May 30, 1961 K. H. SANDMEYER 2,986,455

BONDED ABRASIVE ARTICLES

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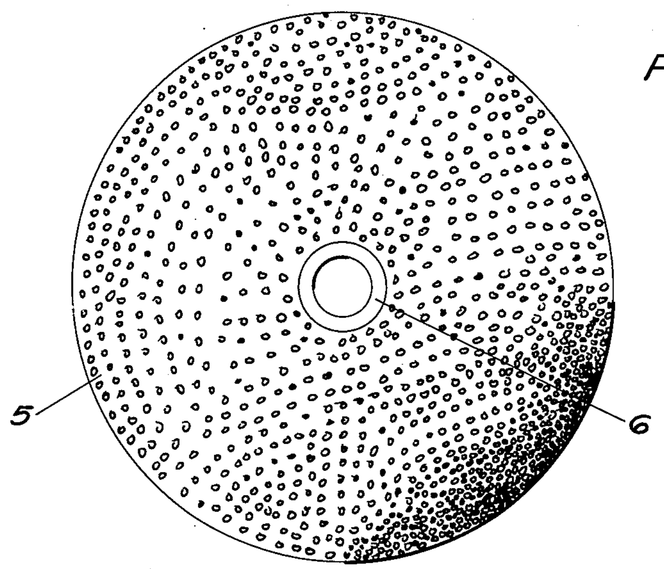


FIG 1

FIG 2

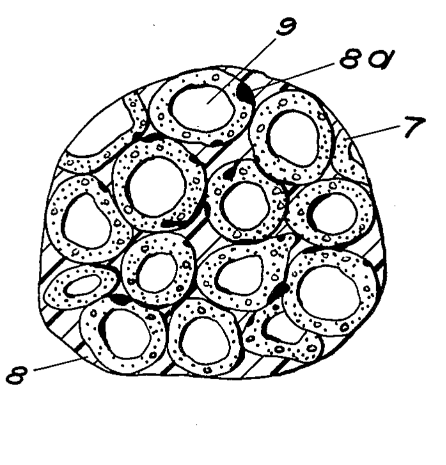
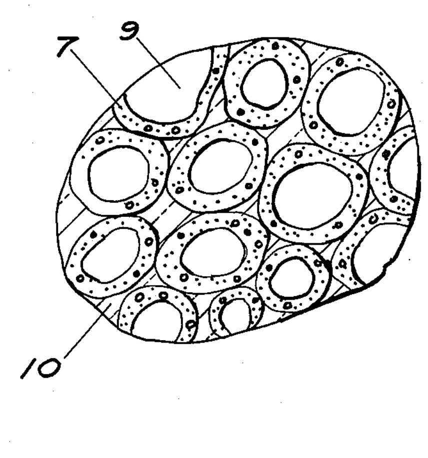


FIG 3



INVENTOR.
KARL H. SANDMEYER
BY W. Foley
ATTORNEY

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BONDED ABRASIVE ARTICLES

Karl H. Sandmeyer, Jamestown, N.Y., assignor to The Carborundum Company, Niagara Falls, N.Y., a corporation of Delaware

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This invention relates to bonded abrasive articles of manufacture such as grinding wheels and other shapes comprising a body or mass of particulate abrasive material held together in an interstitial bonding matrix.

Grinding wheels and other bonded abrasive shapes must not only contain a particulate abrasive material that is held in a surrounding matrix or bond with sufficient tenacity to stand up under the stresses and disruptive forces of the grinding operation, but the body structure of the article must be such that the cutting performance of the article is satisfactorily efficient from the standpoint of rapidity of abrading action or removal of material from the object being ground coupled with an acceptably low rate of wear of the abrasive body. These structural requirements for an abrasive body vary considerably with the kind of material to be ground.

The conventional abrasive wheel of the prior art employs a granular material of selected grit size or sizes such as solid particles or granules of alumina, silicon carbide, boron carbide, zirconia or the like obtained by crushing the crude furnaced material in pig or ingot form to the desired particle size or sizes. While the cutting characteristics of the article are determined to some extent by the nature of the particulate abrasive material used in the wheel, and the type and amount of bonding material used therewith, porosity or openness of the bonded structure to provide coolness of cutting action and freedom from loading is customarily obtained by incorporation within the bond of a pore-forming material that is either volatile or combustible so as to be driven off during the curing or firing of the article to leave a structure of voids within the article when cured or fired, or a material is used that remains in the wheel but is weak and friable in the finished article so as to be readily removed during the grinding operation.

