ABSTRACT

Abrasive material is provided in which a relatively thick, flexible, porous, abrasive layer is secured adhesively to a flexible backing member. In the manufacture of the abrasive material, abrasive grain is first coated with a liquid resinous binder composition after which the coated grain is then mixed with a solid, particulate, resinous binder composition, the latter binder being more resistant, after curing, to distortion when subjected to heat and pressure. The thus-formed free-flowing abrasive mixture is then coated continuously onto a flexible backing member. Afterwards, the layer of abrasive mixture is heated to cause fusion of the solid binder at the interface with the liquid binder. It is then compacted into a relatively dense abrasive layer, and is wound up into a jumbo roll in which condition the abrasive layer is subjected to further heat to cure the binder material.

25 Claims, 3 Drawing Figures
ABRASIVE ARTICLES AND THEIR METHOD OF MANUFACTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to abrasive material and its method of manufacture having, in general, the physical form of coated abrasive material and the performance attributes of a bonded abrasive. More specifically, the invention is concerned with abrasive material and abrasive articles formed therefrom in which a somewhat porous abrasive layer comprising a binder coated grain in a binder matrix is secured to a flexible backing member.

2. Description of the Prior Art
Abrasive products are classified broadly into two distinct classes, namely, coated abrasives and bonded abrasives. Those abrasive articles found in the first-mentioned class are commonly referred to collectively as sandpaper; of the latter-mentioned class of abrasives, grinding wheels are a representative type.

Conventional coated abrasive material, in general, is characterized by a high degree of flexibility and versatility and by a layer of somewhat elongated abrasive grains adhesively secured to a flexible backing member in such a way that their longest axes are generally perpendicular, or nearly so, to the plane of the backing member. The abrasive layer in this material is substantially a single layer of abrasive grain, of a controlled variation in size, and the grains are bonded only at their base, i.e., nearest adjacent the backing member material so that they stick up, cantilever-fashion, in random heights and spacings.

The initial aggressiveness of a properly made coated abrasive product is well known; however, coated abrasive products are also well known to have an inordinately short life. With these products, during continued use, the number of abrasive grains in contact with the work piece, because of the variation in grain size and their orientation, increases. This is because shorter abrasive grains are continually exposed as the taller abrasive grains are worn down. Moreover, the area of contact per grain increases very rapidly as the abrasive grain wears away to flat areas.

It is well known that any abrasive article continues to function by reason of the fact that fresh, sharp abrading surfaces are presented when the old abrading surfaces become too dull or smooth to cut. Sharp abrasive surfaces are provided in an abrasive article when the material being abraded offers sufficient resistance to the passage of dull abrasive grain that the adhesive bond holding the abrasive grain is fractured and broken away and the dull grain is shed. Thus, in a coated abrasive product, shorter, fresh abrasive grains are exposed to the workpiece and cutting ability is somewhat restored.

Where fracture or shedding in an abrasive article occurs during grinding, the decline in cutting rate is retarded and the abrasive product life is extended considerably. However, where dulling of the abrasive grain occurs without shedding, the cutting rate of the abrasive article declines exponentially and rapidly reaches a value below which, even though a major portion of the abrasive grain is unused, it is uneconomical to continue.

In contrast to coated abrasive products, bonded abrasive products, such as grinding wheels, are characterized by a rigid, molded, porous mixture of binder and abrasive grain in which the abrasive grains are more or less supported in all three dimensions. The bond in these abrasive products, as in coated abrasives, plays two important roles. It must hold the abrasive grains so that they can do their work and the bond must be designed to release the abrasive grains which lose their cutting ability. There are two basic types of bonds in a bonded abrasive product, namely, vitrified and organic bonds.

A close-up view of a vitrified abrasive wheel would show the abrasive grains held by a latticework of "bond posts". So long as an abrasive grain remains sharp enough to penetrate the material being ground, the bond will hold onto it. As the abrasive grain begins to get dull, the material being ground begins to resist penetration. When the force of the resistance overcomes the strength of the bond post, the post fractures, releasing the dull abrasive grain from the wheel face.

An organic bonded wheel does the same thing in a different way. Here there are no clearly defined bond posts holding the abrasive grain together. The abrasive grains are evenly distributed throughout a mass of bond. When an abrasive grain dulls and is unable to penetrate the material being ground, it gets hot enough to overcome the thermal resistance of the bond surrounding it. The bond softens and releases the dull grain.

Regardless of the type bond, however, in a bonded abrasive article, the same geometry is found therein at all levels, and the number and orientation of abrasive grains in contact with the workpiece remains constant.

In the manufacture of bonded abrasive products, the choice of and amount of various components in the abrasive mixture are carefully selected so that during use, at the relatively high grinding pressures utilized, fracture of the bond occurs and grain shedding results. Thus, during use, the wear and dulling of the abrasive grain in the abrasive article is balanced by the appearance of new, un worn grain and a somewhat steady state is obtained in which as the wheel grinds away the metal the latter wears away the wheel. This results in a relatively constant rate of cut together with a uniform surface finish of the workpiece. However, in certain instances, for example, where size, form or surface finish is of primary importance, it may be necessary to forego reliance on the self-sharpening characteristics of the abrasive wheel and resort to dressing techniques to give the wheel the desired sharpness.

