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(54) Dry grinding wheel and its application.

(57) Organically bonded abrasive articles comprising seeded sol gel alumina filamentary abrasive particles have high dry grinding performance when the particles have silicon-enriched surfaces.

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This invention relates to a dry grinding wheel and its application.

It has been known from the teachings of US Patent 3,041,156 that the treatment of alumina abrasive particles with an organo-silane prior to formation of an organic bonded wheel results in a wheel that performs better in a wet grinding application by comparison with a wheel in which the particles have received no such treatment. This was believed to be because the particles were thereby protected from the action of water during the grinding action that perhaps would result in significant deterioration of that surface. This reasoning was supported by the observation that little or no improvement was observed in dry grinding applications when a silane treatment was used.

With the development of sol gel alumina abrasive particles, and particularly seeded sol gel alpha alumina abrasive particles which are characterized by sub-micron sized crystal structures, the practice of treating particles to be incorporated into an organic bonded wheel with an organo-silane has continued, and essentially the same results have been observed.

Recently, new abrasive particles have been developed which are formed from a seeded sol gel alpha alumina, made as described for example in US Patent 4,623,364. These new particles have a substantially constant cross-section along one dimension and an aspect ratio along that direction (that is the ratio of the length to the greatest cross-sectional dimension), of at least about one. They are typically made by extrusion of a seeded sol gel material that forms alpha alumina upon firing. According to the above experience, it was expected that a silicon treatment or coating of these new abrasive particles would lead to the same results in a dry grinding wheel application, i.e., it would have little, if no effect.

Applicant has found, however, that those new abrasive particles surprisingly exhibit a behavior that is quite atypical of alumina abrasive particles in organic grinding wheels, insofar as the dry grinding performance can be significantly improved by treating the particles to provide them with a silicon enriched surface. In view of the prior experiences, this is unusual and unexpected.

Accordingly, the invention provides an abrasive article according to independent claim 1 and a method of making use of same according to independent claim 7. Further features and details of the invention are evident from the dependent claims, the description and the examples. The claims are intended to be understood as a first non-limiting approach of defining the invention in general terms.

The present invention provides an abrasive article comprising an organic bond material and abrasive particles formed of sub-micron sized crystals of a seeded sol gel alpha alumina, said particles having a substantially constant cross-section in one dimension and an aspect ratio in that dimension of at least about one, and having a silicon-enriched surface.

The invention provides especially organic bonded grinding wheels and specifically wheels in which the abrasive particles comprise seeded sol gel alpha alumina in the form of extruded filamentary particles.

When the surface of the particles is described as "silicon-enriched", it is implied that the surface of the particles has a silicon content that is at least an order of magnitude greater than the body of the particles. The silicon is in the form of a silicon-containing compound and, in the finished abrasive product, this may be silica, although this is not invariably the case. Usually the body will contain only trace amounts of silicon or a silicon-containing compound, whereas the surface will have a coating extending over at least a significant part of the particle surface area of silica or a silicon-containing material.

The coating can be applied as an organo-silane compound, preferably one that contains functional groups that aid in producing a uniform coating over the particle surface. Such functional groups include, for example: amino, acrylic, methacrylic, vinyl and mercapto. Alternatively, the silicon can be applied as colloidal or fumed silica or, in the form of a compound such as a silicon ether, silicon ester, silicone or silicate.

The bond that is used can be any resinous formulation useful for the formation of organic bonded abrasive articles. These are often based on phenolic resins and particularly resols. They may, however, comprise other components such as novolacs, urea/ formaldehyde resins, cross-linking additives, elastomers, fillers, grinding aids and the like.

The silicon-containing compound may be applied by any convenient procedure such as immersion of the particles in a solution, sol, colloidal dispersion, or other fine dispersion of the compound. The particles can also be tumbled with a finely divided form of the compound. It may also be desirable to include with the compound an additive that will enhance the adhesion of the compound to the particles.

