CALCIUM CARBONATE

Abrasion Characteristics of Huber's Ground Calcium Carbonate (GCC) Products versus Competitors

The use of high-performing mineral fillers like Ground Calcium Carbonate (GCC) in thermoplastic systems often causes concern about abrasion and damaging effects to extrusion and die equipment. Properly selected, highly engineered GCC products present no concern for abrasivity.

GCC and Abrasivity Backgrounder

Abrasion characteristics of any material are a function of hardness, concentration and particle size.

Hardness is typically measured on the Mohs scale, where a diamond is 10 and talc is 1. A higher Mohs hardness will scratch or abrade a material with a lower number. Calcium carbonate is a soft mineral with a Mohs of 3.

Hardness Scales

Mineral	Mohs Relative Hardness	Scratch Test	Vickers kg / mm^2
Talc	1	Easily Scratched by Fingernail	2.4
Gypsum	2	Scratchable by Fingernail	36
Calcium Carbonate	3	Easily Scratched by Knife	109
Fluorite	4	Scratchable by Knife	189
Apatite	5	Difficult to Scratch with Knife	536
Orthoclase	6	Scratches with Steel File	795
Quartz	7	Scratches Window Glass	1,120
Topaz	8	Scratches Quartz	1,427
Corundum	9	Scratches Topaz	2,060
Diamond	10	Glass Cutter	10,060

Since ground calcium carbonate is a naturally mined material, impurities exist in all ore bodies. Almost all contain some dolomite ($CaMg(CO_3)_2$) with a Mohs of 4, while others contain mica (Mohs 3) or graphite (Mohs 1-2). None of these softer minerals are of concern for abrasion.

However, almost all GCC has some silica (Mohs 7) present. This may or may not present a concern depending on the concentration and its particle size, as we discuss in greater detail later.

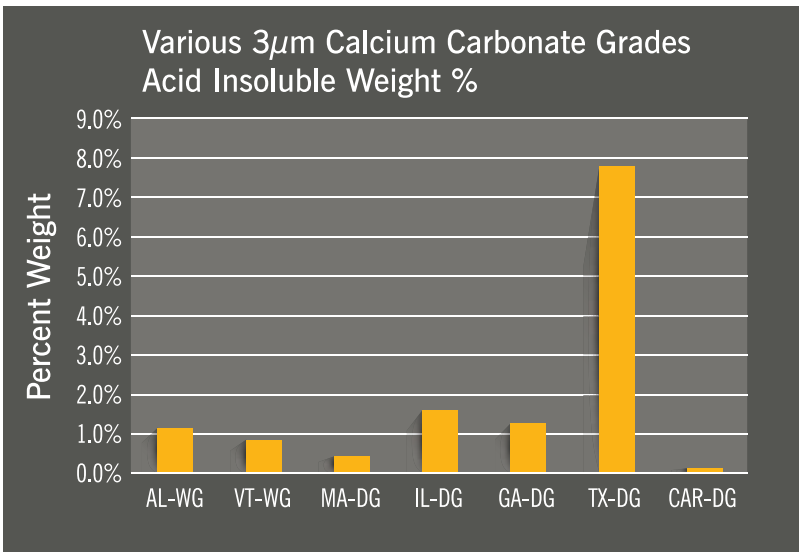
Finally, particle size of the GCC is an important parameter. Coarse-grit sandpaper is far more abrasive than fine-grit sandpaper, even though the grit is composed of the same material. So the median particle size and distribution of the GCC is critical, AS IS THE PARTICLE SIZE AND DISTRIBUTION OF THE IMPURITY.

There are several ways to deal with silica content in the production of GCC. Many ore bodies produce very white GCC, but are high in silica. To address this, ores are first milled to a 20-45µm particle size and undergo froth floatation. In this process, the GCC is slurried with water and a floatation chemical that binds to the silica. Air is bubbled through the mixture and the froth that forms carries the silica with it while the GCC sinks. While not 100% effective, it does remove the majority of the silica. Since the product is already wet, economies of ultra-fine grinding favor wet milling to the desired particle size. GCC slurry is then dried, which is an energy intensive process.

An alternative production method is to start with an ore body with inherently low silica and dry mill it as found. This production method usually results in a slightly less bright product, but has favorable economics.

The Experiments

Various 3µm GCC products were obtained from producing locations in the U.S. All products were mined from ore in that geographic region with the state identified. The exception is "CAR" which is Caribbean sourced ore that was milled at Huber's GCC manufacturing facility in Quincy, Illinois. The products were measured for acid insolubles (primarily silicas and silicates). Most exhibited a low level of acid insolubles, whether wet ground (WG) or dry ground (DG), reflecting the underlying quality of the ore deposit or the efficiency of the wet floatation process. The obvious exception is the **Hubercarb® M3 calcium carbonate** produced in Marble Falls, Texas. This sample was selected as a lot on the very high side of the acid insoluble range encountered during normal operations.