Heretofore, others skilled in the coated abrasive art have made various and numerous attempts to provide in a single abrasive product the desirable features of coated abrasives and bonded abrasives. In general, however, to our knowledge, where these attempts have involved the provision of a thicker abrasive layer, in the nature of a bonded abrasive article, on a flexible backing member, they have been met with only a limited degree of commercial success. Examples of prior art disclosing such a thick abrasive layer on a flexible backing member are U.S. Pat. Nos. 1,953,983; 2,001,911; 2,115,897; 2,194,472; 2,242,877; 2,682,733; 2,682,735; 2,743,559; and 2,770,928.

In the research and development work which culminated in our invention, an initial attempt was made to utilize abrasive mixtures conventionally used in bonded abrasive wheel manufacture. These wheel mixes, however, were found unsuitable for the continuous manufacture of a coated abrasive-type product. Al-
though initially free flowing, the conventional wheel mixes, during storage, showed a marked tendency to pack and become agglomerated in the lower part of the coating feed storage vessel. These agglomerations, particularly in the lower part of the vessel, made it most difficult and sometimes impossible to discharge the abrasive mixture. While it is not definitely known what caused these agglomerations, it is theorized that such is caused at any one point in the storage vessel by the mere weight of the abrasive mixture above on the below it. Apparently this weight (static pressure) acts on the mix below it similar to the pressure in a wheel mold thus tending to compress the bond and abrasive grains together into a bonded abrasive form. In any event, we have found the problem of agglomerations has prevented the making up, in advance, of any great quantities of a conventional bonded abrasive mixture for continuous coating onto a backing member.

Even when making up and coating less quantities of conventional wheel mixes, thus tending to avoid the packing problem, these abrasive mixes have been found to result in an abrasive layer having undesirable fracture and shedding characteristics. In contrast to bonded abrasives, the use of coated abrasives articles normally involves the application of considerably less pressure during grinding. Thus, adhesive bonds which would normally fracture in a wheel and permit the abrasive grain to desirably shed have not been found to suitably fracture when the abrasive mixture was coated on a flexible backing member. The application of grinding pressures higher than that used conventionally in coated abrasive usage and necessary to fracture the bond in conventional wheel mixes to permit shedding was found undesirable as it resulted in, in many instances, destruction of the flexible backing member. On the other hand, modifying the abrasive mixture by the inclusion of fillers therein to make the bond weaker and therefore more friable, as is conventionally done in bonded abrasive manufacture, failed to produce a suitably desirable failure rate. These modifications although the fillers and amounts thereof were widely varied, resulted in bonds either excessively friable, even at the relatively low grinding pressure utilized in coated abrasive applications, or not friable to the degree desired.

SUMMARY OF THE INVENTION

Quite surprisingly and, it is believed, contrary to what one might expect in view of the prior art, we have discovered an abrasive mixture and a process for using it to manufacture an improved abrasive article which not only remains free flowing, thus making it particularly suitable for storage and the continuous coating onto a flexible backing member, but which also allows the manufacture of an abrasive materials in the nature of a coated abrasive material having an abrasive layer of improved cutting and wearing characteristics.

The abrasive mixture, in accordance with our invention, is formed into a layer thereof and after curing, comprises basically abrasive grain coated with a binder in a matrix binder of greater thermal resistance. Thus, the binder forming the abrasive grain socket or coating, on being subjected to heat and pressure, deforms and permits the abrasive grain on meeting sufficient resistance to penetration by the workpiece to be picked out of and shed from the abrasive layer.

The abrasive material of our invention has the desirable characteristics found generally in coated abrasive material; however, quite advantageously, this abrasive material additionally provides, during use, an abrasive layer in the nature of a bonded abrasive which sheds, however, under relatively low grinding pressures thus resulting in restored cutting ability, a relatively constant rate of cut, and maintenance of a uniform surface finish. Moreover, with the abrasive layer of our invention, which preferably is a layer at least several grain diameters thick, an abrasive product of predetermined grinding characteristics, flexibility, wide track capability, cool running, and the general adaptability of a coated abrasive article, can be provided and of longer product life than realized heretofore in coated abrasive products.

By our invention, the usefulness of coated abrasive type products may be extended into heavier stock removal applications. Moreover, it has been found possible to grind metals usually considered too hard for conventional coated abrasive material. In particular, the abrading of difficult-to-machine metals such as, e.g. titanium and stainless steel alloys has been greatly improved.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be better understood by reference to the drawing in which like numerals refer to the same parts in the various views and in which:

FIG. 1 is a cross-sectional view in part of an abrasive product according to the invention;

FIG. 2 is a greatly enlarged view of a section of the abrasive layer only in FIG. 1 showing the physical nature of this layer; and

FIG. 3 is a schematic representation of the process by which our novel abrasive materials is manufactured.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to the drawing, there is disclosed in FIG. 1 thereof a portion of abrasive material 10 having a physical appearance somewhat similar to that of conventional coated abrasive material. Abrasive material 10 has a flexible backing member 11 on the front side of which is provided an adhesive layer 12 which anchors a porous, compacted abrasive layer 13 to the backing member. A similar abrasive layer may be desired in some instances, for example, in the manufacture of an abrasive disc, on the other side of the backing member.

