

Physical Properties of Commercial Casting Slips

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Introduction

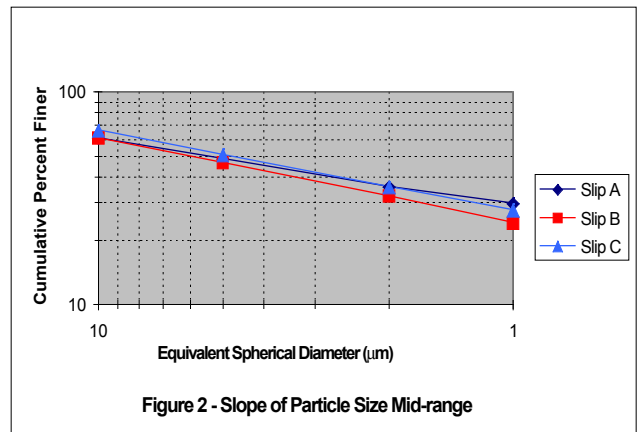
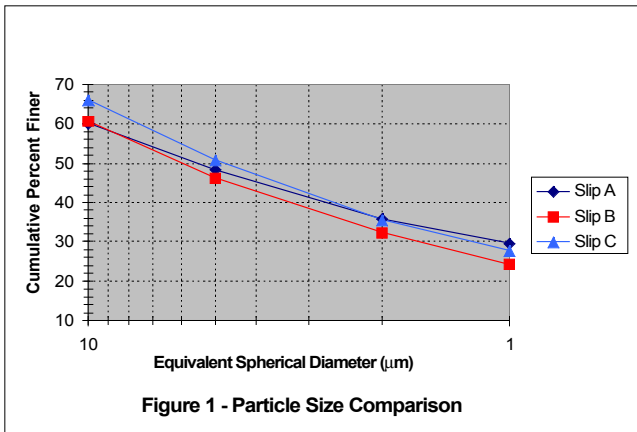
There have been several surveys of commercial casting slips designed to evaluate the performance differences between them. Usually these surveys collect the samples during a short period, then evaluate them. For this reason, the slip samples come from a somewhat even distribution of the industry. In this evaluation, the slip samples are taken from a period of about 9 months ending in the spring of 1997. The samples consist of those received at the Spinks Research & Development Laboratory from an international group of sanitaryware plants. Some of the samples represent repeated, periodic samples from the same plant, others are samples associated with specific projects.

Laboratory Testing

The slip samples were tested for particle size distribution (PSD) using the sedimentation technique for the Micromeritics Sedigraph 5100. Casting rate tests (C/R) were performed on samples on a Bariod filter press using Whatman #5 filter paper with air pressure at 90 psi for a period of 30 minutes. The results are reported in grams of filter cake after the slip was drained from the Bariod for a period of 5 minutes. Moisture retention was determined by drying the filter cake at 105° - 110°C overnight, then reweighing the cake. The moisture retention is reported on the dry weight basis. Modulus of rupture (MOR) was tested by deflocculating the slips to minimum viscosity and casting 5 bars of 0.75 inch diameter. The bars were air dried for 8 hours, then oven dried overnight at 105° - 110° C, cooled in a desiccator, a broken on a 2 inch span.

