Improved Consistency of Slurry and Shell Properties using Particle Size Control of Ceramic Flours

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Abstract

Particle size distribution changes of ceramic flour can affect slurry properties including slurry density, rheology, and coating thickness. Shell properties that can be affected are permeability, thickness, edge coverage, and strength. For critical applications like Titanium and DS/SC casting, control of particle size can mean the difference between success and failure. Methods and examples are presented on how to improve particle size control.

Introduction

It has been common for operators in the shell dipping room to experience some slurries that are more difficult to drain than others. In most shell rooms there were one or two operators, usually with years of experience, that could be counted on to use their skills to apply good coatings even if the slurry had draining problems. This variability from slurry to slurry was most notable in the critical prime slurries but is certainly not limited to those slurries. All slurries experienced similar variation.

The use of robots rather than experienced operators to apply prime coatings to wax assemblies requires that this variability is reduced or eliminated. The robots, at least for now, cannot adapt to unexpected differences from slurry to slurry. The source of variability can be from any of the materials in the slurry as well as from the changes in the slurry as it is being used. Since the refractory powder loading for prime slurry is about 80% by weight and is the largest single component of the slurry, this paper is focused on investigating the refractory powder and what can be done to reduce slurry variability resulting from the powder. The purpose of the paper is to show how particle size of the refractory can have large effects on slurry properties and thus on casting quality.

Experimental Work

For this work, Tabular Alumina was chosen as the material to investigate. This is a material that is commonly used to make prime slurries for Super Alloy Equiaxed, Directionally Solidified, and Single Crystal castings. To make slurries, I started with Shellbond 107 binder, a polymer enhanced colloidal silica binder available from Buntrock Industries. Equal parts of commercially available 200 and 325 mesh Tabular Alumina were added to the binder. Antifoam and surfactant were also used as necessary. Particle size distribution and surface area of the two powders were measured at the Buntrock Lab. See Figure 1.

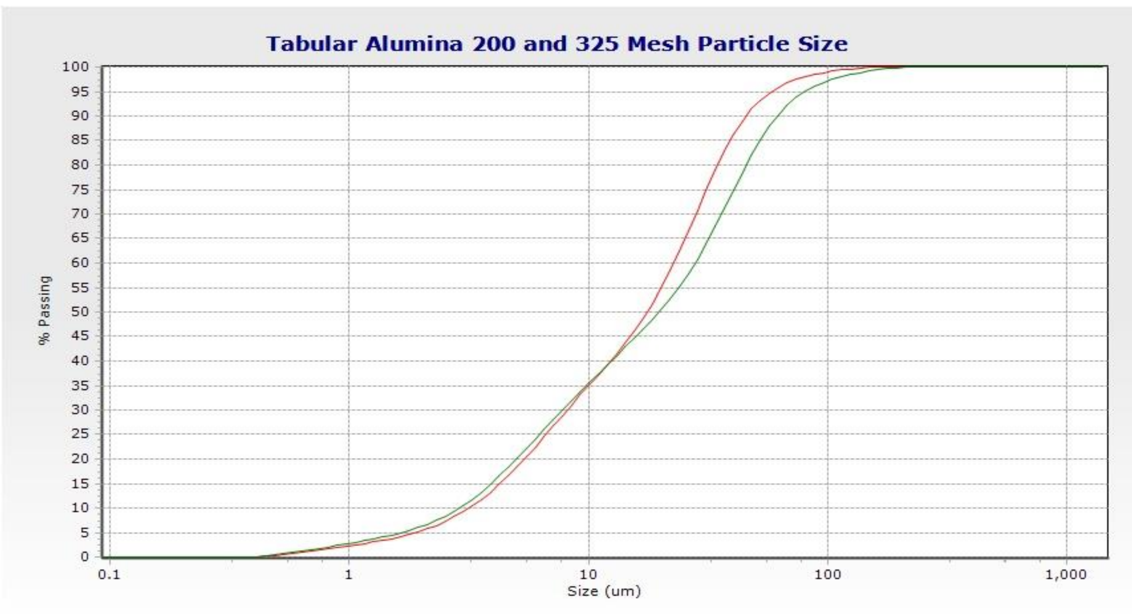

Figure 1. Particle size of Tabular Alumina used to make slurry. (Red line is 325 mesh.)