The backing member 11, which is employed in our invention, may be any of various flexible materials conventionally used in the manufacture of coated abrasives. Merely by way of example, the backing member may be of paper, cloth, vulcanized fiber, metal, etc. The so-called cloth backings may be of natural fibrous materials such as cotton, linen, etc.; man-made fibrous materials, of staple or continuous length fibers, such as nylon, polyester, etc.; or of inorganic fibrous materials such as glass. These cloth backing members may be either of woven or non-woven construction. Particularly good results have been obtained in the practice of the invention with backing members of woven natural fibrous material.

Adhesive layer 12 is a thin layer of suitable adhesive material preferably a rigid, high modulus thermosetting resin, the more preferred one being a heat-hardened phenol-formaldehyde resinous composition. These ad-
hesive compositions are conventionally used as "maker adhesives" in the manufacture of coated abrasive material and a detailed description thereof is deemed unnecessary. As is well known, phenol-formaldehyde adhesive compositions are applied to a backing member as a solvent solution, a desirable solvent such as water or alcohol/water being used to adjust the solution to the desired viscosity for coating. The adhesive composition, as is conventional, may contain, if desired, fillers such as calcium carbonate, cryolite, clay, etc. Other adhesive compositions which, on curing, result in a relatively hard, heat resistant adhesive layer may be used rather than a phenolic, such as those comprising epoxy, polyester, polyurethane and the like.

Abrasive layer 13, contrary to that conventionally found in coated abrasive articles, has abrasive grains 14 unoriented and distributed throughout the abrasive layer. The abrasive grains, the reason for which will appear hereinafter, are surrounded by or encapsulated in a socket 15 of adhesive binder. These binder coated abrasive grains are in turn bonded together in abrasive layer 13 in a matrix 16 of binder. The amount of binder matrix is insufficient, however, to fill the interstitial space between the abrasive grains thus leaving pores 17 in the abrasive layer. The structural configuration of the abrasive layer is better seen in the greatly enlarged view of a section thereof in FIG. 2; however, this illustration, it will be understood, is not intended to picture any exact arrangement of the abrasive grains. Some of the grains in an actual abrasive layer in a product of our invention may be substantially in contact with one another and others more or less slightly spaced apart.

Binder material 15 surrounding the abrasive grains, although desirably somewhat heat resistant, is, at the temperatures usually attained during coated abrasive usage, distortable, particularly under pressure. This feature i.e., the thermal distortable nature of the binder material, results in, as hereinafter will become more evident, breakdown of the abrasive layer. In application of pressure during grinding, abrasive grains 14, as they become excessively dull, become hotter. This is turn imparts more heat to binder material 15 and permits abrasive grains 14 to be picked out, so to speak, on distortion of the binder 15 from the socket formed thereby. The picked out abrasive grains are then shed thus providing new cutting surfaces. Binder matrix 16, meanwhile, remains heat resistant at the grinding temperatures attained and, moreover, tends to resist fracture. Nevertheless, with this combination of binder materials, i.e., one more heat resistant than the other, an abrasive layer is obtained having the desired combination of performance characteristics.

Various binder material combinations may be used in the practice of the invention so long as they possess the necessary differences in thermal resistance. A particularly useful combination has been found in using an epoxy resin in conjunction with a phenol-formaldehyde resins composition. A suitable, and one of the preferred epoxy resins for use in the invention is EPON 812 available from Shell Chemical Company. Such an epoxy resin is preferred because of its relatively low viscosity (9–15 poises) and its rather high level of solubility of powdered phenol-formaldehyde resin. Other epoxy resins of higher viscosity may be used, for example EPON 1009, also available from Shell Chemical Company. Regardless of what binder material is used, however, to coat the abrasive grain, it must be less heat resistant than the matrix binder and, in general, will be deformable at temperature above about 240°F.

For the matrix binder, a two stage, heat reactive, powdered resinos phenolic composition, as before mentioned, is preferred. One such material, which can be used with good results in combination with EPON 812, is available commercially from Union Carbide Corporation (Plastics Division) under the trade designation BRP5417. This material, once cured, is heat resistant and will char i.e., degrade and pyrolyze, at about 500°F.

Although the amount of and ratio of different binder compositions will depend upon the particular components used in combination, where the combination is the above-mentioned epoxy-phenolic combination, the epoxy component should be at least about 0.6 per cent by weight of the abrasive grain. In any event, the amount of binder should be sufficient to provide a coating around, or socket for, the abrasive grains.

As mentioned above, other binder material combinations are useable in the practice of the invention. In place of the specific epoxy resins mentioned, other epoxy resins such as Dow D.E.R. 669 (Dow Chemical Company), and Bakelite ERL250 (Union Carbide Corporation), may be used as well as other resins binders which are less resistant to distortion at temperature above about 240°F. Instead of the phenolic component above-disclosed, Varum 1364 (Varum Chemical, Division of Reichold Chemicals, Inc.), Mon. Resinoc 755 (Monsanto Company, Plastics Division), Durite AD 5042 (Borden Chemical Company), may be substituted. However, regardless of what combination of binder material is used, the binder material making up the matrix is, preferably, at least somewhat soluble in the binder composition surrounding the abrasive grain. Where the binder material for the matrix is insoluble in, or not soluble to the desired degree, in the liquid adhesive binder for the socket, a solvent component can be used in the socket binder composition in which both binders are relatively soluble. In the practice of our invention, we have found that furfural, which is a solvent for both epoxy resins and phenol-formaldehyde resins is desirablely added to the binder composition for coating the abrasive grain.