Results

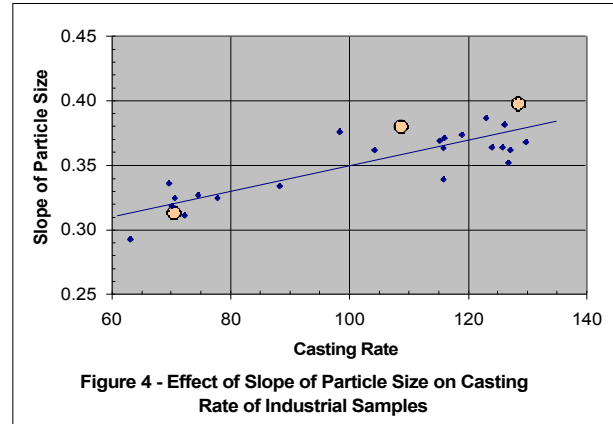
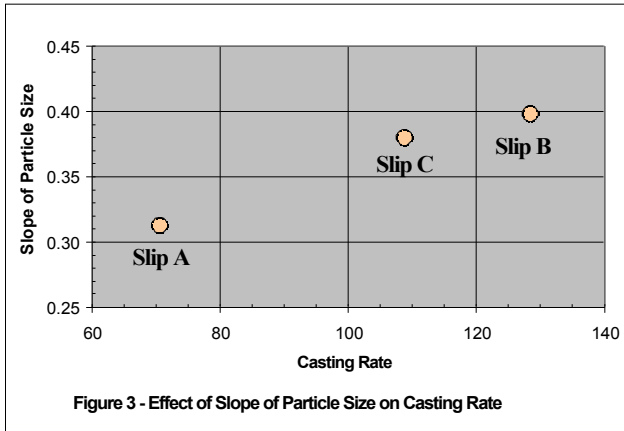
A comparison of PSD of three of the slips is shown in Figure 1. The plots of these distributions show a crossing pattern, but as typically observed, the order of the C/Rs are as one would predict simply by the percent finer than 1µm. Figure 2 illustrates that there is apparent linearity of the PSD when the CPFT is plotted logarithmically. The slope of this log-log plot can then be compared to the casting rate as shown in Figure 3.



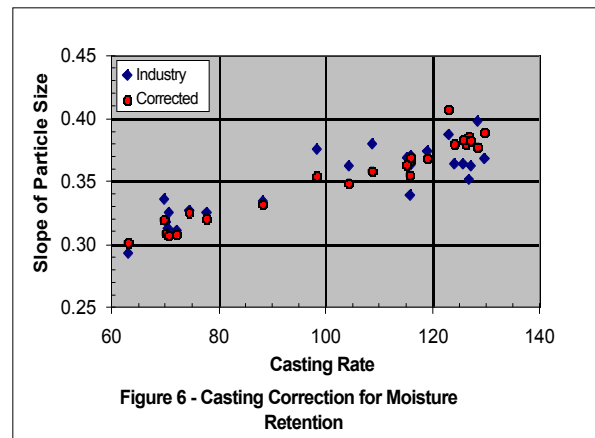
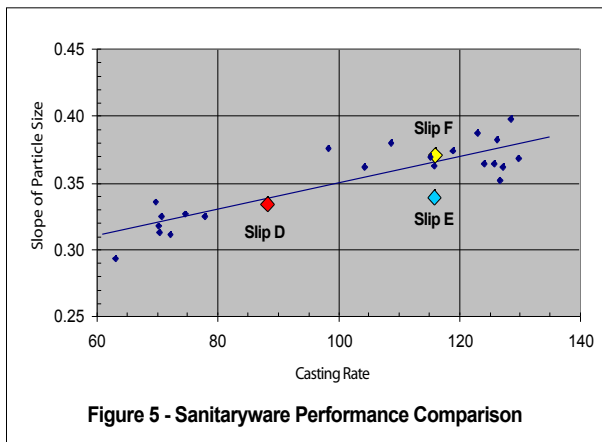
It is interesting that the seemingly small change in particle size at 1 µm from 24% for Slip B to 29% for Slip A would account for the 85% difference in casting rate exhibited by these two samples. Because of this type of extremely sensitive behavior, and because the repeatability of the Sedigraph is about ±1% at best, it became apparent that using a single particle size point for casting performance determination is risky. In fact, in this set of samples, comparing C/R statistically to the mass percent less than 1 µm

produced a square of the correlation coefficient (r^2) of 0.60. By using the slope of the particle size instead of the 1 μ m percent, however, as shown in Figure 4, the r^2 improves to 0.74.

In Figure 5, three different samples are emphasized to compare slips with similar slopes or similar casting rates. Slips D and E, although having similar slopes, are quite different in casting rate. When other data was compared, the most significant difference between the two appeared to be the moisture contents of 20.5% (dwb) for Slip D and 23.0% for Slip E. It appears that the means for producing the higher casting rate for Slip E is to under deflocculate the slip. Slip F, equal in casting rate to Slip E, but exhibiting an higher slope that is consistent with a coarser body, has a moisture content of 21.3%. The MOR of Slip D is just over 700 psi, substantially higher than the coarser Slip F with about 475 psi MOR.