It is an object of the present invention to provide abrasive wheels and other bonded shapes of satisfactory open body structure without resort to the use of pore-forming materials or fillers.

It is a further object of the invention to provide bonded abrasive articles especially adapted for the grinding of materials requiring an abrasive body of open structure for the grinding operation.

Other objects and advantages accruing from the present invention will become obvious as the description proceeds.

I have discovered that grinding wheels and other bonded abrasive shapes of porous, open structure and free-cutting characteristics and especially adapted for the cutting and grinding of certain materials requiring such open structures in the grinding medium can be made in which part, and preferably all, the abrasive component of the article is in the form of hollow spherical or globular abrasive particles. One such spherical abrasive material that I have found highly satisfactory for use in carrying out the present invention is fused alumina bubbles.

Alumina bubbles are a well known industrial product, having been originally developed for use in the making of aluminum metal by electrolytic reduction methods, and subsequently used also as a refractory insulating ma-

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terial. Alumina bubbles are available in particle sizes as coarse as 6 mesh and finer. Methods of making fused alumina bubbles or hollow spheroidal abrasive particles of other composition are well known and need no further description herein. Briefly, fused alumina bubbles are made by fusing a high grade of alumina to the molten condition and pouring a stream of the molten material onto a rapidly rotating disc or into a high velocity gaseous blast to dissipate the material into fine droplets that solidify to form hollow spherical particles, the size of which depends upon such factors as the size, composition and temperature of the molten stream and the velocity of the gaseous blast or rotating disc used for dissipating the stream.

In making abrasive articles in accordance with the present invention, the alumina bubbles or other spherical abrasive particles of selected particle size or sizes are mixed with a suitable bonding material, care being taken to avoid as much as possible any crushing or breakdown of the hollow abrasive spheres. The bond can be modified by the inclusion therewith of inert or active fillers and other modifying agents, as may be desired. The resulting mix is placed in a mold and subjected to pressure to form an abrasive body of the desired shape. The molded article is removed from the mold and subjected to the necessary heat treatment to mature the bond. The times and temperatures required for maturing the bond are those conventionally followed in the making of bonded abrasive articles and depend upon the type of bond used. Ceramic bonded articles are always matured following the removal from the mold, whereas articles utilizing an organic bond, such as a phenolic resin condensation product, can be either formed by a hot-pressing operation in which the bond is partially or fully matured at the time of formation in the mold by simultaneous exposure to heat and pressure, or the article can be molded, removed from the mold, and the bond subsequently cured by a time-temperature treatment. After curing or firing, the abrasive body is suitably dressed in accordance with conventional practices. For example, grinding wheels after maturing of the bond are bored, faced, bushed, edged and speeded in accordance with standard practices employed in the manufacture of bonded abrasive wheels.

In order that the invention may be more clearly understood, reference is made to the various figures of the drawing which present illustrative embodiments of the present invention, and in which:

Figure 1 is a side view of a grinding wheel made in accordance with the present invention;

Figure 2 is a highly enlarged schematic sectional view of a fragment of a resin-bonded grinding wheel made in accordance with the present invention; and

Figure 3 is a view similar to Figure 2, depicting a ceramic-bonded grinding wheel fragment.

The following specific examples are illustrative only and are not to be construed as in any way limiting the scope of the present invention.

EXAMPLE 1

Resin bonded alumina bubble grinding wheels of the type depicted in Figure 1, consisting of a mass or body 5 of resin bonded alumina bubbles and provided with a central mounting arbor 6, were made as follows:

	Parts by weight
Alumina bubbles, 6 to 14 mesh particle size (U.S. Standard Sieve Series)	820
Powdered phenol aldehyde condensation product resin	180
Solvent solution (75% furfural, 25% cresol)	50

The alumina bubbles were first wet by mixing with the solvent solution, after which the powdered phenolic resin was added in small increments with continued mixing until all the powdered resin had been taken up and distributed throughout the mixture of alumina bubbles. A phenolic resin that can be used is that known and sold by the Bakelite Co. as "Bakelite BRP-5417" phenolic resin. Mixing was carried out in a 12" Lancaster mixer using mixes up to 3500 grams in size. Approximately 2 minutes' mixing time was required for wetting the bubbles with the solvent solution followed by approximately 4 to 6 minutes' mixing time for adding and mixing in the powdered resin. Because of the coarse size of the alumina bubbles, screening of the mix was not required.