Any type abrasive grain material may be used in the practice of the invention. Those materials which may be found especially suitable are silicon carbide, aluminum oxide, garnet, flint, diamond, emery, fused zirconia-alumina, etc., in grits of 120 and more coarse. Depending upon the abrasive product characteristics desired, the abrasive grain can be of the blocky type ordinarily used in bonded abrasives or of the spindly type usually found in coated abrasive material.

Within our inventive concept, it is possible to provide abrasive material with abrasive layers of various performance characteristics. The performance characteristics, e.g., amount cut, shed, etc., of abrasive layer 13, in addition to being influenced primarily by the resinous binder combination, are influenced also by the volume ratio of abrasive grain, bonding resin, and pores, as well as by the size and type of abrasive grain, fillers, active or otherwise, and the amount and type of binder materials. The optimum abrasive product for any one application may be determined readily by one skilled in the art. However, the inventive concept is deemed useful in any abrasive mixture having from about 38–52% by volume abrasive grain, and from about 10–50%
by volume) resinous binder composition, the remainder being voids. Preferably however, the binder composition is from about 20–32% and the abrasive grain is from about 40–52%, and even more desirably these components in the abrasive layer are about 24–32% and about 42–48%, respectively, the remainder being voids.

An abrasive layer of any desired hardness can be made in accordance with the invention. In general, however, the density of this layer is no greater than the loose packed density of the abrasive grain. Otherwise, during manufacture of the abrasive material the backing member may be damaged, or the abrasive grain may be fractured.

In the event, in certain grinding applications, it is desired to alter the hardness or wear characteristics of the abrasive layer, a more easily friable bond may be obtained by adding certain fillers to the matrix composition. Those filler materials having a modulus lower than that of the matrix resin binder may be used in the invention. Examples of those suitable include hollow phenolic spheres, calcium carbonate, powdered polyethylene, and polyvinyl chloride, etc. For certain applications it may be desirable to add to the matrix composition reactive fillers or grinding aids. In this category, in addition to the powdered polyethylene and polyvinyl chloride above-mentioned, are included, among others, potassium fluoroborate, ferrous oxide, cryolite, sodium silico fluoride, and iron pyrites. The filler component can be added to the matrix composition in quantities sufficient to weaken the matrix bond the degree desired or to accomplish and other result desired. As is before obvious, some fillers may be used to accomplish a dual purpose, e.g., bond diluent and grinding aid. The exact amount of any filler required to accomplish any desired result will depend upon the kind of filler and the fineness thereof, this being readily determined by one skilled in the art of abrasive manufacture.

For general purpose applications, an abrasive material, according to the invention, having an abrasive layer of intermediate hardness and having desirable performance characteristics may be manufactured using grain having either a blocky shape or a spindly shape in an amount from 42–48% by volume. Softer abrasive layers, which are particularly suitable in applications involving high stock removal thus requiring shedding resulting in exposure of new cutting points, are manufactured using conventional spindly shaped coated abrasive grain in order to obtain uniform volume distribution. In relatively hard abrasive products wherein the abrasive layer the abrasive grain is greater than about 48% (by volume), the grain shape preferably is blocky in order to allow, as hereinafter described, adequate compaction of the abrasive layer in manufacture.

The thickness of the abrasive layer will, of course, determine to some extent the life of the abrasive material. We have discovered the preferred thickness for abrasive belts to be from about 25 mils (0.025 inch), which represents about 1 grain layer for 40 mesh abrasive grain, to about 125 mils (0.125 inches). At thicknesses above about 125 mils the abrasive layer tends to become unwieldy and too strong for proper flexing and performance. Other than in abrasive belts, the abrasive layer thickness can be essentially as thick as desired. Above about ½ inch thickness, however, the abrasive product loses its resemblance to a coated abrasive product and more nearly resembles a bonded abrasive. In any event, the abrasive layer thickness should be at least slightly greater than the largest dimension of the biggest abrasive grain in the layer.

The invention will be, it is believed, better understood by reference to FIG. 3 of the drawing in which is illustrated apparatus which may be used in the method of manufacture of abrasive material according to the invention. This apparatus basically includes an unwind section, an adhesive coating section, a coated grain section, a drying section, a compacting section, and a windup section. All of these are indicated in the drawing by appropriate legend. These various sections are supported by a table or flat-like support denoted in the drawing by reference numeral 18. The table or flat-like support 18 is supported in a horizontal plane by a plurality of vertical posts 19.

In the practice of the invention, flexible backing member 11 is withdrawn continuously from supply roll 20 rotating in the direction indicated in the drawing by the arrow. Supply roll 20 comprising idler roll 21 and backing member 11 is located under and on wind stand 21. The backing member passes around brake roll 22, guide rolls 23, 24 and through the nip formed by rolls 25, 26.