The preferred additives are amino-silanes such as those available commercially from Union Carbide as A-1100 and Dow Corning as Z 6032.

The abrasive particles comprise seeded sol gel alpha alumina particles and preferably have a density that is at least 95% of the theoretical density. They preferably have a hardness that is at least 18 Gpa, although densities of as low as 16 Gpa can, on occasions, be useful. The shape of the particles, however, appears to be critical in securing the advantages of the invention. The reason for this dependance is not fully understood but it may relate to the generally micro-crack free surface of particles that are formed by a shaping process, as opposed to being formed by crushing larger bodies. The shaping process results in a generally constant cross-sectional shape along one dimension and an aspect ratio of at least about one. The cross-section can be any convenient shape such as round, oval, square, triangular, star-shaped and the like. Deviations from this constancy of cross-sectional shape may be tolerated, such as would result from the accretion of relatively small particles to the outside surface of the abrasive particles, so long as the basic underlying shape remains essentially constant. Generally, a round cross-section is preferred for its simplicity. The greatest dimension of the cross-section is conveniently expressed as a grit size and this can range from 16 to about 400 or more. With decreasing size, however, it becomes more difficult to produce such shaped particles such that the preferred sizes are from about 20 to about 240 grit. Although in certain applications, a very coarse grit gives very desirable results, it is found that in other situations finer grits such as 150 to about 240 can display even greater superiority.

The aspect ratio of the particles can be from about 1 to about 10 or even higher. The higher ratios, however, raise handling problems and, particularly in coated abrasive applications, are difficult to orient appropriately with conventional application techniques. It is, therefore, usual to use particles with aspect ratios of from about 3 to about 6.

The seeded sol gel abrasive particles can be used in admixture with other abrasives such as fused alumina, fused alumina-zirconia, silicon carbide, CBN, and friable filler/abrasive particles such as bubble alumina and conventional mineral particles such as cryolite and the like.

The form of the abrasive product can be a wheel or wheel segment or any other form of abrasive tool. It can also be a coated abrasive belt or pad with the abrasive particles held on a usually flexible substrate by a maker coat, and overlaid with a size coat.

It is found that the advantages of the invention are observed most clearly when the product is used in very aggressive grinding conditions. As the pressure or the downfeed is reduced, the advantages tend to reduce or sometimes disappear.

The invention is now described with reference to the following Examples which are for the purpose of illustration only.

Example 1:

A number of wheels were produced using extruded seeded sol gel abrasive particles with a grit size of 24 and an aspect ratio of about 1.7. In each case, the bond used was Norton Company's B65 system and active fillers were used. The proportions of each component were kept constant.

The only difference between the wheels was that one, (A), received a coating of Union Carbide's A-1100 amino-silane to a level of 0.05% by weight of the grain, a second, (B), had similar amount of Dow Corning's Z 6032 amino-silane and the third, (Comp.), received no treatment at all.

The silane was applied to the grain in the form of a 25% aqueous solution which was added in the amount necessary to give an application level of 0.05% by weight. This was mixed for 15 minutes and then placed in an oven at 140 degrees centigrade for 12-24 hours to drive off the water.

The wheels were 406.4 mm x 3.3 mm x 25.4 mm in size and had rough sides. The test performed was a cut-off test on a Stone M-150 cut-off machine operating in dry
mode. The wheel speed was 2865 rpm and three break-in cuts were made before measurements were made. The test bars were 38 mm diameter 304 stainless steel. Cuts were made at 2.5 sec/cut and 4.0 sec/cut. Different wheels were used for each cut rate. A total of 30 cuts were made with each wheel and two wheels of each type were tested. The average of all the parameters measured for each wheel type was calculated and the results are set forth in Table 1 below.

