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ABRASIVE ARTICLE

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The present invention relates to a novel abrasive body possessing improved properties; and, more particularly, it relates to an abrasive body of superior mechanical strength which high strength is maintained over long periods of time. The invention also relates to a novel method for preparing the abrasive product.

The present application is a continuation-in-part of application Serial Number 211,193 filed February 15, 1951, now abandoned.

Abrasive bodies, that is, dense, rigid structures having abrading properties, such as grinding wheels and the like, are well known. In such bodies abrasive grains are bound into a dense, rigid structure by means of a thermosetting resin binder in the final, infusible, insoluble state. It is also common practice to incorporate a finely-divided filling material in the resin binder. Because of the formation of water in the resin during the "curing" of the body, that is, during the conversion of the resin to the insoluble, infusible state, it has been the practice to incorporate in the mixture, as part of the filler, a dehydrating agent prior to shaping and curing thereof. This dehydrating agent takes up the water formed preventing the abrasive body from swelling and distorting.

The dehydrating agent normally employed for this purpose is quicklime (CaO), although magnesium oxide (MgO) may be used. At least a portion of the quicklime reacts with the water to form hydrated lime, $Ca(OH)_2$, so that in the final product at least a portion of the lime is present as calcium hydroxide. While the incorporation of quicklime solved the problem of swelling during the manufacture of the abrasive article, and increased to some extent, the strength of the article, a secondary problem arose in that it has been found that, with such abrasive bodies containing lime, in time, particularly under conditions of high humidity as is common in shops where such abrasive bodies are employed, the mechanical strength decreases to the point where the use of the article must be discontinued. Moreover, because of this decreased strength, the use of such abrasive bodies, particularly when the abrasive body is a grinding wheel, becomes hazardous. In addition, it has been found that very strict control of the quicklime must be maintained to prevent the formation of an unsatisfactory product. In other words, the quicklime of commerce generaly loses about 1–3% of its weight on ignition. Such quicklime had to be fired prior to use to reduce its ignition loss to less than 1%, usually 0.5% before it could be employed in the preparation of abrasive bodies. Various attempts to remedy the foregoing difficulties in the past have not proved successful.

It is a principal object of the present invention to provide an abrasive body whose mechanical strength does not decrease with time.

Another object of the invention is to provide an abrasive body possessing a higher mechanical strength than those heretofore available.

Further objects including the provision of a novel method for making abrasive bodies will be apparent from a consideration of the following specification and claims.

The abrasive body of the present invention comprises abrasive grains bound into a rigid structure by a binding phase which comprises a thermosetting resin in the final, infusible, insoluble state, and finely-divided filler comprising an alkaline earth metal fluoride selected from the group consisting of the calcium, magnesium and barium fluorides, and an alkaline earth metal compound selected from the group consisting of lime and magnesia. Herein, in connection with the final abrasive product, the terms "lime" and "magnesia" refer to the oxide or hydroxide as well as to mixtures thereof, since, as will be pointed out hereinafter, the proportion of the initial oxide employed as dehydrating agent which is converted to the hydrated form will vary depending upon various factors, and since, from the standpoint of the present invention, it is immaterial what proportion of the original oxide is present as such or as the hydrated form.

The present invention is based upon the discovery that the incorporation of at least one of the stated alkaline earth metal fluorides in the binding phase of an abrasive body containing a thermosetting resin and calcium oxide and/or magnesium oxide, as a dehydrating agent, provides a product which possesses an improved mechanical strength, and which maintains its high mechanical strength over long periods of time even when used under conditions of high humidity. While the exact reasons for this are not fully understood, the following theory is advanced by way of explanation. As indicated above, the calcium or magnesium oxide functions as a dehydrating agent by virtue of its ability to combine chemically with water to produce the corresponding hydroxide. The hydroxide formed both during the manufacture of the abrasive body, due to the formation of water by the resin during curing thereof, and during the product's use, particularly under conditions of high humidity, is believed adversely to affect the resin, reducing its mechanical strength. It is believed that the finely-divided alkaline earth metal fluoride dispersed throughout the binding phase of the present product neutralizes the hydroxide or otherwise eliminates its deleterious influence on the resin component. At any rate, as stated, the presence of the alkaline earth metal fluoride enhances the mechanical strength of the finished product and also results in a product which maintains its high mechanical strength over long periods of time. Moreover, it has been found that when the alkaline earth metal fluoride is incorporated in the binding phase the quicklime, which is preferably employed as dehydrating agent, need not be rigidly controlled as to ignition loss as previously, and that the high mechanical strength and maintenance thereof can be achieved even if the quicklime of commerce is employed without preliminary calcination.