Brake roll 22 is fitted with an air actuated cylinder (not shown) which is conventionally used to give controlled tension on a traveling web-like member. Rolls 25, 26 in combination with roll 27, all of which rotate in the direction indicated, form a conventional 3-roll reverse roll coater. Although other coating roll systems may obviously be used, a reverse roll coater is particularly suitable in obtaining a uniformly thick adhesive layer over a relatively wide thickness range. Roll 26 having a rubber periphery is driven while rolls 25, 27, both of which have steel surfaces, are idler rolls. The rolls, as is conventional, can be adjusted to provide the desired nip and therefore adhesive layer thickness.

A film 28 of adhesive formed by extruding adhesive mass 29 through the nip formed by rolls 26, 27 is applied to the backing member. The adhesive mass is desirably a composition, as before-mentioned, comprising a liquid, heat reactive phenolic resin having a viscosity of at least 1000 cps. A preferred coating weight for this composition is from about 3.0 to about 15.0 lbs., more preferably from about 3.0 to about 9.0 lbs. per sandpaper maker's reel.

In some instances, it may be desirable to provide this "maker adhesive" by other methods. One such alternate method involves coating the backing member previously with a front size which can be dried to a non-tacky state but still remains heat flowable. The abrasive mixture, as hereinafter described, is applied to this dried front size layer, the front size, as well as the abrasive mixture, being then subsequently subjected to heat, whereby the front size layer becomes tacky and the layer of abrasive mixture adhered to the backing member.

After being coated with adhesive mass 29, the adhesive-coated backing member 11, supported on support member 30, then passes under the abrasive mixture coating apparatus 31 by means of which is imposed on the backing member a sufficient quantity of the desired abrasive mixture. Support member 30, used in the practice of our invention, is a grid of square metal bars that have been surface ground to give an uniformly planar surface. The bars are spaced apart to allow excess
coated grain from the coating and spreading operation, hereinafter described, to fall through the support means and be recovered and recycled. Obviously, if desired, other support means can be provided such as, for example, a plurality of sequential rotating rolls or a perforated metal plate.

A sufficient amount of the abrasive mixture, which is dry and free flowing, is applied to the backing member to result in an abrasive layer having a thickness of at least as great as the largest dimension of the largest size abrasive grain in the mixture. However, a primary advantage in our invention resides in the ability to provide an abrasive article having more than substantially a single layer of abrasive grain. Where flexibility is of concern, however, a layer having a thickness no greater than about 0.250 inch, preferably no greater than about 0.125 inch, is desired.

The abrasive mixture, in the preferred aspect of the invention, is prepared by mixing with a predetermined amount of solid binder material the desired abrasive grain coated with a liquid binder composition. Any combination of solid and liquid binder materials, as before-mentioned, may be used in the practice of the invention so long as it provides in the abrasive product an abrasive layer which sheds desirably at relatively low grinding pressures and in such a manner as to produce an extended uniform rate of cut. The liquid resin binder should, however, have a relatively long flow or gel time. This allows for more uniform bond formation between abrasive grains.

The preferred combination of binder materials, as before-mentioned, has been determined to be a composition comprising a liquid epoxy binder and a composition comprising particulate, solid phenolic formaldehyde. A solvent component in which both the liquid and solid binder materials are soluble at least to some degree, is included, in the preferred instance. Thus, the abrasive mixture remains free flowing allowing storage in relatively great quantities and continuous application to a backing member. Furfurial is a solvent found to be highly suitable. However, there is no requirement that the solid binder material in fact need be soluble at all in the liquid binder composition or solvent therein. The solid binder need be merely wet by the liquid binder composition for the abrasive mixture to remain free flowing.

The exact abrasive mixture to be used in the practice of our invention can vary considerably depending upon the characteristics desired in the abrasive layer. In general, however, a satisfactory abrasive mixture will be obtained, where, in the case of the preferred binder combination, the weight ratio of epoxy to furfurial is from about ¾ to about ¾ and the wet to dry (solid phenolic binder) weight ratio is from about ½ to ¾. Obviously this ratio depends on many factors including grain size and shape, as well as particular binder material. The dryness or flow properties, as well as the compacting qualities, of the abrasive mixture, are affected somewhat by the humidity of the air in which the coating operation is performed and by the total amount of resin in respect to abrasive grain. Merely by way of example, an abrasive mixture, in which the liquid binder composition/solid binder composition ratio is ¼, remains free flowing at a temperature of 60°-85°F, when the relative humidity is from about 10 to 80%.

Other techniques may be used than above-described in forming the dry, flowable abrasive mixture. The abrasive grain can be, for example, precoated with an epoxy resin, the resin partially cured or dried to a non-tacky state, and then subsequently tackified or solvated at its outer exposed surface prior to or in conjunction with mixing with the solid binder material. An alternative procedure would involve coating the abrasive grain initially with a solvent, e.g., furfural, for the resin binder materials and afterwards sequentially adding the binder material, the solid binder material being added last.

The dry, free flowing, abrasive mixture, after deposition on the backing member, is then spread uniformly into an uncured abrasive layer by means of a spreader. This spreader, which may be adjusted vertically, is desirably a V-shaped member having the apex extending opposite to the direction of travel of the backing member. The base of the spreader extends laterally the width of the backing member whereby an abrasive layer is provided uniformly over the entire backing member.

