PREBONDED AGGREGATES

INTERAGGREGATE BOND
This invention relates to the production of bonded abrasive articles wherein the abrasive granules are held firmly in a setting of binder whereby they continue to cut until worn away. This invention is in contradistinction to the action of ordinary abrasive articles wherein it is intended that when an abrasive granule is worn to dullness the increased friction causes the granule to fracture, exposing a fresh cutting edge, or to break out of the bond structure entirely, making way for bringing into action an unworn granule. In further contrast to ordinary abrasive articles, those with which the present invention is concerned are extremely dense with substantially all the space between the abrasive granules filled with binder and require periodical sharpening to bring fresh cutting edges into play, whereas ordinary abrasive articles are somewhat porous to facilitate the action described above.

An extremely dense structure is made necessary by the character of the work to be done, or by the nature of the abrasive material used. In cutting certain extremely hard materials a relatively porous bond structure would be so weak as to let loose the abrasive granules at the first attempt to cut the material thereby making the cutting operation inefficient with respect to the work. In the use of certain rather expensive abrasives, such as diamonds and boron carbide, this premature breaking out of the granules before they have been completely used up would render the process inefficient with respect to the abrasive, regardless of the work.

It has been suggested to bond abrasive granules into dense cutting tools by means of metals such as zinc or by mixing the abrasive specifically diamonds, with finely divided electrolytic iron particles and molding the mixture under great pressure to form a dense homogeneous article.

Such articles have a number of disadvantages however. As stated above they must be dressed or sharpened periodically as the granules wear to remove bond from around the granules to enable them to penetrate the work, and provide space for accumulation of material cut from the work. This is difficult to do without unduly loosening the granules from their foundation, especially in the case of finely divided abrasive material because of the small spaces between adjacent grains and the relative softness of the bonds used. For this reason it is practically impossible to use satisfactorily in this way extremely fine abrasive material, such as the diamond dust produced in crushing and otherwise preparing larger granules for use. Furthermore, there are certain disadvantages in the use of dense metal bonds with respect to the action of the wheel as a whole. More accurately it might be said that there are certain valuable characteristics for an abrasive article bonded with other materials, such as resins, or rubber which are not present in a metal article. These advantages are difficult to define but no less present and may be said to give a grinding wheel better grinding characteristics.

It is an object of our invention therefore to provide a method of making abrasive articles, of the dense type described above, by which the cutting properties of the article can be controlled closely within a wide range of variation; to provide a method wherein a binder for holding the abrasive grains in their setting and a binder for providing the wheel structure are selected as having the properties best suited to the purpose for which they are intended; to provide a method wherein abrasive grains are formed into aggregates by means of a binder having the properties of thoroughly wetting the grains when liquid or plastic and forming a relatively hard brittle binder for the grains when set, the aggregates being then bonded into a dense body by a binder which is liquid or plastic at a temperature which does not injure the first binder whereby it dries, with or without pressure, into all spaces between the aggregates and all spaces communicating therewithin the aggregates. It is a further object to provide a method of making abrasive articles wherein the cutting qualities of the finished article can be selectively determined by varying the properties of the binders used with respect to the grain used and with respect to each other. It is a further object to provide a structure which combines the advantages of the use of small abrasive granules with the cutting power and clearance spaces characteristic of abrasive structures utilizing large abrasive granules. It is also an object of the invention to provide a means of utilizing abrasive dusts which could otherwise not be utilized in a bonded condition, in the production of abrasive articles whose properties approach those of articles formed of larger abrasive granules.

The aggregates may be formed in a manner to make them somewhat porous whereby the binder used to form the abrasive article penetrates the pores of the aggregates to assist in holding the aggregates in place, or the aggregates may be made to have a dense structure with substantially no voids therein.
The binder used to form the aggregates may be any one suitable for use in binding abrasive grains including those already used in the production of abrasive articles. These include inorganic binders such as metals, clays and glasses, and organic binders such as resins (thermoplastic and heat hardenable), rubber, and cellulose derivatives. The method of making the aggregates will depend on the nature of the binder used and will be described by reference to specific examples below. The binder used may be any one which can be put in a liquid or plastic form, as in solution or in the molten state, whereby it will penetrate and fill all spaces in a mass of aggregates, for example, a solution of a resinous binder, or a mixture of a liquid resinous binder and a finely divided solid resinous binder, or a molten thermoplastic binder such as certain resins and metals. Of course the binder selected should be one which can be used at a temperature which will not injure the binder in the aggregates.