The preparation of the abrasive product of the invention will present no problem to those skilled in the art since, as is well known, the general procedure involves the mixing of the abrasive grains with the binding phase, and the pressing of the resulting mixture into the desired shape and the "curing" of the shaped body by heat to convert the resin into the insoluble, infusible state. However, the important feature insofar as the method of the present invention is concerned, is the thorough distribution of the stated alkaline earth metal fluoride, in finely-divided form, throughout the binding phase.

The abrasive grains from which the abrasive body is prepared may be selected from a wide variety of materials well known in the art. The particular abrasive grain selected will, of course, depend upon the use intended for the abrasive body and upon the properties desired. Examples of abrasive grain are fused alumina, emery, corundum, diamond, the various carbides such as silicon carbide, boron carbide, tungsten carbide, tantalum carbide, and the like. The size of the abrasive grain may also vary widely depending upon the properties desired in the final product. The selection of any particular material for use as an abrasive grain and the particle size

distribution thereof, are considerations well known in the art and will present no problem to those skilled in the art. The proportion of abrasive grain in the product will vary somewhat as known to those skilled in the art. Generally, the abrasive grain may make up as low as about 40% of the final abrasive product, and generally, it will range between about 60% and about 96%, by weight of the product. Preferably, the abrasive grains make up between about 65% and about 90% of the product. The remainder of the product comprises the hereinafter-described binding phase.

The resin employed in the binding phase of the abrasive body will, as stated, be of the thermosetting type so that it may be converted by heat, and also under pressure if desired, into a form which is no longer fusible at high temperatures and which is no longer soluble in ordinary solvents. There is a wide variety of such resins available as is well known in the art and examples of such materials are the phenol-aldehyde resins, particularly the phenol-formaldehyde resins; the resorcinol-aldehyde resins, particularly the resorcinol-formaldehyde resins; the urea-aldehyde resins, particularly the urea-formaldehyde resins; the melamine-formaldehyde resins; the furfuryl alcohol resins; furfuraldehyde resins; furfuryl alcohol-furfuraldehyde resins; the alkyd resins; and the like, as well as various mixtures of such resins. Of the various resins available the thermosetting phenol-formaldehyde resins are preferred. In preparing the product of the invention, the resin will, of course, be in the initial state of condensation or polymerization so that it can be rendered fluid to facilitate the formation of the continuous binding matrix, and also, in certain situations, to facilitate the shaping of the body. The initial resin may be in powdered condition or in the liquid state, or a mixture of powdered and liquid resins may be employed. Powdered resins are preferred. In addition, resin-forming ingredients may be employed in making up the mixture, as for example when furfural is employed to wet the abrasive grain, or when phenols, for instance commercial cresylic acid, are employed to wet the binding ingredients when a powdered resin is employed. In such situations, heat subsequently applied during curing causes these ingredients to enter into and become part of the resin binding phase. In the binding phase of the product of the present invention the resin will generally comprise between about 33% and about 80%, by weight, thereof, and preferably, the proportion of resin in the binding phase will be between about 45% and about 60%. It will be understood that there may be incorporated in the binding phase, or in the resin, a small amount of a curing catalyst to facilitate conversion of the resin into the final, infusible, insoluble state. For example, when phenol-aldehyde resins are employed, hexamethylene tetramine may be incorporated therein to provide a convertible resin and to facilitate conversion thereof to the final, infusible, insoluble state.