Yellow Bars = Acid Insoluble Weight % WG = Wet Ground DG = Dry Ground
AL = Alabama VT = Vermont MA = Massachusetts IL = Illinois GA = Georgia
TX = Texas CAR = Caribbean

To examine the abrasivity of GCC products, the samples from various ore sources and milling methods throughout North America were tested. A Brabender® torque rheometer with #6 rotors was modified with a removable soft brass (D65 hardness) pin through one of the rotors (Photo 1).

A standard twin screw, tin-stabilized high fill (30 phr calcium carbonate) PVC pipe recipe was run for 16,000 cycles. To minimize the effects of PVC thermal degradation, 10 runs of 20 minutes each were required with 80 rpm rotor speed for each data point.

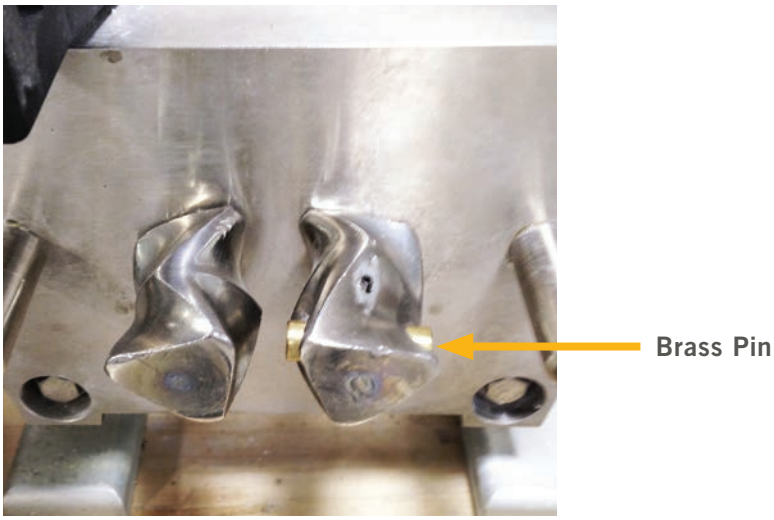
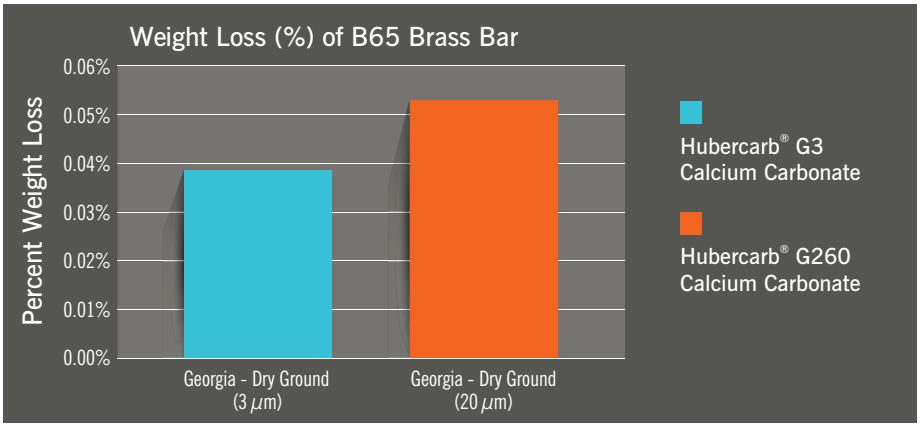
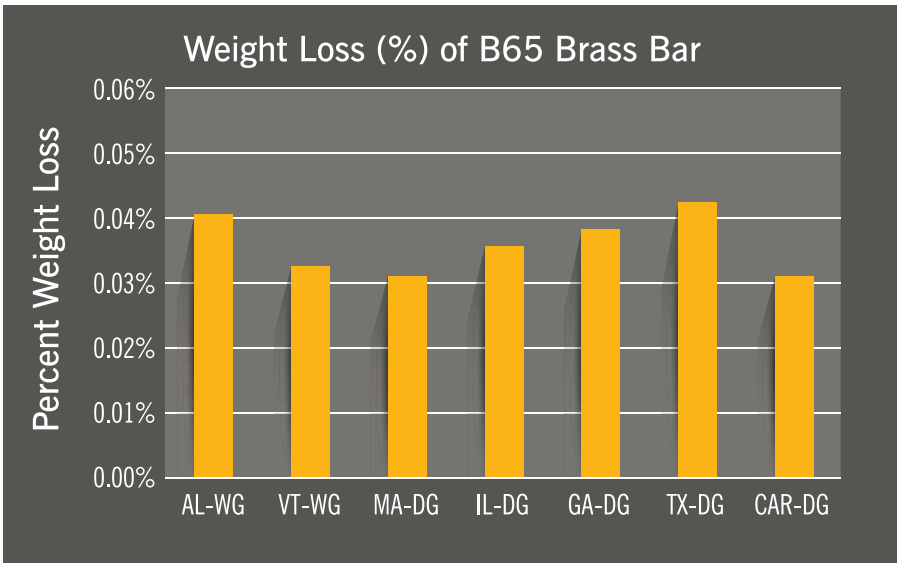