The invention will be described with reference to the use of specific binders for the grain and for the aggregates. It is to be understood however that the invention is not limited thereby but includes the use of any combination of binders to selectively control the cutting action of the resulting abrasive product. Furthermore, although the invention specifically provides means of using finest from valuable abrasive materials, it is evident that the principles of the invention apply to use of other, larger, or less expensive abrasive materials.

A type of abrasive article which can be made in accordance with the applicants' invention is illustrated in the accompanying drawing. This drawing shows a fragmentary section of an abrasive wheel, the section being taken in a plane at right angles to the axis of the wheel.

Prebonded aggregates are indicated on an enlarged scale, each aggregate containing a plurality of abrasive particles (such as diamond dust) which have been strongly bonded under heat and pressure. The aggregates are formed by crushing the bonded mass after it has cooled. The aggregates are thereafter united by means of a dense bond which makes intimate contact with the irregular surfaces of the aggregates.

In the drawing abrasive particles 2 are shown in clusters, each cluster containing abrasive particles which have been prebonded with a binder 3 before the breaking up of the prebonded mass into aggregates. The binder 3 may be composed (as mentioned above in some of the examples) of metal or glass. After the prebonded mass has been broken up into aggregates the latter are formed into an abrasive article with the aid of an interaggregate binder, such as for example of a phenol condensation product resin, and the whole article is heated in this case under pressure to form a hard dense bond.

Example I

Diamond particles can be incorporated in metals such as copper, nickel or cobalt. They can also be incorporated in metal alloys, such as those used to hold tungsten carbide particles in forming high speed cutting tools. In the process of incorporating diamond particles in metal the diamonds are mixed with metal which is in finely divided form. The amount of bond material used is that needed substantially to fill the volume between the abrasive particles. Simple calculations based upon the specific gravity, apparent density, grain size, etc. of the materials to be used permit the calculation of this amount with reasonable accuracy. The mixture is pressed and subjected to temperatures ranging from approximately 700°C to 1500°C depending on the metal used. Diamonds are subject to oxidation at temperatures above 700°C. It is desirable therefore that the mixing should be performed in a non-oxidizing atmosphere such as may be produced by deposition of finely divided carbon on the mix or by the use of an atmosphere of hydrogen. A hydrogen atmosphere facilitates the "wetting" of the diamond particles by the metal. It is desirable also that the heating should be rapid to minimize the action of any residual oxygen in the mix on the diamonds.

The mix can also be subjected to jarring while the metal is in a liquid or softened condition in order to bring the metal into closer contact with the abrasive particles, so that the attractive forces between the metal and the abrasive particles may be more fully utilized and so that a dense mass of metal and included abrasive may be obtained. After the mixture has cooled the mass is broken up by any convenient method common to the art of crushing into aggregates, each of which has a plurality of abrasive particles.

Another hard abrasive that can be thus incorporated with metal is boron carbide. Boron carbide can be alloyed, or incorporated into intimate mixture, with a number of metals, and metal-bonded aggregates can be prepared by either of the following processes.

Example II

Powdered metal or metals, such as copper, silver, nickel, cobalt, iron, and boron carbide particles are mixed. The mixture is pressed and then heated somewhat above the melting-point of the metal to bring the metal into intimate contact with the boron carbide particles. In some cases such intimate contact can be obtained by "sintering" the mixture at temperatures below the temperature of complete melting of the metal. After the mass thus formed has cooled it is subdivided into aggregates.

Examples III

A mixture of boron carbide and a metal is heated until the entire mass becomes fluid. On the mass the boron carbide crystallizes to give fairly well developed crystals embedded in a metal matrix. The temperature required to produce fluidity of the entire mass is usually about 2000°C or higher, depending on the metal used and on the proportions of metal and boron carbide. Examples of metals which can be used singly or in combination in this manner with boron carbide are copper, nickel, cobalt, iron, etc. The cooled mass is broken up into aggregates containing boron carbide crystals and interconnected metal.

In the production of metal bonded aggregates, alloying agents may be incorporated into the metal to produce a satisfactory degree of brittleness for crushing purposes and to give the proper grinding action. These addition agents are well known in the metallurgical art and need not be described in detail. As specific examples, copper can be emmbrided by the addition of tungsten, aluminium or tin, the amount added being dependent upon the properties desired in the bonded aggregate. This also constitutes a mechanism for controlling the slow but necessary breakdown of the metal bonded aggregate dur-
ing use; this in turn makes possible considerable control of the cutting properties of the abrasive article because the brittleness or toughness of the bond and abrasive may be adjusted to suit the character of the cutting action desired. Copper may also be embrittled by dissolving therein boron carbide as disclosed in Example XIII.