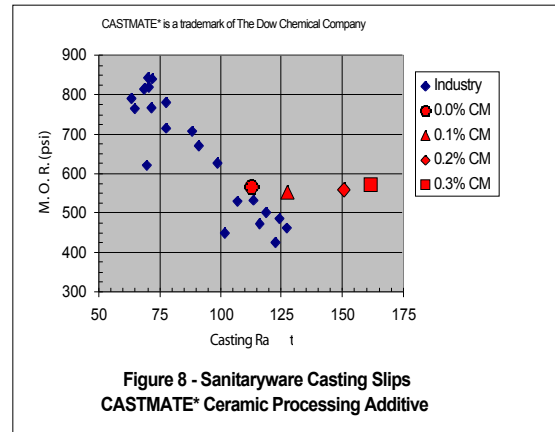
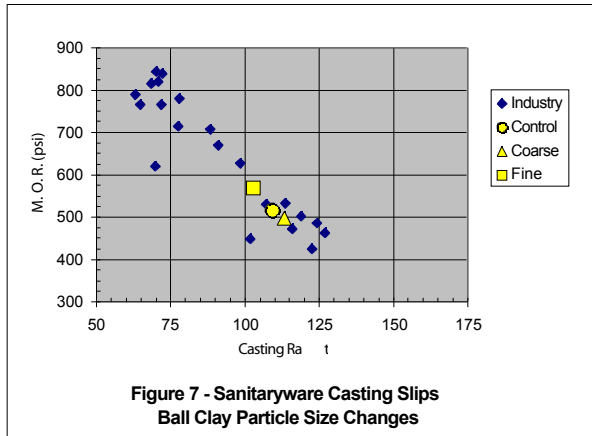


Several of the sample slips exhibit the behavior of the Slip D and E pair, that is, casting rate can be accelerated beyond the predicted, but in each case, the moisture retention is elevated. To account for this moisture difference, a multiple regression analysis was performed. The result of the multiple regression is an equation defining the relationship between C/R, moisture retention, and the slope of the particle size distribution. This analysis was the statistical equivalent of adjusting all the slip samples to produce castings with the same moisture content. These corrected values are plotted in Figure 6. The corrected values are shown in red compared to the uncorrected values shown in blue. The r^2 value in this case is 0.94, a significant improvement. The implication is that the slope of the particle size and moisture retention are dominant in the C/R performance of this set of slip samples.



It was mentioned in the discussion of Figure 5 that Slip F with the steeper slope of the particle size had a lower MOR than Slip D. Lower slope values typically mean higher ball clays or materials with more fine particles. For that reason, they usually produce an increase in the MOR over slips with higher slopes. This concept is illustrated in Figure 7.

The MORs of the industrial samples were compared to their casting rates in same manner as the comparison used between slope of the particle size and casting rates in Figures 4 and 5. A laboratory slip was produced using 33% ball clay. The test slip was adjusted to a typical viscosity used in the sanitaryware industry in the United States and evaluated for C/R and MOR. The 33% ball clay fraction was then changed to incorporate, in one case, more coarse clays, in the second case, more fine clays. These changes were accomplished in this manner in order to minimize changes in chemistry of the bodies. The results, shown in Figure 7, indicate that in the absence of changes other than by traditional methods, the trade-off between casting rate and MOR is a fixed principle.



One non-traditional method for increasing C/R is the addition to the slip a CASTMATE* Ceramic Processing Additive from The Dow Chemical Company. Progressive additions of CASTMATE* of 0.1%, 0.2%, 0.3% of the dry weight of the slip produced significant increases in the casting rate without sacrifice to the MOR values. Although moisture retentions were increased for the slips with CASTMATE* additions, the typical softness associated with increased moisture was not observed.

Conclusions

The lack of correlation sometimes observed between the mechanical properties of a casting slip and the particle size can be the result of inadequate presentation of the particle size data. Using the slope of the mid-range between 10 μ m and 1 μ m was useful for the slips of this survey in predicting slip performance. Greatly improved correlation of results between casting rate and particle size was observed when a correction for moisture retention was applied.

* Trademark of The Dow Chemical Company