Surface Area: 200 mesh Tabular Alumina = 0.95 sq m/gm

325 mesh Tabular Alumina = 0.94 sq m/gm

Note that there is little difference at the finer end of the particle size curves for the two materials. The Surface Area is nearly identical for the two materials also. The properties of the slurry were measured after slurry stabilization and are given in Table 1. Properties of a modified slurry are also presented in Table 1. This is explained later in the paper.

Table 1. Slurry Properties of Alumina Slurry

Property	Units	200/325 Slurry	Modified Slurry	Comments
Zahn #5	Seconds	25.1	25.0	
Density	grams/cc	2.55	2.64	
Surface Tension	dynes/cm	32.4	32.6	
Plate Weight	grams	1.56	1.72	Buntrock Small Plate
Coating Thickness	mm	0.076	0.092	On glass slide

During testing of the 200/325 Alumina slurry, it was noted that the draining was poor and the slurry continued to drip for a long time. To investigate the poor draining, we measured the Brookfield viscosity of the slurry. An important characteristic of slurries and how they perform is their viscosity at variable shear rates. Most investment casting slurries are non-Newtonian, which means that their viscosity is independent of shear rate. Water, for example, has the same viscosity independent of how fast it is stirred. Investment casting slurries are not that simple. A Brookfield viscometer is often used to measure the viscosity of non-Newtonian fluids. A Zahn cup can not be used for this type of measurement. A Brookfield Viscometer is shown in Figure 2. The spindle is turned at various selected speeds and the viscosity is displayed and recorded. There are also various sizes of spindles, if needed, for higher or lower viscosity materials. Spindle 3 was used for all the measurements in this paper. The Brookfield viscosity of the 200/325 Alumina slurry was measured and is shown below in Figure 3 along with the Brookfield viscosity curve of the modified slurry, which is explained later.

Figure 2. Brookfield Viscometer

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Looking at the 200/325 Alumina slurry viscosity curve (Figure 3), reveals that the overall viscosity is low even though the #5 Zhan viscosity is fairly high (25 sec.) . Additionally, the Brookfield viscosity curve increases at the higher RPM values. Neither of these features is desirable. In order to improve the slurry, I added 6% by weight of finer particle size Alumina. This Tabular Alumina had an average particle size of 5 microns and a surface area of 3.36 sq.m/gram. The particle size distribution of the original 200/325 slurry and the Modified slurries are shown in Figure 4. Significant improvements were made in correcting the draining of the slurry, and slurry properties. See Table 1 again to compare the properties of the two slurries.