Best results were obtained when the mixes were used for molding within one or two hours after preparation of the mix. The resulting mix was placed in the mold cavity and pressed at a pressure of 1,000 pounds per square inch with a holding time of approximately 5 seconds. The resulting wheel was removed from the mold and subjected to the following oven curing schedule. The temperature was raised from room temperature to 350° F. in 20–30 hours, held at 350° F. for 5–10 hours, and cooled gradually down to room temperature over a period of 10–20 hours.

An alumina bubble grinding wheel, 12 inches outside diameter, 1 inch thick and 5 inches inside diameter or arbor, made in accordance with the composition and procedure of Example 1 above, had a density of 23.0 grams per cubic inch in the uncured condition and 22.4 grams per cubic inch density after cure. Another grinding wheel made according to Example 1 above and having an outside diameter of 8 inches, thickness of 15/16 of an inch and a 7/8 inch arbor, when subjected to a speed test, broke at 19,720 surface feet per minute.

Examination under the microscope of the body structure of resin-bonded alumina bubble grinding wheels made in accordance with Example 1 above, and reference in connection thereto is now made to Figure 2 of the drawing, discloses that the alumina bubbles **7** are held together in an interstitial matrix of cured resin, a portion **8*a*** of the resin bonding material impregnating crevices and pores in the walls of the individual alumina bubbles to strengthen and reinforce them. Examination of the structure of the wheel further discloses that porosity or open structure within the wheel is provided to a marked extent in the form of cavities **9** within the individual alumina bubbles making up the wheel structure, thereby avoiding the need for an extraneous pore-forming material as a constituent of the wheel body. One particular advantage of obtaining porosity within a wheel structure by means of the use of hollow spheroidal abrasive particles is the fact that the porosity is not derived from pores buried within the bond but is directly associated with the abrasive particles so that the latter are fully exposed to provide optimum cutting performance during use of the abrasive body.

Resin bonded alumina bubble grinding wheels, made in accordance with Example 1 herein, have been used with highly satisfactory results for the grinding of rubber, paper fiber board materials and plastics.

EXAMPLE 2

Grinding wheels 12 inches outside diameter, 1 inch thick and 1¼ inches inside diameter were made from the following mix, the same process being followed as set forth above for Example 1.

	Parts by weight
Alumina bubbles, 14 and finer	820
"Bakelite BRP-5417" powdered phenol aldehyde resinous condensation product	18
Solvent solution (75% furfural, 25% cresol)	50

The molded shapes had a density of 26 grams per cubic inch in the uncured condition and a density in the cured condition of 25.7 grams per cubic inch. The resulting wheels rendered excellent performance in the grinding of rubber rolls such as typewriter platens and the like.

EXAMPLE 3

Rubber bonded alumina bubble grinding wheels can be made as follows:

	Parts by weight
Alumina bubbles	70–90
Depolymerized rubber	5–20
Pulverized sulphur	2.5–10
Powdered phenolic resin	5–15
Mineral filler (e.g., cryolite, MgO, clay)	0–30

The above ingredients are thoroughly mixed by adding the depolymerized rubber to the alumina bubbles to coat them, after which the dry ingredients are mixed in thoroughly, neutral creosote oil to the extent of 5–20 parts by weight per 1000 parts of dry materials being added as needed to maintain bond dispersion. The resulting mix is placed in a mold and hot-pressed at 300° F. and 500–2500 p.s.i. to vulcanize the rubber, the wheel being held in the mold 5–20 hours depending upon the size of the wheel.

EXAMPLE 4

Ceramic bonded grinding wheels, size 8 inches outside diameter by ½ inch thickness by 2 inches inside diameter and size 12" x 3" x 1¼", were made from the following mix:

	Parts by weight
Alumina bubbles, 6 to 14 mesh size	65
Ceramic bond	35
Dextrin	5
Water	6

The ceramic bond had the following composition:

	Parts by weight
Borosilicate frit	20–30
Potassium feldspar (orthoclase)	35–50
High-silica clay	20–40

The above ingredients were intimately mixed in a 10" Hobart mixer. The alumina bubbles were first wet with the water after which the ceramic bond and dextrin were blended in and mixing continued until the bond uniformly coated the alumina bubbles. Wetting of the alumina bubbles required approximately 2 minutes' mixing time and blending in of the ceramic bond and dextrin required an additional 4 to 6 minutes' mixing. The mixes were not screened. The resulting mix was placed in a steel mold and pressed at 1000 pounds per square inch with a holding time at maximum pressure of 5 seconds. The molded shapes were removed from the molds, dried and fired at 1250° C. The time required to reach the maturing temperature (1250° C.) varies from 12 to 84 hours, depending upon the size of the wheels and the kiln load. Similarly, holding time at maturing temperature ranges from 4 to 12 hours, followed by cooling at a rate somewhat slower than the heat-up rate. The fired wheels were edged, finished and bushed according to standard practice and speed tested prior to use. The resulting wheels are useful in the grinding of concrete and bronze.

