

Effect of Poly(vinyl chloride) Resin Type in the Preparation Process of Slush Powder

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ABSTRACT: During the preparation of the poly(vinyl chloride) (PVC) slush powder, we found that PVC resins obtained by different polymerization methods affected many properties of slush powder and its products. Two types of commercial PVC resins were used for slush powder preparation: mass poly(vinyl chloride) (M-PVC) and suspension poly(vinyl chloride) (S-PVC). We used the Haake rheomix test to characterize the absorption of plasticizers into PVC resins, and the results showed that M-PVC absorbed the plasticizers more quickly than S-PVC. The fusion behavior of the two slush powders was studied by the thermal plate test and Haake rheomix test, and the results

showed that the slush powder of M-PVC was easier to fuse than that of S-PVC. The different properties of the two resins and slush powder could be explained by the morphology, average size, and size distribution. Due to the "skin" of the particles' surfaces, the wider size distribution, and the large size of particles, S-PVC absorbed the plasticizers more slowly and was more difficult to fuse. © 2002 Wiley Periodicals, Inc. *J Appl Polym Sci* 86: 3331–3335, 2002

Key words: poly(vinyl chloride) (PVC); blending; morphology

INTRODUCTION

Slush molding is a cyclic process for making hollow plastics products and is also called rotational molding. It is mostly used for making toys and tanks containers.¹ At the beginning of 1990s, a new product appeared, the instrument panel skins for cars, and the material used was poly(vinyl chloride) (PVC) slush molding powder.

The process^{2,3} of slush molding is shown in Figure 1. As shown, slush molding begins with mold heating. Then, the mold is coupled with the powder container and is rotated for certain cycles. After PVC adheres to the mold, it is sent to another oven to melt further and to densify the powder. The last two steps are the cooling and removal of the product out of the mold.

It has been found that compared with any other polymer process, such as thermoforming molding, injection molding, or blow molding, slush molding has the following advantages:^{4,5} (1) the molds are simple and relatively inexpensive, (2) molds of different sizes and shapes can be run together on the same equipment, and (3) products are stress-free with no weld line or sprue mark. Compared with the common PVC composites, PVC slush molding powder has high thermal stability, good flow properties, and good fusion

behavior, which affect the properties of the final products.

During preparation of PVC slush powder, we found that the PVC resins obtained by different polymerization methods affected many properties of slush powder and its products. Our aim in this work was to study the relationship between the types of PVC resins and the properties of slush powder and its products.

EXPERIMENTAL

Materials

Two types of commercial PVC resins were employed for slush powder preparation: mass poly(vinyl chloride) (M-PVC) and suspension poly(vinyl chloride) (S-PVC); the *K* value of each resin was 66.

Metal soap stabilizers and other necessary additives were also used in the recipes.

Methods

PVC slush powder was prepared by dry blending. This was carried out in a high-speed mixer, with stock temperature measurement facilities, a jacket temperature controller, and a separate cooling chamber unit. The process of blending was shown in Figure 2.

We used the Haake rheomix test to characterize the absorption of the plasticizers into the PVC resins. The stabilizers, costabilizers, and antioxidants were mixed with PVC resin first; then, the mixture and plasticizers

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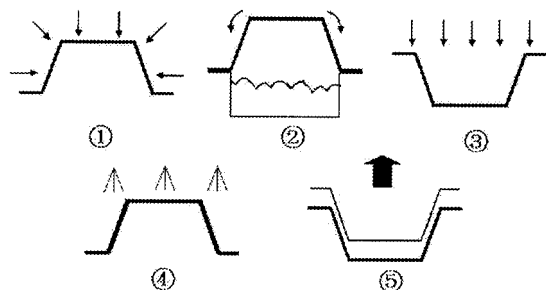


Figure 1 Slush molding process.

were added to a Haake rheomix (Haake PolyLab System, Germany), which was heated to a certain temperature, for example, 110°C; the speed employed was 30 rpm.