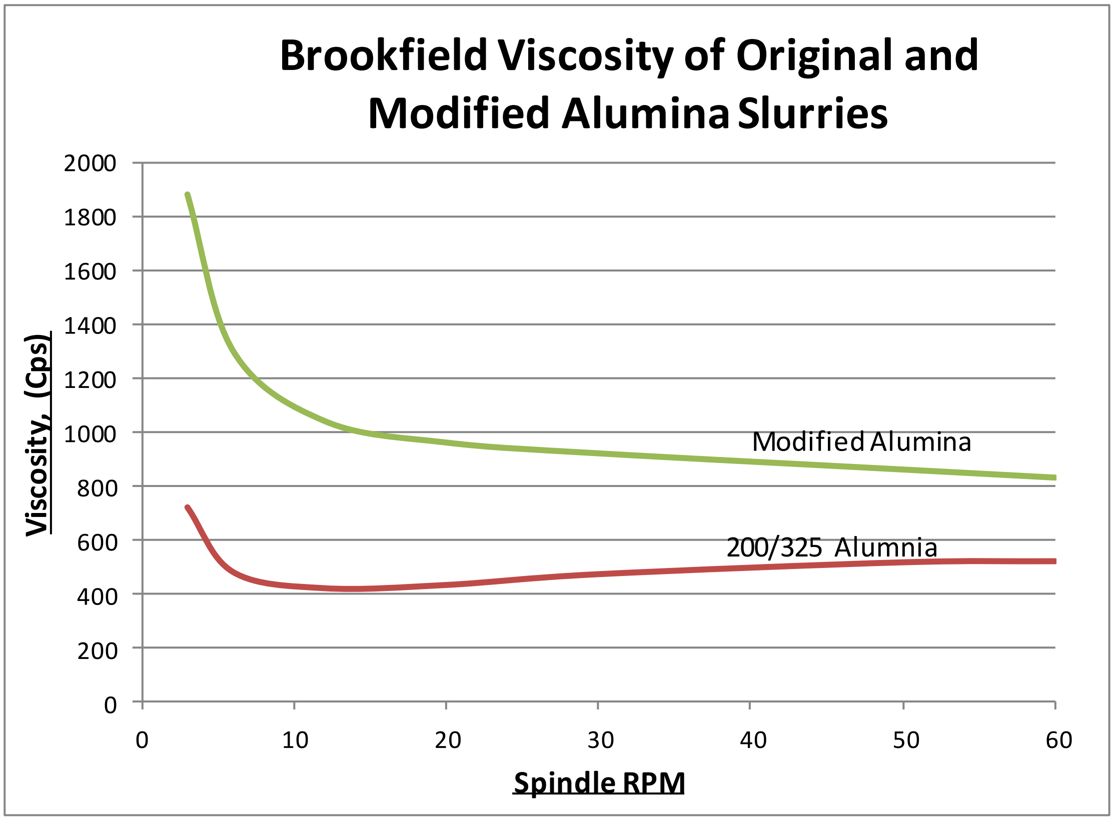

Figure 3. Brookfield viscosity curves for two Alumina slurries.

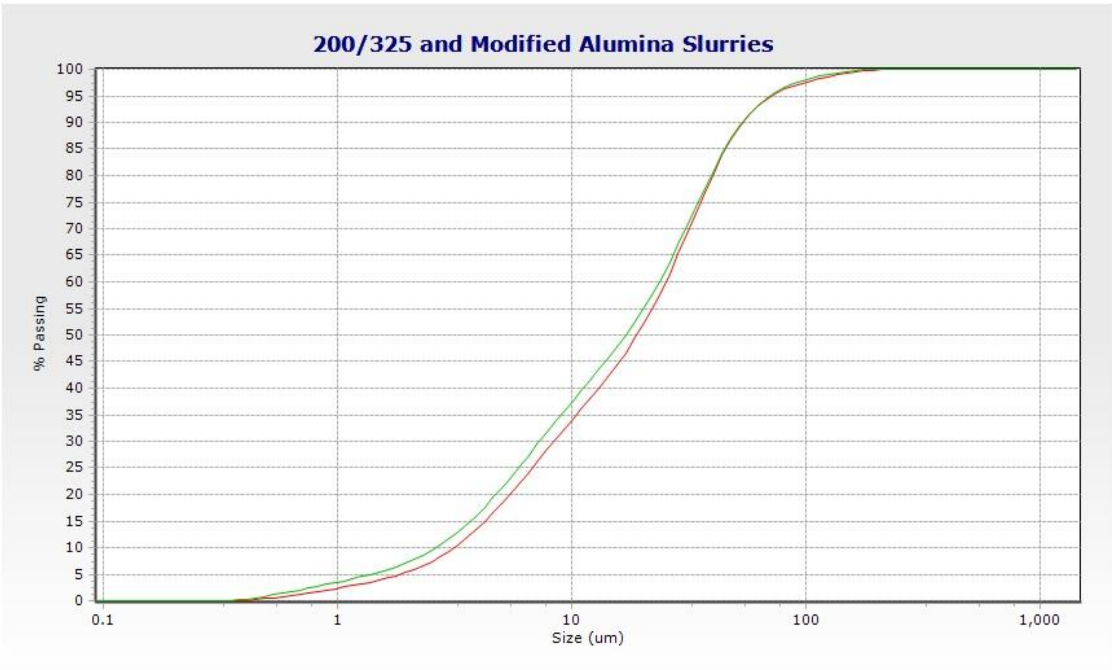

Figure 4. Paricle size of the 200/325 and Modified Slurries. Green is Modified Slurry.

Discussion

Investment casting prime slurries can be greatly affected by particle size distribution of the flour being used. Many critical slurry properties drainability, wet coating thickness and slurry density can be altered by seemingly small changes to particle size distribution. These slurry properties can have an influence on casting quality. It has been shown that just using standard refractory material can result in undesirable slurry properties. Therefore, better particle size control of refractory powders is needed and can be done with additional effort. The data presented here is not intended to be a recommendation for any particular particle size distribution, but is merely to demonstrate how a seemingly small difference in particle size distribution can affect slurries and potentially castings. Buntrock Industries currently does this type of higher level of control of particle size for customers purchasing Yttria and Zirconia powders for Ti casting and Alumina powder for DS/SC applications in three domestic and 4 foreign investment casting companies.