As indicated above, the product of the invention is made up of two main components, namely the discontinuous phase of abrasive grain and the continuous phase, or matrix, termed the binding phase. The binding phase comprises the described thermosetting resin and a finely-divided filler at least a portion of which is lime and/or magnesia and at least a substantial portion of which is the stated alkaline earth metal fluoride. Referring specifically to the dehydrating agent employed in preparing the product, calcium oxide (quicklime) is the preferred material. While magnesium oxide may be employed alone, it is when employed, generally used in conjunction with quicklime, the latter making up at least half of the combined compounds. With respect to the alkaline earth metal fluoride, the preferred compound is magnesium fluoride. Thus, in the binding phase of the preferred product of the invention, the finely-divided filler will comprise lime and magnesium fluoride, the term "lime" being as herein-defined.

Filling materials are substantially insoluble, inorganic materials which are capable of existing in discrete finely-divided form. Examples of such materials are cryolite, clays, quartz, calcium carbonate, calcium sulphate, the alkali metal fluoborates, iron sulfide, various metal oxides, such as chromium oxide, finely-divided metals, and the like. The filler, in addition to the lime, most generally employed in the binding phase of abrasive bodies is finely-divided cryolite, and such material is the preferred material for making up any balance of the filler in the binding phase of the present product.

The filler will generally make up between about 20% and about 67%, preferably between about 40% and about 55%, of the binding phase, and in the product of the present invention the alkaline earth metal fluoride will make up at least about 10%, generally at least about 20% of the filler, and preferably at least about 50% of the filler will be the finely-divided alkaline earth metal fluoride, the remainder being the lime and/or magnesia and any other filler material as mentioned above. Along with the lime and/or magnesia, the alkaline earth metal may make up substantially all of the filler. The filler, including the lime and/or magnesia and alkaline earth metal fluoride, as stated, will be finely-divided and generally it will possess a particle size less than about 150 mesh and preferably less than about 200 mesh.

As stated above, lime and/or magnesia will be present in the binding phase. Although the dehydrating agent employed in the preparation of the article will be calcium and/or magnesium oxide, at least a portion thereof will be converted to the hydroxide during the preparation of the product, and additional oxide may be converted to the hydroxide after the preparation of the product and during its use due to moisture in the atmosphere. The amount of oxide in the product converted to the hydroxide will depend upon various factors including the proportion of oxide employed, the amount of water formed during the conversion of the resin to the final, infusible, insoluble state, the humidity and other moisture conditions encountered in the product's manufacture, storage and use, and the length of time during which the product is subjected to such conditions. Since the advantages of the present invention are gained whether a large proportion of the oxide has been converted to the hydroxide or whether a small portion of the oxide has been converted leaving the balance thereof in a condition potentially convertible to the hydroxide after the product has been manufactured, this component of the binding phase is referred to generically herein and in the claims as lime and/or magnesia to include both the oxide and the hydroxide of calcium and/or magnesium as the case may be. In the preparation of the binding phase, the amount of oxide employed will usually range from about 7% to about 75% of the filler and thus in the product of the invention, the lime and/or magnesia will make up between about 7% and about 75% (calculated as the oxide) of the filler. Preferably, the lime and/or magnesia makes up between about 10% and about 50% of the filler.

In preparing the product of the invention, a moldable mixture comprising the abrasive grain and the binding phase is prepared. A wide variety of procedures is available for preparing this moldable mixture, so long as the finely-divided alkaline earth metal fluoride is thoroughly distributed in the mixture, and in accordance with the present invention, any of these procedures may be employed. In general it may be stated that the method comprises mixing abrasive grain, an initial thermosetting resin and a finely-divided filler comprising calcium oxide and/or magnesium oxide and the alkaline earth metal fluoride, and shaping the mixture under pressure. For example, a dry mixture of the various materials may be made by mixing the abrasive grain, powdered resin, filler, including the alkaline earth metal fluoride and calcium oxide and/or magnesium oxide, together in the desired proportions, following which the mixture is pressed into the desired shape,

either under heat in which case the resin is at least partially converted to the infusible, insoluble state, or at ordinary temperatures following which the shaped body is subjected to a heating cycle to convert the resin. Or the resin, in a liquid condition, can be mixed with the abrasive grain, and filler, including the alkaline earth metal fluoride and the calcium oxide and/or magnesium oxide, in which case the resulting plastic mixture can be pressed into the desired shape, either under heat and pressure, or the mixture may be first formed into the desired shape following which the shaped article is subjected to a heating cycle. Furthermore, the abrasive grains may be wetted with a resin or resin component, in the liquid state, or other liquid, and the thus wetted grain may then be mixed with additional resin, or resin component, in the powdered state, and also with the filler, including the alkaline earth metal fluoride and the calcium oxide and/or magnesium oxide, and the resulting mixture then molded as previously stated.