We also used the Haake rheomix test to study fusion behaviors. The rotation speed was 30 rpm, and

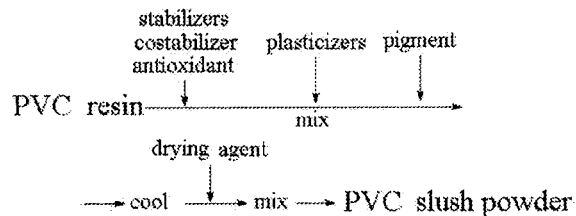


Figure 2 PVC slush powder preparation process.

the original temperature was 120°C. The slush powder was added, and the temperature was increased at a rate of 5°C/min from 120°C to about 200°C.

We also studied the fusion behaviors of the slush powders with a thermal plate test. We heated the thermal plate to a certain temperature, pouring the powder on it; sometime later, the thermal plate was put into a cool water pool for quick cooling. Then, the

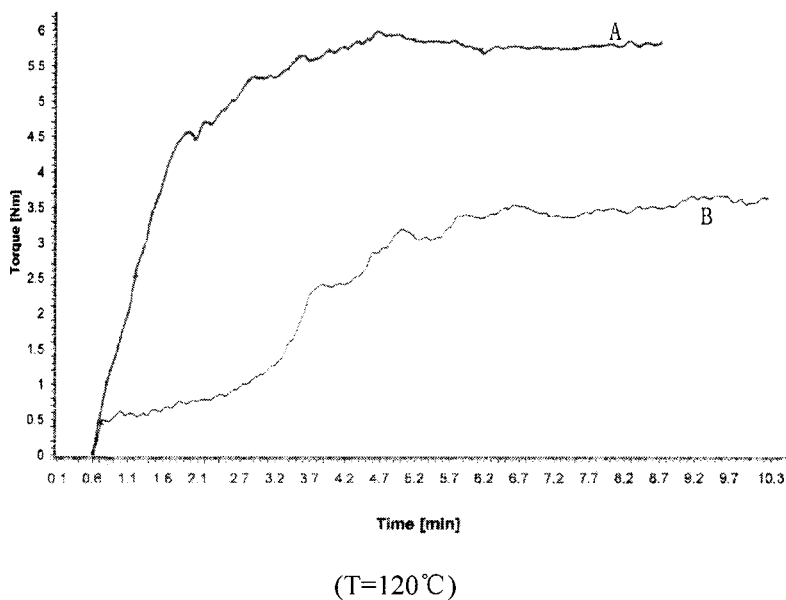
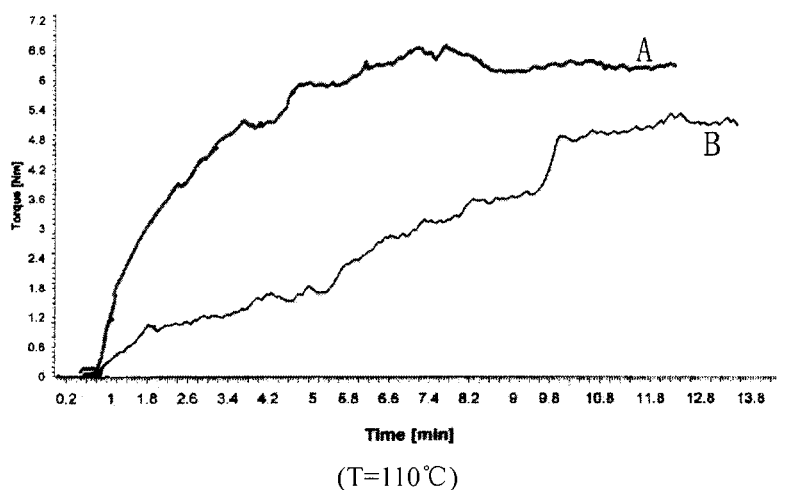


Figure 3 Relationship between blending time and torque: (A) M-PVC and (B) S-PVC.