Dense masses of abrasive particles and an interconnecting medium can be made by mixing diamond particles with powdered glass and melting the glass in contact with the diamond particles in a reducing atmosphere. One glass which has been found suitable for this purpose is made by fusing, crushing and screening the following:

**Ingredients:**

<table>
<thead>
<tr>
<th>Parts by weight</th>
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<tbody>
<tr>
<td><strong>Borax</strong></td>
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<tr>
<td><strong>Flint</strong></td>
</tr>
<tr>
<td><strong>Soda ash</strong></td>
</tr>
<tr>
<td><strong>Zinc oxide</strong></td>
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A small amount of dextrin as a temporary binder may be used when compacting a mixture of glass and diamonds. For firing, an oxidizing atmosphere is maintained at 600° C. until the dextrin has burned away, then the article may be transferred to a graphite container and quickly heated for a short time at 900° C. in a reducing atmosphere followed by any convenient cooling schedule.

After a dense mass containing abrasive particles distributed throughout has been prepared by one of the methods described above, it is broken up into much smaller aggregates in each of which a number of abrasive particles are held in a comparatively non-porous structure or aggregate. These lumps or aggregates are then admixed with a bonding material such as a heat hardenable resin; e.g., a phenolic condensation product resin in the A or B stage. In view of the comparatively non-porous character of the aggregates they can be molded with such a resin bond (and inert filler if desired) in a compact body having few pore spaces. The tendency is for the resinous bond to flow into and fill in the pores of the abrasive aggregates.

The molded body is cured at high pressures and at temperatures which produce a curing of the bond, and the body may be subjected to a baking process to further cure the bond.

It is possible to use a wide range in proportion and variety of abrasive aggregates, bonds and fillers for making abrasive articles. One mix which may be used comprises:

<table>
<thead>
<tr>
<th>Per cent by weight</th>
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<tbody>
<tr>
<td><strong>40 mesh and finer aggregate clusters of glass bonded diamonds; the diamonds used comprising a mixture of grit sizes passing an 80 mesh screen and being retained on a 200 mesh screen</strong></td>
</tr>
<tr>
<td><strong>Fused alumina particles passing a 325 mesh screen</strong></td>
</tr>
<tr>
<td><strong>B stage phenol-formaldehyde type resin</strong></td>
</tr>
<tr>
<td><strong>Previously cured and crushed phenol-formaldehyde type resin, screened to pass a 100 mesh screen</strong></td>
</tr>
</tbody>
</table>

The above mixture is formed into an abrasive wheel by hot pressing in a mold at a pressure of 2000 lbs. per sq. in. and a temperature of 350° F. for 20 minutes. Further curing is accomplished by clamping the mold parts securely together and baking the mold and contents for 16 hours at 350° F.; upon cooling and disassembly of the mold, the abrasive wheel is ready for use.

Instead of a bonding material composed of a heat hardenable resin, a thermoplastic resin can be used. An example of such a resin is a polymerized resin that can be made from a vinyl acetal base. The vinyl acetal is polymerized by means of light or heat until the viscosity of a molar solution of the resin in benzol is about 15 centipoises. About seventy percent of the acetal groups are replaced by acetaldehyde. The resultant resin is thermoplastic and is well adapted for molding in combination with fillers to form strong structures of low porosity. It is also possible to use mixtures of reversible and irreversible types of resin to bring about desired elasticity, toughness and resilience of the bond.

Another method of utilizing finely divided abrasive in aggregates is to form aggregates containing diamond particles or hard carbide particles bonded with glass, and then to unite the glass bonded abrasive aggregates by means of a metal which is somewhat softer and more resilient than the glass. In the process of bonding, the aggregates are surrounded by molten metal under pressure to make a dense structure. Aside from the aggregates and binders therefor, described above, aggregates may be made using other binders, such as rubber, resin solutions, and clay.

In making resin bonded aggregates with normally solid heat hardenable resin 220 grit abrasive grain is mixed with a solution of "A" stage phenol formaldehyde resin in acetone in a proportion to supply 3% of resin based on the abrasive grain. The mixture is then dried in the oven for 6 to 10 hours at 150° F. and the temperature is then raised to 250° F. and held at that figure for one half hour. The resulting mass is then cooled, crushed, and screened to produce a fraction of aggregates having the desired size.