Table 1 Cut-Off Test Results							
Wheel	Time/Cut Sec.	A.T. mm	Avg.G Ratio	Std. Dev.	E kw	Rel.G %	Rel.Pow. %
Comp. 1	2.5	3.33	3.27	0.4	10.9	100	100
	2.5	3.28					
	4.0	3.33	5.51	0.39	7.2	100	100
	4.0	3.25					
A	2.5	3.28	8.42	0.01	11.35	258	104
	2.5	3.28					
	4.0	3.28	9.94	0.32	7.77	180	108
	4.0	3.28					
B	2.5	3.23	7.33	0.68	11.33	224	104
	2.5	3.23					
	4.0	3.23	9.52	0.57	7.77	173	108
	4.0	3.28					

In the above Table:

- A.T. indicates average thickness of the wheel and therefore of the cut made;
- Avg. G Ratio is the metal removal rate divided by the wheel wear rate over the thirty cuts made with each wheel and averaged for the two wheels tested;
- Std. Dev. indicates the standard deviation from average G Ratio value reported;
- E is the average of the power consumed in making the thirty cuts with each wheel; and
- Rel.G and Pow. give the % improvement over Comp. 1 shown by A and B.

From the above data, it can clearly be seen that the silane treatment produces an improvement of the order of 100% in the grinding ratio at a comparable power draw-down.

Example 2:

In this Example, a Taguchi-style study of four variables was made. These variables were:

Resin Bond: Two bonds were used, the bond used in Example 1 and a second phenolic resin bond identified by the Norton designation "B25".

Wheel Thickness: 3.3mm and 4.1mm.

Cut Rate: 2.5, 3.5, and 4.5 sec/cut.

Silane Treatment: With and without the treatment described in Example 1.

The result showed that the G Ratio for untreated grits was 11.2650, whereas the treated grain product showed a G Ratio of 16.2145. This represents a 44% improvement.

Example 3:

This Example is essentially a repeat of Example 1, with the exception that 36 grit abrasive grains were used. In addition,
very aggressive cutting conditions were used. At a one second per cut rate for a T grade wheel made from grains that had been pre-treated with the A-1100 amino-silane, the G Ratio measured was 125% of that measured for a similar wheel in which the grains had not been pre-treated with the amino-silane. However, when the cut rate was reduced to 2.5 seconds, there was no significant difference in the measured G Ratio. This result may also reflect a decreasing impact of the amino-silane treatment on the G Ratio with decreasing grit size.

Example 4:

This Example is similar to that reported in Example 2 and is based on a Taguchi designed series of tests with the results set forth in an ANOVA level average table as shown in Table 2 below.

Table 2

G-Ratio				
	Aggressive Cut		Mixed Cuts	
Treatment	24 Grit	36 Grit	24 Grit	36 Grit
w/A1100	12.295	9.985	18.375	12.6925
None	7.920	8.765	14.415	12.3794

In the above Table 2, the silane treatment was as described in Example 1, the "aggressive" cut rate was one second per cut and the "mixed" cut rate averaged the values obtained at the aggressive rate (one), and three at slower, less aggressive rates (2.5 sec.).

From this data, it can be seen that the advantage of the silane treatment is most apparent when the wheel is used at aggressive cut rates and with coarser grit sizes.

Example 5:

This Example demonstrates that the degree of improvement shown in Example 1, in the context of extruded filamentary grains, is not shown in conventional crushed grain of similar grit size under similar grinding conditions.

Essentially the same test as is described in Example 1 is used to evaluate wheels containing standard crushed seeded sol gel alumina grain abrasive (24 grit), from Norton Company, on 1018 steel and 304 steel. The wheels were formed under identical conditions except that one set received a silane treatment as described in Example 1 and a second set did not. The sets of wheels were then subjected to side-by-side tests at a variety of grinding conditions. The results are set forth in Table 3.