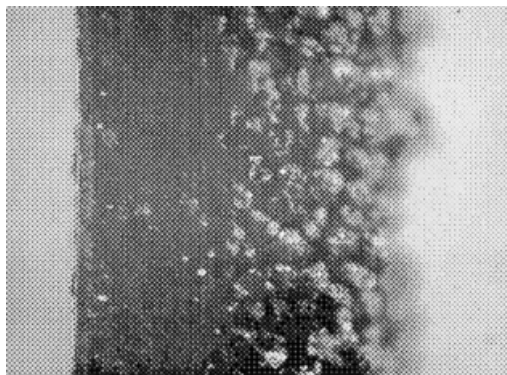


Figure 4 Section photo of a plastic sheet from the thermal plate test (M-PVC slush powder, 20 s).

plastic sheet was cut, and a section photo was taken under the microscope.

The morphology of the PVC resin particles was studied by scanning electron microscopy.

RESULTS AND DISCUSSION

Dry blending process

During the preparation of the slush powder, the speed of the PVC resin absorbing plasticizers was an important factor for the whole process, but it was difficult to measure this value in the process.⁶ By using the Haake rheomix test to record the curves of the torque and time, we obtained the speed of absorbing plasticizers at the blending temperature.

As shown in Figure 3, at the beginning of the blending process, because plasticizers had not been absorbed by the PVC resin, they could act as a lubricant, leading to a lower torque. With the process going on, more and more plasticizers were absorbed by the PVC

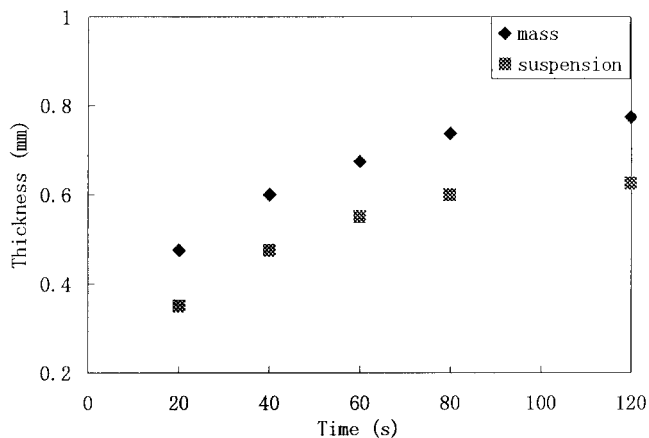


Figure 5 Relationship between fusion thickness and residence time.

resin, and the torque increased. When the plasticizers had been absorbed completely, the torque reached the maximum. As shown in Figure 3, for any value of experimental temperature, the time to reach up to the maximal torque of M-PVC was shorter than that of S-PVC, which means that the absorption speed of the plasticizers of M-PVC was faster than that of S-PVC. So, the M-PVC alternative featured the higher product efficiency.

Fusion behavior of the two slush powders

Thermal plate test

To simulate the slush molding process, we used a thermal plate to test the fusion behavior of the slush powders.¹ Figure 4 shows one of the section photos. As shown in the photo, by fusing and densifying, the thickness was nearly uniform, so it was possible for us