Rubber bonded aggregates are made from the following ingredients:

<table>
<thead>
<tr>
<th>Percent</th>
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<tbody>
<tr>
<td><strong>Smoked sheet</strong></td>
</tr>
<tr>
<td><strong>Sulfur</strong></td>
</tr>
<tr>
<td><strong>Abrasive grain</strong></td>
</tr>
</tbody>
</table>

The smoked sheet is made plastic in the customary roll mill and the sulfur and grain then worked into the plastic mass to form a homogeneous mixture. The mixture is then vulcanized under proper conditions of pressure and temperature to produce a mass that may be crushed to form aggregates.

Ceramic bonded aggregates are made by mixing 5% clay bond with 95% abrasive grain with suitable additions of liquid to give the mixture the proper consistency. The mass is then baked to vitrify the bond at 1250° C. After cooling sufficiently the vitrified mass is broken up to produce aggregates each containing a plurality of abrasive grains.

The aggregates thus made may be rebonded into dense structures by means of any binder which is plastic at a temperature which will not injure the aggregates, to flow into all spaces between the aggregates and spaces communicating therewith within the aggregates, e.g. thermoplastic resins, low melting metals such as copper and zinc, and mixtures of liquid resin and solid resin.

Articles made according to this invention may be somewhat smooth-surfaced when first made. They may be made ready for use by subjecting the working surfaces to a gentle disk action by oscillating the article slowly over a surface...
plate charged with fine, granular loose abrasive which cuts away the bond between the aggregates due to its relative softness and also small portions of bond from the abrasive clusters, thus leaving protruding cutting edges. This disking process, or its equivalent, may be resorted to periodically during the use of the article to remove any detritus lodged in its working surface or to bring new cutting edges into use. It is an important advantage of the invention that a relatively fine abrasive granules may be provided with relatively large clearance spaces between aggregates. Relatively large non-abrasive spaces on the working face of the abrasive article are filled with the binder for the aggregates, which spaces may be made concave or hollow by removal of the binder therefrom by a proper dressing action to provide clearance spaces for the abrasive granules and space for the accumulation of material removed from the work. If the binder for the aggregates is made relatively softer than the binder for the grains, the dressing action will tend to remove more material from between the aggregates than in the aggregates, thus providing the proper setting for the aggregates.

Abrasive wheels made by bonding abrasive aggregates of the type described above and in the manner described have many advantages. The abrasive particles are surrounded for the most part by material that adheres more firmly to the abrasive granules than most resinous bonds. Again the abrasive aggregates have a comparatively large size and can be made with roughened surfaces so that the resinous bond used in uniting the aggregates can hold the aggregates strongly. Moreover the use of different bonding materials in combination with closely compacted abrasive aggregates makes it possible to obtain an exceptionally wide range of cutting characteristics.

The present invention makes it possible to use more efficiently abrasive dusts such as diamond fines, since the aggregates give some of the effects of larger abrasive particles such as are commonly selected for use in the manufacture of bonded diamond articles. There is always an excess of fine grit sized material produced in crushing diamonds to obtain the larger sizes used for diamond abrasive wheels, etc. Insufficient market exists to absorb the quantities of fines produced and the material is therefore relatively inexpensive. This invention makes it possible to utilize the fines to do a large portion of the work of coarser, more expensive grits. Similar remarks apply to the utilization of the finer particles obtained by crushing other rare and costly abrasive materials.

We claim:
1. The steps in the method of making an abrasive article which comprise mixing diamond particles with powdered glass and a carbonaceous binder, heating up the mixture in an oxidizing atmosphere at temperatures below the melting point of the glass until the carbonaceous binder is substantially dissipated, then heating the mixture in a reducing atmosphere until the glass is melted around the diamond particles, cooling the mass and crushing the cooled mass to form aggregates consisting of diamond particles and glass, and bonding the aggregates with a reactive resin under heat and pressure.
2. The steps in the method of making an abrasive article which comprise mixing diamond particles with powdered boro-silicate glass and a carbonaceous binder, heating up the mixture in an oxidizing atmosphere at about 600° C. until the carbonaceous binder is substantially dissipated, then heating the mixture for a short time to about 900° C. to melt the glass around the diamond particles, crushing the cooled mass to form aggregates consisting of diamond particles and glass, and bonding the aggregates with a reactive resin under heat and pressure.
3. An abrasive article comprising aggregates composed of glass-bonded diamond particles and an interaggregate bond composed of synthetic resin cured in intimate contact with said aggregates.
4. An abrasive article comprising aggregates composed of diamond particles bonded with a boro-silicate glass and an interaggregate bond composed of a synthetic resin and a hard filler which have been compressed into intimate contact with said aggregates under pressure and heat.

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