The conversion of the resin into the final infusible, insoluble stage will present no problem to those skilled in the art, since various methods for acomplishing this are well known. As indicated above, the conversion, or at least a portion of the conversion, may take place during the molding step, as when the mixture is molded under heat and pressure. The generally preferred method of converting the resin to the insoluble, infusible stage, however, comprises first, the shaping of the mixture into the desired form, as in a press, following which the shaped article is subjected to a heating cycle in which heat is applied until the resin is converted. Such a curing cycle will usually comprise slowly heating the shaped article to the curing temperature and maintaining the article at this temperature for an extended period of time. As is known, the exact curing temperature will vary depending upon the particular resin selected. Generally, particularly with the phenol-formaldehyde resins, the curing temperature employed will be above about 330° F. and may go as high as about 400° F.

The preparation of the product of the invention will be more clearly understood from a consideration of the following specific examples which are given for the purpose of illustration and are not intended to limit the scope of the invention in any way.

EXAMPLE I

50 parts, by weight, of a dry, powdered, thermosetting phenol-formaldehyde resin (nown as Bakelite BR14740) are mixed with 41 parts, by weight, of finely-divided magnesium fluoride having a particle size of 200 mesh and 9 parts, by weight, of calcium oxide.

Furfural is added to the abrasive grain (fused alumina, 25% by weight, of which was #10 grit, 25% of which was #12 grit, 25% of which was #14 grit and 25% of which was #16 grit) in a Hobart-type mixer until each of the grains has been wetted with the furfural. The furfural is in an amount equivalent to 30 cc. per pound of dry binding phase mixture. To 84 parts, by weight, of the wetted grain are added 16 parts of the dry binder mixture in a tumbling barrel. To the resulting mixture is then added creosote oil in the amount of about 15cc. per pound of dry binder mixture to form a moldable mass.

The mixture is then pressed in the form of a grinding wheel, and the wheel is then heated from room temperature to 360° F. over a period of four hours and is held at this temperature for an additional 16 hours. The resulting grinding wheel possesses high mechanical strength and has been found not to lose this strength upon standing in an atmosphere of high humidity over a long period of time.

EXAMPLE II

A. 54.5 parts of a dry, powdered phenol-formaldehyde resin (consisting of a mixture of equal parts by weight of Bakelite BR14740 and Monsanto Resin 766) are mixed with 37 parts of magnesium fluoride and 8.5 parts of calcium oxide. This binding phase mixture is divided into parts each of which is mixed with a different amount of abrasive grain, of the same type as employed in Example I, as follows:

	Mix 1	Mix 2
	Percent	*Percent*
Grain	86	84
Binding phase	14	16

The procedure employed in preparing each mix is the same as in Example I including the wetting of the grain with furfural and the addition of creosote oil.

Each of the above mixes is further divided into parts and molded into abrasive bodies following the procedure set forth in Example I, each product, however, differing as to density as follows:

Product	1a	1b	1c	2a	2b
Density: lb./cu. in	.0870	.0900	.0940	.0920	.0960

Each of the products, made in the form of bars, was broken transversely immediately after preparation to determine mechanical strength, and each was tested further after aging for three days at 110° F. and 98% relative humidity to determine the loss in strength if any. The results of these tests are given in Table I hereinafter set forth.