Photo 1

Examining the effect of GCC particle size with a fixed ore source, a comparison of Hubercarb® G3 (3µm median) with Hubercarb® G260 (20µm median) calcium carbonate from Marble Hill, Georgia, clearly shows that the larger particle size calcium carbonate abrades more than the finer one, as expected.



When all 3µm products were compared for abrasion, there did not appear to be a wide data spread. It did not make a significant difference as to the ore source or the grinding method. The products from ore sources low in acid insolubles (like Hubercarb® W3N calcium carbonate) tended to be on the low end of the range, and those with high acid insolubles (Hubercarb® M3 calcium carbonate) tended to be on the high end of the range, but the Alabama wet ground material was also at the upper end of the narrow range despite a lower amount of acid insolubles.



Yellow Bars = Acid Insoluble Weight % WG = Wet Ground DG = Dry Ground
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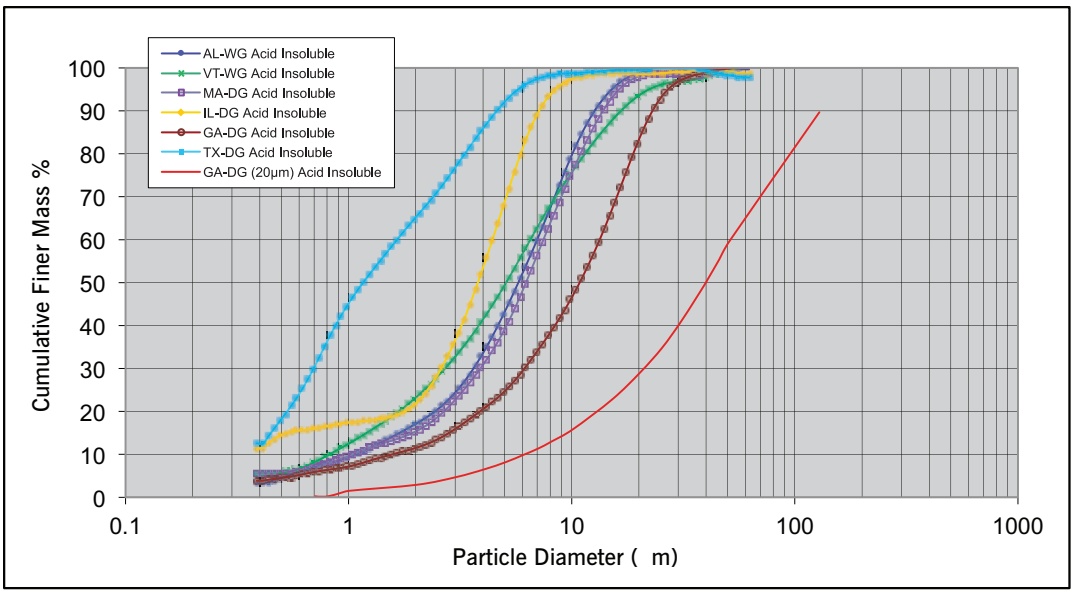
These findings are applicable to polyolefin masterbatches.

The data points out an inconsistency, because the expected result of the Hubercarb® M3 calcium carbonate would be high abrasion. However, this study backed up experiential evidence where the Marble Falls, Texas, Hubercarb M3 calcium carbonate has been used for decades with no abrasion issues.

To further explore this inconsistency, a study of the particle sizes of the actual acid insoluble (silica fraction) was undertaken. The acid insoluble fraction of each product was measured for particle size. In all GCC products, except one, the median size of the acid insoluble fraction exceeded that of the GCC. This is logical since the GCC products are either dry or wet centrifugally classified and the density of silica (2.65 g/cc) is essentially the same as calcium carbonate (2.71 g/cc). Being the harder of the two materials, silica will be less likely to fracture and results in a slightly larger particle size.