Figure 3 shows schematically a fragment of a ceramic bonded wheel body made according to Example 4, and reveals the alumina bubbles **7** held together in the interstitial ceramic bond **10**. The porosity of the wheel structure is provided in the form of the cavities or voids **9** within the bubbles **7**.

EXAMPLE 5

The following mix was used to make wheels 8" x ½" x 2" in size with satisfactory results, the procedure for making the wheels being the same as that set forth above for Example 4. Mix as follows:

	Parts by weight
Alumina bubbles, 14 and finer	77.0
Ceramic bond (as in Example 3)	23.0
Dextrin	3.0
Water	4.1

The foregoing examples are representative of the present invention in its preferred form wherein the alumina bubbles or other hollow spheroidal abrasive particles constitute the sole abrasive constituent of the abrasive article. However, the invention can also be followed in modified form by incorporating the hollow spheroidal hard, abrasive particles in the abrasive body in conjunction with conventional granular abrasive material wherein the hollow spheroidal abrasive material, because of having a hardness comparable to the abrasive grain of the body, functions as an abrasive and as a filler, and yet introduces the same type of porosity or openness of structure in the abrasive body as that referred to above in those examples where it constitutes the whole of the abrasive component of the article, but to a lesser extent. The following examples are illustrative of such modified forms of abrasive bodies.

EXAMPLE 6

Resin bonded grinding wheels can be made of the following compositions:

	Parts by weight
Abrasive grain	65–95
Powdered phenolic resin	5–25
Filler (such as cryolite)	0–15
Alumina bubbles	1–30
Solvent solution (75% furfural, 25% cresol), 10–35 parts/1000 parts of dry ingredients	

The mix is prepared in accordance with the procedure set forth above for Example 1 and the abrasive wheels formed by cold-pressing at 500–3000 p.s.i., followed by a soaking bake of 5 to 10 hours at 350° F., with suitable heat-up and cool-down periods similar to those given above for Example 1.

As an example of the making of abrasive bodies in accordance with Example 6, 12″ x 1″ x 4″ phenolic resin-bonding grinding wheels embodying 24 grit silicon carbide grain, and similar size grinding wheels embodying 24 grit fused aluminum oxide grain, together with 6% 6–14 mesh fused alumina bubbles were made and used on a surface grinder at a table speed of 40 feet per minute and an infeed of .005″ to grind the ends of 1″ black iron pipe with highly satisfactory performance results.

EXAMPLE 7

Resin bonded grinding wheels can be made by hot-pressing procedure, using the following compositions:

	Parts by weight
Abrasive grain	65–80
Powdered phenolic resin (such as "Bakelite BRP-5417")	8–15
Fillers, such as cryolite	5–15
Fused alumina bubbles	1–10
Lime	0–3
Solvent solution (75% furfural, 25% cresol), 5–25 parts by weight/1000 parts dry ingredients.	

For example 20″ x 2½″ x 6″ phenolic resin-bonded grinding wheels, using fused aluminum oxide abrasive grain, and containing 1.6% by weight of 16–40 mesh size alumina bubbles, were made by hot-pressing for one hour at 3000 p.s.i. and 330° F., followed by a soaking bake at 325° F. for 10–20 hours. The resulting wheels performed satisfactorily in the grinding of Type 304 stainless steel at 230 pounds' work pressure.

EXAMPLE 8

Vitrified bonded grinding wheels were made as follows:

Mix A

	Parts by weight
20 grit fused alumina	900
Ceramic bond (same as Example 4)	100
Dextrin	20
Water	20

Mix B

14 and finer alumina bubbles	770
Ceramic bond (same as Example 4)	230
Dextrin	30
Water	37

The above compositions A and B were first mixed separately and then intimately blended. The resulting blended mixture was placed in a mold and an 8″ x ⅝″ x 1½″ grinding wheel formed by pressing at 1000 p.s.i., and fired at 1250° C. as described in Example 4. After finishing, the wheel was used for grinding bronze and similar soft metals with satisfactory performance results. Wheels so made were tested for breaking strength and broke at speeds of 17,794 s.f.p.m.