B. Abrasive bodies were prepared following the identical procedure as set forth in section A hereof, using, however, 37 parts of cryolite in place of the magnesium fluoride. In this case also one group of products (designated herein as group 3) contained 86% of abrasive grain and 14% of binding phase, and the other group of products (designated herein as group 4) contained 84% of abrasive grain and 16% of binding phase. The products also differed in density as in the case of the products prepared in section A hereof as follows:

Product	3a	3b	3c	4a	4b
Density: lb./cu. in	.0870	.0900	.0940	.0920	.0960

Each of these products was tested immediately after preparation for mechanical strength and each was again tested after aging for 3 days at 110° F. and 98% relative humidity to determine the loss in strength.

The data from the foregoing tests are set forth in the following table:

Table I

	Product									
	1a	1b	1c	3a	3b	3c	2a	2b	4a	4b
Density, lb./cu. in	.0870	.0900	.0940	.0870	.0900	.0940	.0920	.0960	.0920	.0960
Transverse modulus as prepared, lb./sq. in	3,570	3,910	4,640	3,310	3,880	4,440	4,300	5,020	4,620	5,020
Transverse modulus after aging 3 days at 110° F., 98% R. H., lb./sq. in	3,540	3,840	4,590	2,280	2,460	3,500	4,230	5,080	3,160	4,410
Change in strength, percent	−1	−2	−1	−31	−37	−21	−1.5	+1.0	−26	−12

EXAMPLE III

Following the procedure of section A under Example II for product "2*b*," four different abrasive bodies were made, using, however, quicklimes having ignition losses of 0.3%, 0.97%, 1.45% and 3.5%, respectively. (These products are designated therein as 5*a*, 5*b*, 5*c* and 5*d*, respectively.) These were tested immediately after preparing and also after aging for 3 days at 110° F. and 98% relative humidity to determine the loss, if any, in strength. The results are given in Table II hereinafter set forth.

Following the procedure under section B of Example II for product "4*b*" (37 parts of cryolite in place of magnesium fluoride) four different abrasive bodies were made using also quicklime having ignition losses of 0.3%, 0.97%, 1.45% and 3.5%, respectively. These products are designated herein as 6*a*, 6*b*, 6*c* and 6*d*, respectively. These products were tested for mechanical strength immediately after preparation and also after aging for 3 days at 110° F. and 98% relative humidity to determine the loss in strength.

The results of the foregoing tests are set forth in Table II below:

Table II

	Product							
	5*a*	5*b*	5*c*	5*d*	6*a*	6*b*	6*c*	6*d*
Density, lb./cu. in	.0960	.0960	.0960	.0960	.0960	.0960	.0960	.0960
Ignition loss of CaO, percent	0.3	0.97	1.45	3.5	0.3	0.97	1.45	3.5
Transverse modulus as prepared, lb./sq. in	4,830	4,700	4,880	4,270	4,740	4,370	4,630	4,000
Transverse modulus after aging 3 days at 110° F., 98 percent R. H., lb./sq. in	4,930	4,650	4,860	4,260	3,900	3,930	4,060	3,650
Change in strength, percent	+2.0	−1.0	−.5	−.2	−17.0	−10.0	−12.5	−9.0

EXAMPLE IV

A. 54.5 parts of dry, powdered, thermosetting phenol-formaldehyde resin (equal parts of Bakelite BR14740 and of Monsanto Resin 766) are mixed with 37 parts, by weight, of finely-divided barium fluoride and 8.5 parts of calcium oxide, the fluoride and oxide passing through a 200 mesh screen. This binding phase mixture is divided into parts each of which is mixed with a different amount of abrasive grain, of the same type as employed in Example I, as follows:

	Mix 7	Mix 8	Mix 9
	Percent	*Percent*	*Percent*
Grain	82	84	86
Binding phase	18	16	14

The procedure employed in preparing each mix is the same as in Example I including the wetting of the grain with furfural and the addition of creosote oil.

Each of the above mixes is further divided into parts and molded into abrasive bodies following the procedure set forth in Example I, each product, however, differing as to density as follows:

Product	7*a*	7*b*	8*a*	8*b*	9*a*
Density: lb./cu. in	.0980	.0940	.0960	.0920	.0870

Samples of each of the products, made in the form of bars, are broken transversely immediately after preparation to determine mechanical strength, and samples of each are tested after aging for three days at 110° F. and 98% relative humidity to determine the loss in strength. The results of these tests are given in Table III hereinafter set forth.