Table 3

Substrate/ Treatment	G-Ratio at Specified Cut Rate 2 sec/cut	3.5 sec/cut	4 sec/cut
1018 Steel			
No Treat.	6.89	10.98	----
Silane Treat.	5.49	10.97	----
304 Steel			
No Treat.	7.90	----	12.94
Silane Treat.	8.17	----	13.69

As can be seen from the above, the silane treatment has only an insignificant effect at the aggressive grinding conditions, whereas the same treatment produces a spectacular improvement with the filamentary abrasive particles.

Example 6:

This Example illustrates the effect of varying the amount of silane used on the grinding performance of an organic wheel com-prising filamentary sol gel alumina abrasive particles.

The same silane treatment was used as is described in Example 1 with the difference that 1/2x, 1x, 2x, 5x, and 10x silane addition levels in the treatment solution described in Example 1 were used. Thus, for example, 1/2x indicates that enough silane was added to provide a coating of 0.025% (1/2x 0.05%), of the silane, based on the weight of the grain. The results on 301 steel at 1 sec/cut and 4 sec/cut grinding rates are shown in Table 4 below. The results at the higher rate are given in parentheses.

Table 4

Silane Treatment	Metal Removal in^3/min.*	Rel. G-Ratio %	Rel. Power %
None	6.03 (3.34)	100 (100)	100 (100)
1/2x	5.98 (3.29)	2417 (200)	124 (123)
1x	6.08 (3.36)	2408 (133)	122 (119)
2x	5.89 (3.36)	2016 (134)	120 (115)
5x	6.03 (3.36)	2016 (160)	116 (127)
10x	6.08 (3.36)	1514 (160)	116 (111)

*1 in^3 = 16.39 cm^3

These results indicate that heavier silane treatments are not necessarily advantageous in terms of higher G-Ratio or lower power consumption. Indeed, there seems to be little advantage in using a silane addition level over about 0.1% by weight of the grain.

Example 7:

This Example shows the advantage from the use of the silane treatment when the grain particles have been previously treated with a conventional iron oxide/glass frit treatment to coat the grains with a coarse textured ceramic layer designed to improve adhesion between the organic bond and the abrasive particles. As in Example 1, enough of the same silane was added to give a coating on the grain equivalent to 0.05% of the grain weight. The results of the grinding test, performed on 301 steel using the procedure set forth in Example 1, are set forth in Table 5 below.

Table 5

Silane Treatment	Metal Removal in^3/min.*	Rel. G-Ratio %	Rel. Power %
1 sec/cut			
None	5.98	100	100
Treated	6.08	1090	113
4 sec/cut			
None	3.42	100	100
Treated	3.47	232	120

As will be seen, the same pattern of advantage is also shown with these treated abrasives as was demonstrated above.

Claims

1. An abrasive article comprising an organic bond material and shaped abrasive particles formed of sub-micron sized crystals of a seeded sol gel alpha alumina, said particles having a substantially constant cross-sectional shape in one dimension and an aspect ratio in relation to that dimension of at least about one, and having a silicon-enriched surface.

2. An abrasive article according to claim 1 in which the aspect ratio of the particles is from 1 to 5.

3. An abrasive article according to claim 1 or 2, in which the grit size of the particles is from 16 to 35.

4. An abrasive article according to one of the preceding claims, in which the particles incorporated into the articles have a surface coating comprising from 0.02 to 1.0% of the total weight of the treated particles of a silicon-containing compound, the weight of the compound being expressed as silica.

5. An abrasive article according to one of the preceding claims in which the surface coating applied to the particles is selected from amino-silanes, silica sols or gels, and fumed silica.

6. An abrasive article according to one of the preceding claims, in which the organic bond material is selected from phenolic resins, optionally with cross-linking components incorporated therein.

7. A method of dry grinding a substrate which comprises contacting the substrate with an abrasive product under abrading conditions said product comprising an organic bond material and abrasive particles formed of sub-micron crystals of a seeded sol gel alpha alumina, said particles having a substantially constant cross-sectional shape in one dimension and an aspect ratio in relation to that dimension of at least about one, having a silicon-enriched surface, especially according to one of the preceding claims.