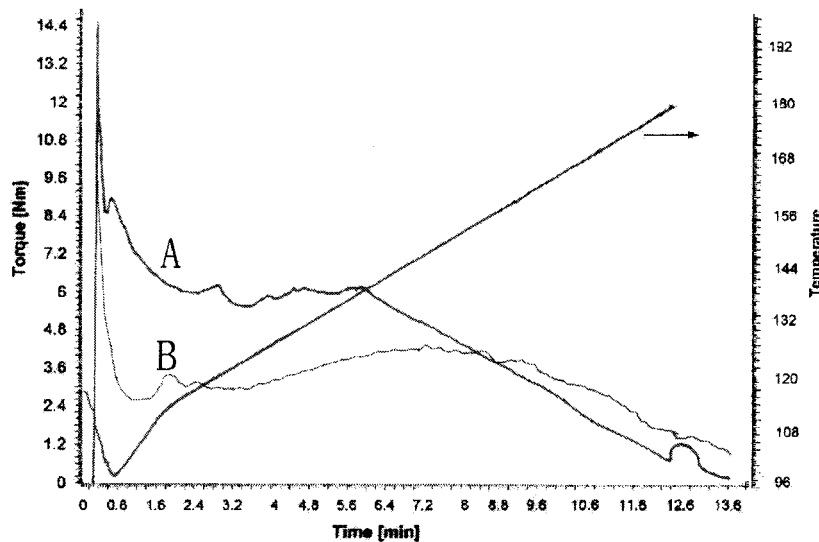


Figure 6 Relationship between blending time and torque with the temperature increase.

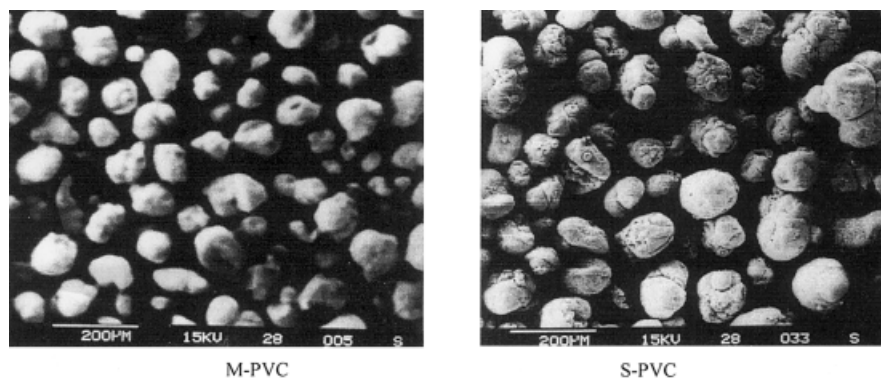


Figure 7 Scanning electron micrographs of M-PVC and S-PVC.

to measure the thickness through the microscope with a scale on the ocular. Figure 5 shows the relationship between the thickness and the residence time.

Thickness increased with the time, and the trends of the two powders were similar, but at the same time, the thickness of slush powder of M-PVC was thicker than that of S-PVC, which meant that the former was easy to fuse at the same temperature.

Haake rheomix test

On the basis of the curves of the torque and time obtained by the Haake rheomix test, the fusion time and temperature of the slush powder was studied (see Fig. 6).

When the PVC powder was added into the internal mixer, the torque increased very quickly, and then with the time extended, the torque reached a plateau. When the time further extended, with the temperature increase, the powder began to fuse, leading to a torque rise followed by a decrease at higher temperatures, where viscosity decreased. So, according to the curve of torque and time, we obtained the fusion time information (at the maximum torque on the plateau), and moreover, we also obtained the fusion temperature data. As shown in Figure 5, the starting fusion time of the slush powder of M-PVC was about the 6th min,

whereas the fusion time of that of S-PVC was about the 8th min, which meant the former was easy to fuse at low temperatures.

Morphology of particles

The absorption speed of the plasticizers of M-PVC was faster than that of S-PVC, and the slush powder of M-PVC was easier to fuse, as discussed in previously. So, we needed to study the morphology of the particles to discover the cause of these phenomena.

Figures 7 and 8 show the scanning electron micrographs of M-PVC and S-PVC. As shown in Figure 7, the shape of M-PVC was more regular and uniform. As shown in Figure 8, there was a skin covering the S-PVC particles, and the boundary of the S-PVC particles was clear, whereas the boundary of the M-PVC was ambiguous, and the surface of the particles of M-PVC was rougher than that of S-PVC. As a result, M-PVC absorbed the plasticizers more quickly than S-PVC, and when the slush powder was heated, S-PVC slush powder was more difficult to fuse because of the skins on the particles. Further research showed that the particle size distributions of the two PVC resins were different, which is shown in Figure 9.