Afterwards backing member 11 with the layer of abrasive mixture thereon, supported on members 33, is passed through a conventional tunnel heater 34. Therein the abrasive layer temperature will depend, of course, upon a number of factors, e.g., heater media temperature, residence time, etc. However, the temperature of the abrasive mixture should be high enough to cause further fusion of the solid binder material and to prepare the layer of abrasive mixture so that it can be easily compacted into a cohesive layer. In general, and preferably, the temperature of the layer of abrasive mixture should not be above about 240°F. Otherwise, blistering of the abrasive layer may occur due to rapid release of volatiles. However, by using the highest possible oven exit temperature, a shorter hot soak cycle cycle, as hereinafter described, may be used. Thus, in the hot soak cycle, there will be less chance for damage to the backing member from prolonged heating. Various means of heating, as is believed obvious, may be used; however, because of the extreme free flowing nature of the abrasive mixture, the heating means provided should be of the non-contact type, e.g. dielectric and infrared.

On emerging from the tunnel heater, the layer of abrasive mixture is then, while still sufficiently hot to be flowable under pressure, uniformly compacted, to the desired thickness in passing through the nip formed by driven rolls 35, 36. These rolls are steel surfaced, roll 36 being chilled by circulating cold water through. The nip formed by compacting rolls 35, 36 is adjustable by means of air cylinder 37 or the like whereby any degree of compaction desired is obtainable, depending upon the particular abrasive mixture and the initial thickness of the layer thereof. The compacting rolls, if desired, can be covered or coated with release materials such as the silicone rubbers, fluorocarbons such as Teflon, and the like.

The compacted abrasive web then passes to the windup section whereat it is wound into a jumbo roll 38. This winding is accomplished by means of driven roll 39, rotating in the direction indicated by the arrow, supported on roll stand 40. However, contrary to the usual practice in winding jumbo rolls, we have found it absolutely necessary that the abrasive layer be concave in the roll rather than convex. In other words, the winding must be accomplished in such a manner that the abrasive layer faces toward the roll center, as shown in the drawing, rather than toward the outer pe-
riphery of the roll. Otherwise, on subsequent unwinding and flexing, the abrasive web will have the tendency to coil thus making it unsuitable in the formation of coated abrasive type articles. Moreover, should the abrasive web be wound with the abrasive layer convex in the jumbo roll, flexing results in a disrupted abrasive layer which does not lay flat and has a tendency to delaminate, during use, from the backing member.

In practice, it has been found desirable, unless the roll is built slowly, as the roll gets larger in diameter, and particularly with extra large diameter rolls, to maintain the abrasive web in a plane no more than about 10 degrees with respect to the horizontal. Preferably, however, the coated abrasive web between the compacting rolls and the windup roll is substantially in a horizontal plane. This manner of winding avoids any tendency for the abrasive layer to delaminate from the backing member.

During winding of the abrasive web, release web 41 is unwound from roll 42 thereof and is interleaved with the still hot abrasive layer. Roll 42 is mounted in a conventional roll stand 43. The release web may be of any material conventionally used for this purpose, e.g., silicone treated paper, or the like.

The jumbo roll 38, after removal from the winding section, is then heated, as is conventional in the manufacture of coated abrasive material in a hot air soaking room (not shown) to complete cure of the resinous adhesive binders. A suitable curing cycle will depend upon the particular resinous binders used, as well as upon the size of the roll; however, a hot air temperature of from about 200°F to about 310°F. for from about 1/4 hour to about 10 hours is in general found satisfactory.

After hot soaking, the cured abrasive web is made flexible by flexing procedures commonly used in the coated abrasive art. This flexing will permit abrasive articles made in accordance with our invention to be used in grinding applications generally limited to conventional, substantially single layered grain, coated abrasive material. The flexing is accomplished, in general, by passing the abrasive web over a small diameter steel bar while compression is applied by a rubber roll to the material in the nip. Thus the abrasive web is forced to conform to the curvature of the small diameter steel bar so as to crack or break the abrasive layer at regular intervals. Fracturing of the abrasive layer takes place without disrupting the adhesion thereof to the flexible backing member. The abrasive layer breaks into irregularly shaped strips or bars about 1/4 inch wide of varying length running transverse to the web length.

The abrasive layer may be broken so that the flex lines run laterally to the edge, as above-described, or, if desired, so that the lines of break intersect so as to cause diamond-shaped sections of the abrasive layer between the flex cracks. If desired, but this is not deemed necessary for the proper functioning of any subsequently formed coated abrasive article, the flex pattern may be predetermined by impressing grooves or lines in the abrasive layer prior to curing of the binder matrix.

The following examples, will, it is believed, more clearly illustrate the preferred embodiments of our invention.