B. Abrasive bodies are prepared following the identical procedure as set forth in section A hereof using, however, 37 parts of cryolite in place of the barium fluoride. In this case the proportions of grain and binding phase is 84% and 16% respectively, and the samples are pressed to a density of .0960. This product is designated as product 10*a*.

Samples of this product are tested immediately after preparation for mechanical strength, and samples were tested after aging for 3 days at 110° F. and 98% relative humidity to determine the loss in strength.

The data from the foregoing tests are set forth in the following table:

Table III

	Product					
	10*a*	7*a*	7*b*	8*a*	8*b*	9*a*
Density, lb./cu. in	.0960	.0980	.0940	.0960	.0920	.0870
Transverse modulus as prepared, lb./sq. in	4,830	5,090	4,480	4,670	4,460	2,960
Transverse modulus after aging 3 days at 110° F., 98% R. H., lb./sq. in	4,330	4,650	4,140	4,295	4,170	2,745
Change in strength, percent	−10.3	−8.6	−7.6	−8.0	−6.5	−7.3

EXAMPLE V

Abrasive products in the form of bars are prepared following the procedure set forth in Example II, using, however, 37 parts of finely-divided calcium fluoride (through 200 mesh) in place of the magnesium fluoride. The proportions of abrasive grain and of binding phase are 84% and 16%, respectively, and the products are pressed to a density of .0960. The product is designated herein as 11*a*.

Upon testing the product in the same manner as in the previous examples, the following data are obtained:

Table IV

Product	11*a*
Density, lb./cu. in	.0960
Transverse modulus as prepared, lb./sq. in	5,260
Transverse modulus after aging 3 days at 110° F., 98% R. H., lb./sq. in	4,860
Change in strength, percent	−7.5

EXAMPLE VI

Abrasive products in the form of bars are prepared following the procedure of Example II using 37 parts of magnesium fluoride, and, in one case (designated 12*a*), replacing 4.25 parts of the calcium oxide with 4.25 parts of magnesium oxide with and, in another case (designated product 13*a*) replacing 0.85 parts of calcium oxide with a like amount of magnesium oxide.

The proportions of abrasive grain and binding phase are 84% and 16% respectively, and the products are pressed to a density of .0960.

Upon testing samples of the products as in the foregoing examples, the following data are obtained:

Table V

	Product	
	12a	13a
Density, lb./cu. in.	.0960	.0960
Transverse modulus as prepared, lb./sq. in.	4,620	5,750
Transverse modulus after aging 3 days at 110° F., 98% R. H., lb./sq. in.	4,575	5,490
Change in strength, percent	[1] −1.0	[1] −4.5

[1] Although the average loss in strength for 10 samples is low, the root mean square deviation among the various samples is relatively high.

Considerable modification is possible in the selection of the components of the present product as well as in the particular procedure employed in making the product without departing from the scope of the invention.

I claim:

1. An abrasive body comprising abrasive grains bound in a binding phase comprising between about 33% to about 80% of a thermosetting resin in the infusible, insoluble state, and between about 20% and about 67% of a finely-divided filler of which at least about 10% is an alkaline earth metal fluoride selected from the group consisting of the calcium, magnesium and barium fluorides and of which at least about 7% is an alkaline earth metal compound selected from the group consisting of magnesia and lime.

2. The product of claim 1 wherein at least about 20% of the filler is magnesium fluoride and wherein at least about 10% of the filler is lime.

3. The product of claim 2 wherein at least about 50% of the filler is magnesium fluoride.

4. An abrasive body comprising abrasive grains bound in a binding phase comprising between about 33% to about 80% of a phenol-aldehyde resin in the infusible, insoluble state, and between about 20% and about 67% of a finely-divided filler of which at least about 10% is magnesium fluoride and of which at least about 7% is lime.

5. The product of claim 4 wherein at least about 20% of the filler is magnesium fluoride.

6. The product of claim 5 wherein the phenol-aldehyde resin comprises a phenol-formaldehyde resin.

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