were heated from 0 ^{0}C until 300 ^{0}C with a heating rate 10 K/min. The feedstock was characterized in a Different Scanning Calorimeter to examine the feedstock melting temperature. Melting temperature of the feedstock start at

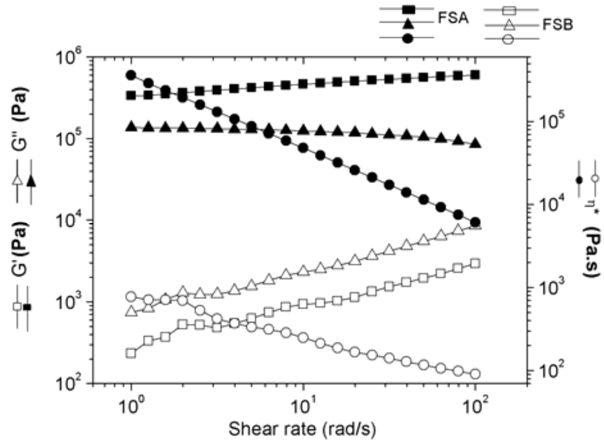

Fig. 1. ***Ares* rheometer curve of FSA and FSB at 150^{0}C.**

56 to 149 ^{0}C.

The method employed to evaluate the feedstock's viscoelastic behavior was implemented in the Ares rheometer at 150 ^{0}C. Ares rheometer curve as shown in Fig.1. described feedstock flow behavior through the value of G' (elastic modulus), G" (viscous modulus) and η(viscousity). It indicated that the elastic properties were dominant in the flow behavior of the FSA. Feedstock B performed a viscous properties prevailed the flow behavior. These phenomena show that at the same powder loading there is a difference in flow behavior between FSA and FSB, as a result of different particle size. FSA, which employed nanoparticles, possessed a larger surface contact for interparticle friction and interaction to thermoplastic binder. This leads to an increase in of flow resistivity thus increasing viscousity.

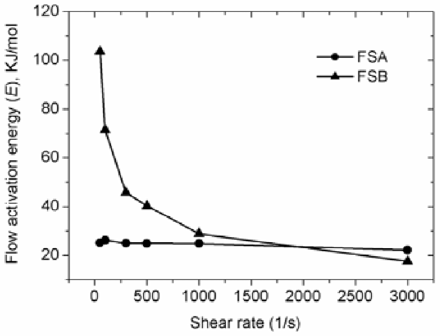

Fig. 2. Flow activation energy.

Rheology properties were also examined in the capillary rheometer at shear rate 10 to 1000 1/s in the various temperatures. Flow activation energy was examined according to following equation

$$\eta = k \exp \frac{E}{R \cdot T} \quad (1)$$

Fig. 2 Show a flow activation energy (E) of FSA is more stable and lower than FSB as increasing shear rate. The small value of E indicates a low sensitivity of viscosity to the feedstock temperatures. If the viscosity is very sensitive to the temperatre variation, any small fluctuation of the temperature will suddenly change the viscosity. Its can caused stress consentration and crack in the molded part.

3. Summary

Nanopowder feedstock has a difference in mixing sequences compared to micropowder feedstock. An oxide layer must be produced on STS nanopowders with controlled oxidation. Nanopowder feeding temperature must below 100 ^{0}C to avoid thermal degradation. Fine particles, with high surface contact to the binder and interpaticle friction performed a more dominant elastic flow behavior and higher viscosity. The nanoparticles for metal injection molding application required more amounts of binder volume than bigger particles. STS 316 nanopowders feedstock performed lower flow activation energy than feedstock with bigger particles.

4. References

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