The specific examples set forth above are not to be considered to be restrictive of the invention. For example, other types and sizes of abrasive wheels, including cut-off wheels, and other abrasive shapes, can be made in accordance with the practices of the present invention. Although all the specific examples have dealt with the making of articles wherein the desired shape has been made by placing the moistened mix in a mold and subjecting the mold contents to pressure, and the bonded article is matured by heat treatment, other forming practices common in the abrasive art can be followed without departing from the present invention such as preparation of a mix of suitable consistency for casting and forming the desired shape by pouring the mix into a mold and allowing it to set or harden. Also, in the case of silicate or glue bonded articles, the shape can be matured by either air-drying or a low temperature oven treatment of the article to set or harden the bonding constituent.

Also, while alumina bubbles have been used in the specific examples as the abrasive material, other hollow spherical abrasive material such as hollow fused zirconia abrasive spheres can be used. It is not intended to include or embrace within the scope of the present invention the use as a filler material of such non-abrasive substances as fine, porous or globular clay, resinous or vitreous articles.

Furthermore, the invention is not deemed to be restricted to any specific organic or ceramic bonding material, or to any specific amount of bond, although abrasive bodies of the present invention normally contain more than 50% by weight of the abrasive constituent or constituents.

Various inorganic or ceramic bond compositions can be used, both of the porcelanic type or vitrified type, such as those derived from frits, clays and frit-clay blends, silicate such as sodium silicate bonds, and magnesium oxychloride cement bonds.

Other organic bonding materials in conjunction with conventional fillers and other modifying agents can be used in carrying out the present invention, including urea formaldehyde resins, melamine formaldehyde resins, epoxy resins (bis phenol A-epichlorohydrin), polyester resins, alkyd resins, shellac, glues, vulcanized rubber derived from depolymerized (melted) crude or butadiene-acrylonitrile rubbers, natural or synthetic rubber latices and the like.

Actual grinding operations with abrasive wheels made in accordance with the present invention demonstrate that the resin-bonded wheels are particularly suitable for the grinding of rubber, leather, wood, plastics, bonded cork, polystyrene foam, paper and similar materials which require a porous open structure for cool, free-cutting and non-loading of the wheels, and in many instances render performances superior to that obtained with the conventional abrasive wheels previously used for the purpose. The ceramic or vitrified bonded products made in accordance with the present teachings are particularly useful in the grinding of concrete and bronze.

Having described the invention in detail, it is desired to claim:

1. An abrasive article comprising spheroidal, fused particles of alumina held together in an interstitial resinoid bonding matrix, said particles being hollow thin-walled bubbles each having a single central cavity.

2. An abrasive article comprising spheroidal, fused particles of alumina held together in an interstitial phenolic resinous condensation product bonding matrix, each said particle being a hollow thin-walled bubble having a single central cavity.

3. Abrasive article adapted for the grinding of rubber, leather, wood and plastic materials, said article comprising a body of small spheroidal fused abrasive particles held together by a resinous bond, each said abrasive particle being a hollow thin-walled bubble having a single central cavity.

4. An abrasive article adapted for the grinding of rubber, leather, wood and plastic materials, said article comprising a body of small spheroidal fused abrasive particles held together by a resinous bond said abrasive particles being hollow thin-walled bubbles each having a single central cavity, a portion of said bond penetrating and impregnating the walls of the abrasive particles to strengthen them.

5. An abrasive article according to claim 4 in which the spheroidal abrasive particles are fused alumina bubbles.

6. An abrasive article according to claim 4 in which the bond is a phenolic resinous condensation product.

7. A bonded abrasive article comprising hollow spheroidal, fused abrasive particles selected from the group consisting of fused alumina bubbles and fused zirconia bubbles, each said bubble having a single, central cavity, said bubbles being thin-walled and being held together in an interstitial bonding matrix selected from the group consisting of silicate of soda, shellac, rubber, and a resinoid.

8. A bonded abrasive article comprising a plurality of hollow, generally spherical, thin-walled bubbles of fused abrasive material selected from the group consisting of fused alumina and fused zirconia, each said bubble having a single, central cavity, and an interstitial matrix bonding said particles together and selected from the group consisting of silicate of soda, shellac, rubber, and a resinoid.

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