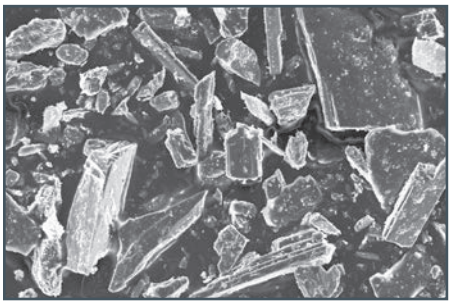
The exception was the Hubercarb M3 calcium carbonate grade from Marble Falls, which had a median particle size of only 1.2 micron meter. As demonstrated earlier, a finer particle sized material of a given hardness results in lower abrasion. **Thus, the relative higher amount of silica in HuberCarb M3 is offset by its very fine particle size.**



The Morphology

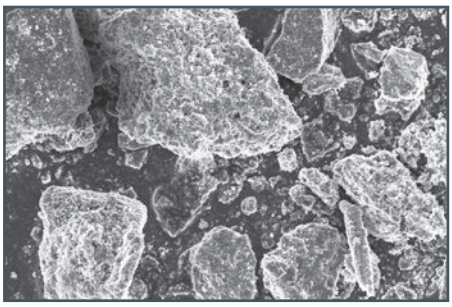
Scanning electron microscopy of the silica fraction illuminates why. The images below show both the 20µm and 3µm median D(50) acid insoluble fractions from the Marble Hill, Georgia, marble and the Marble Falls, Texas, limestone. These clearly show the silica fraction from Georgia as well defined crystals which would be resistant to fracture. However, the Texas material appears porous and friable. It is simple to visualize how easily it would fracture into much smaller particles.

Hubercarb® G260 (Mag = 500 X)
Marble Hill, Georgia



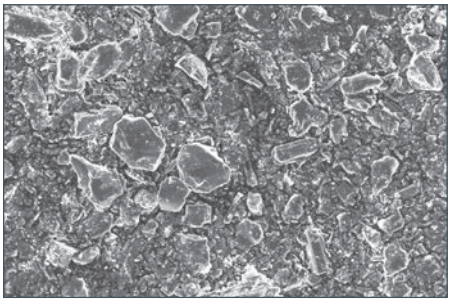
20 µm

Hubercarb® M200 (Mag = 500 X)
Marble Falls, Texas



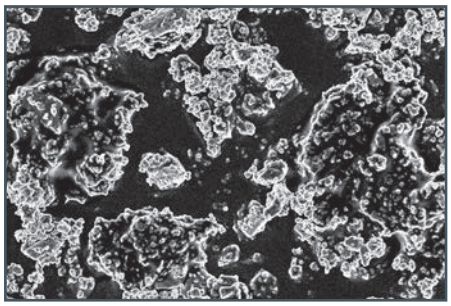
20 µm

Hubercarb® G3 (Mag = 500 X)
Marble Hill, Georgia



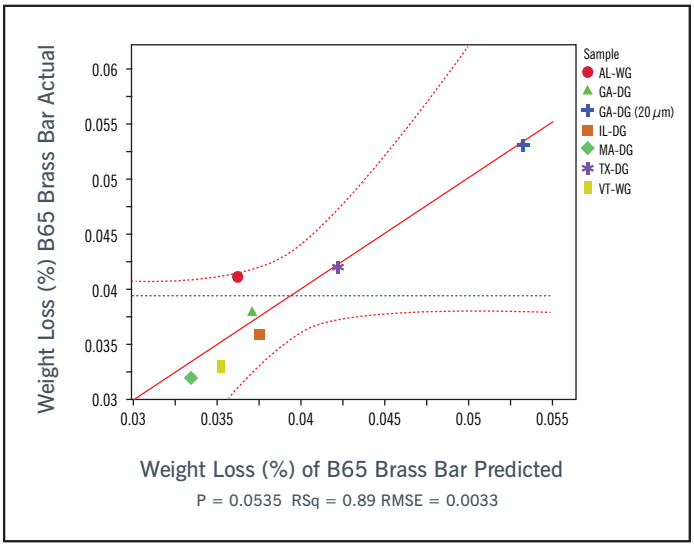
10 µm

Hubercarb® M3 (Mag = 2.0 K X)
Marble Falls, Texas



10 µm

When all factors are taken into account, a statistical correlation to both the amount and particle size of the acid insoluble was developed. A good correlation with an R^2 of 0.89 resulted.



What It All Means...

In summary, when evaluating the abrasion characteristics of a naturally occurring mineral, one must take into consideration both the abrasivity of the mineral and of the impurities. Abrasion is a function of concentration, hardness and particle size of the material and/or impurity. A mineral with a high concentration of a hard impurity is not necessarily more abrasive. It is also highly dependent on the particle size of the impurity.

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CALCIUM CARBONATE

Huber Engineered Materials is your calcium carbonate expert with over 40 years of experience offering product use guidance with unsurpassed technical support and customer service. For more information on our calcium carbonate portfolio of products and their non-abrasivity for a variety of applications, contact us:

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GCC/NoAbrasion/Oct2014