

Molding Properties and Causes of Deterioration of Recycled MIM Feedstock

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Abstract

To lower the cost of MIM products, the gate and runner materials and green parts with defects are usually recycled. It is necessary to understand what causes the recycled products to deteriorate. The results show that the viscosity of the 1R (recycled once) feedstock was slightly lower than that of the fresh material. However, as the number of recyclings increased, the viscosity increased, while the density decreased, and more defects were noticed during solvent debinding. These deteriorations were mainly caused by the increase of the melting point of the backbone binder and the oxidation of the filler or paraffin wax.

Keywords : metal injection molding (mim), deterioration, recycled feedstock, defect

1. Introduction

A lot of waste materials, such as gate, runner, flash, and defective parts, are produced during each step of the Metal Injection Molding (MIM) process. In order to lower the cost of and increase the competitiveness of the MIM process, it is necessary to reuse the waste materials effectively. Two methods are frequently adopted by the MIM industries to recycle the waste materials. One is to add about 30 to 50wt% recycled materials into fresh materials. The other is to use 100% recycled materials.

After recycling, there is little change in the content and characteristics of the metal powders. However, much more significant changes could occur in the binder components. It is very likely that the melting temperatures and degradation temperatures of the binder components could cause binder evaporation or deterioration of the chemical bonds during the process. This could change the binder to powder ratio and thus cause variations in the characteristics of the feedstock. An example was given by Kulkarni^[1], who demonstrated that different green densities, viscosities, and lengths were obtained in the molded specimens when the feedstock was recycled. As the number of recycling iterations increased, the discrepancies increased. Since little has been reported to date on this topic, the objective of this study was thus to study the effect of different iterations of recycling on the degree of the deterioration of the material.

2. Experimental and Results

The component of the original powder was MIM2200, with 6wt% binder (60wt%PW+surfactant, 40wt%PE).

The properties of the feedstock were examined for the fresh material (0R) and four different recycled materials (1R, 3R, 6R and 8R). No fresh materials were added to the recycled materials.

Table 1 and Figure 1 show the result of the green length, green weight, and the spiral flow test using the 0R, 1R, 3R, 6R and 8R materials. Under the same injection pressure, 1R had the longest length and highest weight, indicating that its viscosity was the lowest, even lower than that of the fresh material of 0R. This is possibly due to the fact that the fresh feedstock became more homogeneous after being compounded inside the barrel of the molding machine. This was confirmed by the viscosity data. As the recycling iterations increased, the spiral length decreased, and the viscosity also increased. This was mainly caused by the deterioration of the binder components.

Table 1. The length and weight of the as-molded specimens using the recycled feedstocks.

	0R	1R	3R	6R	8R
Green length(mm)	99.80	99.87	99.74	99.76	99.70
Standard dev. (%)	0.058	0.038	0.028	0.044	0.027
Green weight(g)	21.868	21.873	21.771	21.633	21.151
Standard dev. (%)	0.169	0.155	0.110	0.194	0.170

Figure 2 shows the surface condition of the specimen after solvent debinding in heptane at 50°C for 4 hrs. The specimens that used the feedstock recycled 8 times show more cracks after solvent debinding than those recycled 6 times.



Fig. 1. Spiral flow length of the specimens of 0R, 1R, 3R, 6R and 8R (from left to right)



Fig. 2. The surface of the specimens that used feedstocks recycled 6 and 8 times after solvent debinding, showing more defects in the 8R specimen.

Figure 3 shows the color of the heptane after solvent debinding for different durations. The left beaker is the heptane with the soluble binder components dissolved in it. The middle beaker contained the heptane, which was used to solvent debind the 0R specimen. The right beaker contained the heptane for the 8R specimen. The color change of the heptane used for the 8R suggested that the binder components had deteriorated.



Fig. 3. The heptane color after solvent debinding for pure soluble binder, 0R, and 8R specimens. (From left to right)

To find out whether the deterioration of the binder components was caused by oxidation, the oxygen content of each feedstock was examined. Table 2 shows that the amount of oxygen increased as the recycling iterations increased.

Table 2. The oxygen content of each feedstock with different recycling iterations

	0R	1R	3R	6R	8R
Average (wt%)	0.792	0.824	0.844	0.896	0.895

To further understand why such deterioration was caused by the binder components during the molding process, the oxygen contents of the main binder components, PW and PE, were examined before and after heating to 140°C, which was the barrel temperature in the molding machine. To ensure the accuracy of the data obtained, the oxygen test was conducted carefully using the oxygen-nitrogen analyzer. The amounts of PW and PE

were kept very low because PW and PE can rapidly produce huge amount of gases when heated by the induction coils in the analyzer. Table 3 shows that the original oxygen content of the pure PW was 0.0577wt%. It increased by 40 times to 2.293wt% after being baked at 140°C for 4 hrs. The oxygen content of the original pure PE was 0.0257wt%. It also increased by 20 times to 0.448wt% after being held at 140°C for 4 hours. These results indicated that when PW and PE is heated to high temperatures in air, the C-C chain will degrade and could form C=O with oxygen in the air.

Table 3. The oxygen content (wt%) of PW and PE (wt%) before and after being held at 140°C for 4 hours.

	As-received	After holding at 140°C for 4 hours
PW	0.0577	2.293
PE	0.0257	0.448

The melting points of the PW and PE were also examined. Table 4 shows that the melting point of PE decreased after kneading, which agreed with previous data. The melting point further decreased and reached the minimum at the 3R material. This was possibly caused by the compounding effect. It then increased again as the number of recycling iterations increased. This increase in the melting temperature could very possibly caused by the deterioration of the feedstocks due to oxidation.

Table 4. The melting temperature of PE before kneading and after recycling.

	As-received	0R	1R	3R	6R	8R
Melting temperature of PE (°C)	108.09	93.26	91.63	91.38	92.60	95.44

3. Summary

The molding properties of recycled feedstocks were examined in this study. The best results were attained using the material that was recycled once. As the number of recycling iterations increases, the binder components deteriorate and cause increases in viscosity and melting points of the binder. The main reason that causes the deterioration of feedstock is the oxidation of the PW and PE.

4. References

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