An Evaluation on Media for Milling Concentrated Liquid Dispersions
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Preface: This paper is derived from a more extensive study on the efficiency and longevity of media for horizontal media mills. For access to the full study, please contact technical@americancolors.com.

Concentrated liquid color dispersions are essential in providing the vibrant and memorable colors we see in many different applications. From fiberglass ladders to vinyl interior of a car, the color often originates from a concentrated liquid color dispersion. This involves suspending a solid pigment particle in a liquid via chemical/physical means. This process requires that a pigment particle be reduced to a certain particle size. A few benefits come from the breakdown of particle size such as haptics, color development, and stability. A physical process known as shearing is required to break the particles down to the desired size.

Shearing or *shear strain* is defined as a ratio of how much an object deforms when subjected to a force. Assuming sufficient shear strain, an object (pigment particle) will break or fracture. There are many different ways to achieve such strain on a manufacturing scale but this paper will look at milling, and more specifically the media used to achieve sufficient particle size.

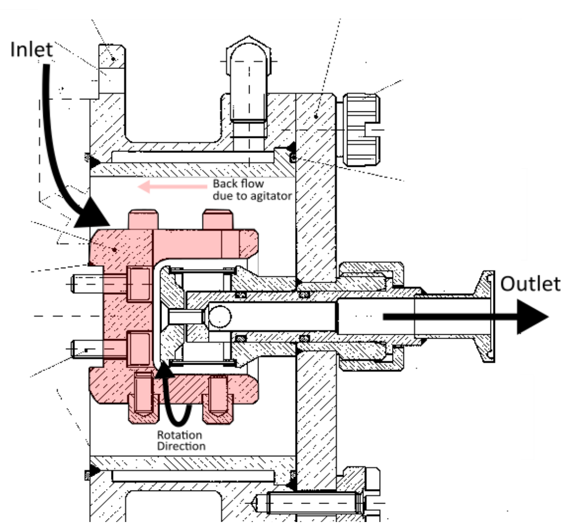

Figure 1: Cutaway view of a 0.25 L horizontal mill. The portion that is highlighted red shows the agitator or impeller. Product flows in from the inlet and exits the outlet.

In order to understand how pigment particles are broken down, an understanding of what a horizontal mill is and how it works is necessary. The main component is the grinding chamber where an impeller or agitator is spun at high velocities inside of a cylindrical chamber. A cutaway view of a 0.25 liter horizontal mill is shown in Figure 1. The agitator transfers energy to the media which transfers energy to pigment particles. This transfer of energy to the pigment is known as a *shearing event*. As a pigment particle passes through the chamber, it will experience millions of shear events. It is important to note that not all of these shear events are successful at breaking down the pigment. Thus, the media can have a substantial impact on grind efficiency.

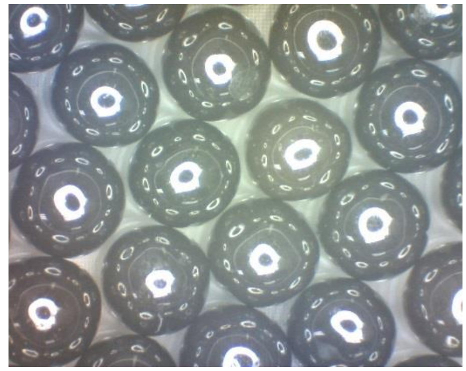

Figure 2: A picture of used 1.5 millimeter Cerium Stabilized Zirconium Oxide media.

There are three types of ceramic media American Colors has employed to achieve a desired pigment particle size. They are zirconium based ceramic material with different compositions. Going from lowest price to most expensive, zirconium silicate, Cerium-stabilized zirconium oxide (see Figure 2), and Yttrium-stabilized zirconium oxide are the three types of media. The best on the market is supposedly the yttrium stabilized, then the cerium stabilized, and last is the zirconium silicate. Different physical characteristics such as the Vickers hardness, size, and composition are marketed by the media manufactures.

The main metrics for determining the best media are longevity and grind efficiency. Longevity is important for several reasons. From an economic standpoint, media that takes longer to wear means decreased frequency of purchasing. From a contamination standpoint, media that doesn’t wear easily is better for the products. White and clear products are particularly sensitive to color pickup. The biggest culprit for color change is the inner lining of the mill chamber. Media can be chosen to reduce the wear on internal mill parts thus less color contamination. The lifetime of media depends on the initial size as well as the screen size inside of the mill. If the media wears down smaller than the screen size then you run the risk of media inside the product which can wreak havoc on pumping systems, coatings, etc. Ideally, the wear pattern is radially uniform or spherical, but any other kind of wear pattern indicates a different kind of wear and potentially breakage. Metrics for longevity include size and sphericity distribution.

Grind efficiency can be directly measured by certain processing parameters such as time and/or number of passes on the mill. Lower processing time has payouts in direct costs and opportunity costs. Less time spent on a product means more time to get the next product in process. Less time spent on a product means less electricity, reduced labor cost, etc.

A study of six different media types was conducted in the ACI lab on a Netzsch Minifer 0.25 L mill. The media selection had two tiers: composition and size. As previously mentioned, we have used primarily three types of ceramic beads at American Colors: Zirconium Silicate, Cerium-stabilized Zirconium Oxide, and Yttrium-stabilized Zirconium Oxide. Within each type of ceramic, two sizes were tested: ~1.5 mm and ~1.0 mm. The product was a carbon black acrylic dispersion that had particle size specification of d90 <10 µm. The goal was to see how different types of media affected the process. Figure 3 shows the results from the experiment.

Media Composition	Size (mm)	Density (g/mL)	# of passes	PSA d90 (µm)	Non - Volatiles	Tint Strength
Zirconium Silicate	1.5	3.7	9	4.35	45.14	100.00
Cerium Stabilized	1.5	6.2	8	5.44	43.64	106.22
Zirconium Silicate	1.1	3.7	4	5.37	43.57	100.47
Cerium Stabilized	1.1	6.2	5	3.94	42.91	102.92
Ytrrium Stabilized	1.1	6.0	6	4.74	43.30	108.04
Yttrium Stabilized	1.0	6.0	5	5.25	43.47	107.89

Figure 3: Results from the media test

The particle size was not recorded until the dispersion achieved a Hegman grind of 7. Once the particle size of <10µm was reached, the number of passes on the horizontal mill was recorded and used as the main metric for determining efficiency. Results show an overwhelming trend between size and processing time. Taking the percent difference of the average number of passes between sizes reveals a ~41% reduction in process time when going from 1.5 mm to 1.1 mm. The only other trend that could be considered was tint strength and density of media. Higher density media seemed to perform better in the tint strength category based on the fact that 75% of the dense media trials resulted in considerably higher tint strength (>105%). The 1.1 mm Yttrium stabilized zirconium oxide performed the best in this study but it an expensive purchase upfront. Cerium stabilized zirconium oxide performed just as well and is considerably cheaper. More studies on longevity would have to be conducted to determine the best media but Cerium stabilized zirconium oxide would be the best choice when considering upfront costs and performance.

As more and more products come through the door at American Colors, we continue to pursue not only chemical solutions to customer applications but also physical solutions. Media selection is one way in which we control our process.