EXAMPLE I

A cotton, twill weave fabric, saturated and backsized with water resistant binders, all of which is conven-

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<tr>
<th>COMPONENT</th>
<th>PARTS BY WEIGHT</th>
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<tr>
<td>BRL2028 (a liquid, caustic catalyzed phenol-formaldehyde resinous composition available from U.C.C. having 85.5% solids (avg) a P/F ratio of 1.3, a gel time (G.E. gel test) of 17.4 min., a viscosity (77°F) of 35000-80000 c.p.s., a pH of 8.4, residual caustic 0.94%, and a water tolerance of (from 20-50%)</td>
<td>3</td>
</tr>
<tr>
<td>BRL1100 (a liquid, caustic catalyzed phenol-formaldehyde resinous composition available from U.C.C. having 68% solids (avg) a P/F ratio of 1.3, a gel time (G.E. gel test) of 19.26 min., a viscosity (77°F) of 800-1200 c.p.s., a pH of 7.5, and a water tolerance of 3000%)</td>
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</tr>
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<td>and which had been adjusted with water to provide a solution viscosity at 72°F of 100000-100000 c.p.s. A sufficient amount of the adhesive composition was applied on the backing member to provide a weight of 6.2±0.5 lbs./sandpaper makers ream.</td>
<td></td>
</tr>
<tr>
<td>The thus-coated backing member was then forwarded to a second coating station whereat an abrasive mixture was applied on the adhesive coated backing member in sufficient amount to provide an abrasive layer, after spreading, having a thickness of 0.105 inch.</td>
<td></td>
</tr>
<tr>
<td>The abrasive mixture was prepared by first mixing together, in a Hobart Mfg. Co. vertical, planer plane brushier, aluminum oxide abrasive grain (spindly shaped) having an average particle size of 335 microns with a liquid adhesive composition comprising:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>PARTS BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>epoxy resin (condensation product of epichlorohydrin and bisphenol-A having an epoxide equivalent of 175-195, a molecular weight of 306, and a viscosity of 9-15 poises (available from Shell Chemical Company under the trade designation EPON 815))</td>
<td>3</td>
</tr>
<tr>
<td>furfural</td>
<td>1</td>
</tr>
<tr>
<td>This adhesive composition, being 2% by weight of the total weight of abrasive grain and adhesive composition, readily wets the abrasive grain thus coating or encapsulating the individual grain particles.</td>
<td></td>
</tr>
<tr>
<td>The thus-coated abrasive grain particles are then mixed (78% by weight wet coated grain based on total) with a solid binder material, 97% of which will pass through a 200 mesh screen, having the following composition:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>PARTS BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a novolak phenol-formaldehyde resinous composition available commercially from U.C.C. under the trade designation Bekaite BDP5417 and containing 9.7-9.9% hexamethylene tetramine</td>
<td>50.9</td>
</tr>
<tr>
<td>FeS (available from Frank Samuel Co.)</td>
<td>3.1</td>
</tr>
<tr>
<td>KBF (available from B&amp;A Chemical Co.)</td>
<td>15.9</td>
</tr>
</tbody>
</table>
Mixing was continued until each liquid binder composition coated grain was uniformly coated with the dry solid binder material composition and the abrasive mixture was of a free flowing character. On close examination each abrasive grain will be seen to be coated with the liquid binder composition, this composition in turn containing on its exposed surface the particles of solid binder composition. When taken in hand, the abrasive mixture is easily dissipated by mere blowing thereon.

After deposition on the backing member, the free flowing abrasive mixture was then spread into a layer of the desired thickness by passing the backing member with the abrasive mixture thereon under a conventional spreader shaped like a snow plow (90° V). This spreader, which at its base end extended the width of the backing member, was positioned so that its apex faced opposite the direction of travel of the backing member.

Afterwards the coated backing member was passed through an infra-red oven wherein the abrasive layer was heated for 1 minute at 220°F. This heating results in development of sufficient green strength in the abrasive layer for it to be compacted.

The heated abrasive coated web was then passed through the nip formed by a pair of steel compacting rolls being spaced apart so as to provide a nip spacing of 0.078 inch. The upper roll was cooled by circulating water there through, whereby the abrasive layer was prevented from sticking to the roll surface.

After compaction, the abrasive coated backing member was then advanced, in a horizontal plane, to a windup section where it was wound up (abrasive layer concave) into a jumbo roll. A release paper (Patapar 34–24T available from Patterson Parchment Paper Co.) was inter-wound with the abrasive web. During windin, as the roll increased in diame. neter, it was moved vertically upwardly to thereby maintain the backing member being wound at an angle no greater than about 10° below the horizontal.

The jumbo roll was removed from the windup section and was then subjected to hot soaking conditions as follows: start cure at 200°F; heat for ¾ hour and raise temperature to 310°F and heat for 5 hours. The binder materials are thus cured to the desired degree after which the abrasive web is ready for processing, in conventional fashion, into various coated abrasive type articles.

**EXAMPLE II**

Abrasive material manufactured as in Example I, was unwound, given a rubber roll flexing (upper roll, 3 inch diameter rubber (Shore D50 hardness); bottom roll, ¾ inch diameter, steel) according to the usual techniques, and was then processed into an abrasive belt as conventionally done in the manufacture of coated abrasive belts.

Several of these belts were then evaluated on a modified FF-8 Hammond Surface Grinder (Hammond Machinery Builders, Inc. of Kalamazoo, Michigan) using Type 304 stainless steel workpieces, a knurled steel contact wheel, an abrasive belt speed of 3000 S.F.P.M., Thread-Kut 99 Grinding Oil, 0.100 inch downspeed, and 6 in./min. table feed. An average grinding ratio (volume metal removed/volume abrasive consumed) of 43 was obtained.