As shown in Figure 9, M-PVC had a narrower particle size distribution than S-PVC, and according to the

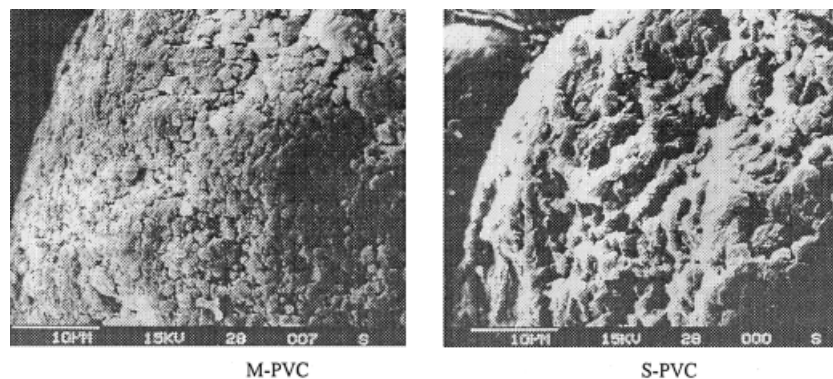


Figure 8 Scanning electron micrographs of M-PVC and S-PVC.

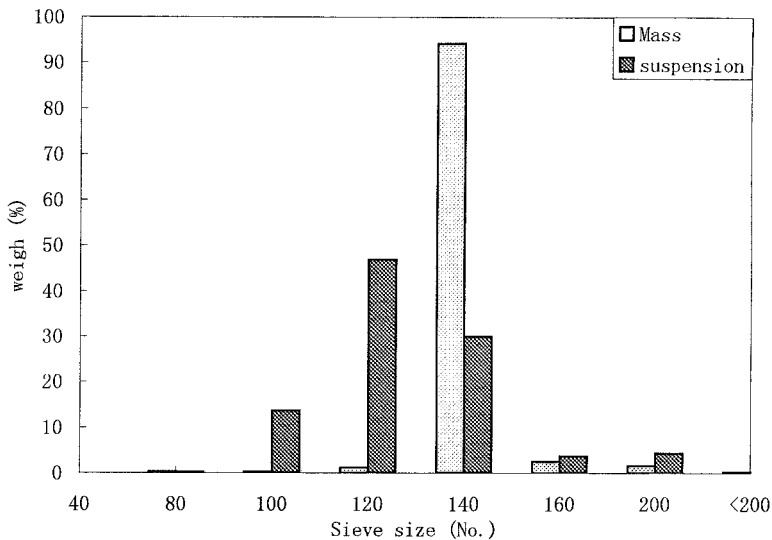


Figure 9 Particle size distribution of M-PVC and S-PVC.

data in Figure 9, the average of particle size could be calculated approximately by the following equation, which refers to the equation for the calculation of weight-average molecular weight:

$$\text{Average particle size} = \frac{\sum d_i \times x_i}{\sum x_i}$$

where d_i is the size of sieve and x_i is the weight proportion of the particles that could not pass the sieve size d_i but could pass the sieve size d_{i-1} . The results are shown in Table I.

From the average particle size data, it was obvious that the particle size of M-PVC was smaller than that

of S-PVC, which may be another reason that the M-PVC slush powder was easier to fuse.

CONCLUSIONS

M-PVC and S-PVC were used to prepare slush powders. The plasticizer absorbing speed of M-PVC was faster than that of S-PVC under the same temperature and the same recipe. Also, the fusion behaviors of the slush powder of M-PVC were also better those of S-PVC. So, M-PVC is more suitable for the preparation of PVC slush powder and slush molding.

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TABLE I Particle Size of M-PVC and S-PVC

PVC resin	Average particle size (number of sieve)	Average particle size (mm)
M-PVC	141	0.106
S-PVC	129	0.116