By way of comparison, a conventional, more coarse abrasive belt (Heavy duty 40 Grit RESINALL Aluminum Oxide) was run, under optimum conditions, on the same test equipment, using the same grinding oil and type workpiece. The results were about 600% better with the abrasive belt of our invention. However, quite unexpectedly, it is believed, though the finer abrasive grain in the abrasive layer of our invention outcut a conventional coated abrasive article having abrasive grain two sizes more coarse, the surface finish resulting was comparable to that produced using a conventional coated abrasive belt of the same abrasive grain size.

As many different embodiments of our invention will readily occur to those skilled in the abrasive art, it is to be understood that the specific embodiments of the invention as presented herein are intended by way of illustration only and not limiting on the invention but that the limitations thereon are to be determined only from the appended claims.

What we claim is:

1. Abrasive material comprising a porous, compacted abrasive layer comprising particulate abrasive grains each being encapsulated in a first binder material, the encapsulated abrasive grains being distributed throughout the abrasive layer in a matrix of a second binder material, said second binder material being more resistant to distortion than said first binder material under pressure at the temperature attained during usage of an abrasive article comprising the abrasive material whereby in usage the first binder material will become heated and distorted sufficiently that said abrasive grains will be desirably shed from the abrasive layer.

2. Abrasive material in accordance with claim 1 wherein said first binder material is distortable at a lower temperature than that attained during actual grinding.

3. Abrasive material in accordance with claim 1 further comprising a flexible backing member having a front side and a back side, said abrasive layer being adhesively secured to said front side.

4. Abrasive material according to claim 3 wherein said abrasive layer is at least as thick as the largest dimension of the largest grain in the abrasive layer.

5. Abrasive material according to claim 4 further comprisng an adhesive layer interposed between said front side and said abrasive layer.

6. Abrasive material according to claim 5 wherein said first binder material softens with heat sufficiently to be distortable at a temperature greater than about 240°F.

7. Abrasive material according to claim 6 wherein said first binder material comprises epoxy resin.

8. Abrasive material according to claim 7 wherein the matrix binder resists distortion when heated even at the temperatures attained during grinding.

9. Abrasive material according to claim 8 wherein said matrix binder material comprises phenol-formaldehyde.

10. Abrasive material according to claim 9 wherein said abrasive layer the abrasive grain comprises from about 38 to 52%, said first and second binder materials comprise from about 20 to 50%, and the remainder of
said layer is voids, all of said percentages being by volume.

11. Abrasive material according to claim 10 wherein said abrasive layer has a thickness no greater than about 0.250 inch.

12. Abrasive material according to claim 11 wherein the density of the abrasive layer is less than the loose packed density of said abrasive grain.

13. Process for the manufacture of abrasive material including the following steps:
   a. preparing a dry, freely flowable abrasive mixture comprising:
      1. coating abrasive grain with a liquid binder composition; and
   b. mixing with said coated grain a predetermined proportion of a solid binder composition;
   c. spreading the abrasive mixture uniformly into a layer of relatively uniform thickness;
   d. heating the abrasive layer thereby to fuse said solid binder with said liquid binder;
   e. compacting the heated abrasive layer to a predetermined thickness; and
   f. heating further said compacted abrasive layer whereby to cure said binders, said first applied binder composition encapsulating each abrasive grain and being less resistant to distortion when heated than said binder in which the coated grains are mixed.

14. Process for the manufacture of abrasive material according to claim 13 wherein said flexible backing member is a continuous web.

15. Process for the manufacture of abrasive material according to claim 14 wherein prior to coating said abrasive mixture onto the flexible backing member, said member is provided with a layer of adhesive.

16. Process for the manufacture of abrasive material according to claim 15 wherein said adhesive layer comprises phenol-formaldehyde.

17. Process for the manufacture of abrasive material according to claim 16 wherein said liquid binder composition comprises epoxy resin and said solid binder composition comprises phenol-formaldehyde.

18. Process for the manufacture of abrasive material according to claim 17 in which said liquid binder composition further comprises furfural.

19. Process for the manufacture of abrasive material according to claim 18 including winding said abrasive coated web into a roll prior to said further heating, said winding being performed so that the abrasive layer faces the center of the roll.

20. Process for the manufacture of abrasive material according to claim 19 including moving said roll vertically upwardly during said winding thereby to maintain the abrasive coated web in a plane no more than 10° with respect to the horizontal plane.

21. Abrasive material according to claim 1 in which the abrasive layer further comprises a filler having a modulus lower than that of the matrix binder material whereby a more easily friable bond is obtained.

22. Abrasive material according to claim 21 wherein said filler is a reactive filler.

23. Process for the manufacture of abrasive material according to claim 13 wherein said solid binder composition is at least partially soluble in said liquid binder composition.

24. Process for the manufacture of abrasive material according to claim 13 wherein the weight ratio of liquid binder to solid binder varies from ½ to ¼.

25. Process for the manufacture of abrasive material according to claim 18 wherein the weight ratio of epoxy resin to furfural varies from ½ to ¼.

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