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3,560,176

EPOXY RESIN BONDED GRINDING WHEEL

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No Drawing. Filed Dec. 19, 1968, Ser. No. 785,400

Int. Cl. C08g 51/12

U.S. Cl. 51—298

13 Claims

ABSTRACT OF THE DISCLOSURE

The invention is directed to an organic resin bond for abrasive. An epoxy resin system containing grinding aid substituents in the molecular structure is described and claimed with halogenated bisphenol-based resins preferred.

References to hardness and softness can often be confusing in the abrasive art. To minimize and, hopefully, to eliminated confusion, reference will be made to physical grade hardness or softness and grinding grade hardness and softness. The physical grade hardness is related to the physical properties of the abrasive article and is dependent upon the materials used, the density of the body, etc.

Grinding grade hardness is a measure of the reluctance or the willingness with which a bond gives up an abrasive grain. Grinding grade hardness is an operational grinding parameter. In general, there is a qualitative correlation between physical grade and grinding grade hardness; there is a direct relationship.

The degree of physical and grinding grade hardness of grinding wheels and abrasive articles is controlled, to a large extent, by the ratios of abrasive grain, bond, and porosity. The softest grade of wheels have the greatest amount of abrasive and porosity and the least amount of bond. The hardest grade wheels have the least amount of abrasive and porosity and the greatest amount of bond.

In the manufacture of grinding wheels, two of the most elusive and yet most necessary properties which must be provided are structural strength and uniformity. It is immediately obvious that structural strength is of great importance. A grinding wheel that lacks strength will not only wear out rapidly, but will also be dangerous to use.

Uniformity is necessary at three levels. First, an abrasive article, a grinding wheel in particular should be structurally uniform throughout. Second, grinding wheels of a given lot should be all alike. Finally, grinding wheels from different lots but made to the same manufacturing specification should be virtually identical or at most varied within prescribed tolerances.

Traditionally, the greatest difficulties in achieving bond strength and uniformity have been encountered in the manufacture of soft grade grinding wheels.

Many bond systems have proved to be quite satisfactory in hard grade wheels. There is an abundance of bonding material present in the raw mixture and, it is relatively easy to make a homogeneous mix. The large amount of bond also assures a high level of strength in the finished grinding wheel.

However, when wheels of a soft grade are made, the selection of a bond system becomes critical. The small amount of bond material present in the mix makes the achievement of a homogeneous abrasive article very difficult. Thus, achieving uniformity requires a great deal of care in processing. Further, with so little bond, present, the developed mechanical strength in soft grade grinding wheels is difficult to achieve.

Over the years, many advances have been made in organic bonded systems for grinding wheels, but no major breakthrough has been previously achieved in the effort

to make a really satisfactory soft grade grinding wheel having a mechanical strength approaching that of a harder graded wheel. Any wheel that has been sufficiently strong has invariably been too hard structurally to give the desired soft grinding action, which is an absolute necessity in many grinding applications. A further problem frequently encountered in the grinding wheel art is the fact that organic resin bond systems can be susceptible to deterioration from the effects of coolant saturation. In soft grinding wheels where bond strengths have been, of necessity, of low or borderline acceptability, such deterioration is a serious problem since even a slight deterioration can so weaken the grinding wheels as to render them useless and unsafe. The coolant attack markedly softens grinding grade during operation causing numerous operating difficulties.

Additionally, there have been developed in the art a number of materials which function as grinding aids, such as the halogens and sulphur. They tend to improve the efficiency of grinding. They also tend to improve the ease of grinding in a great many applications.

Grinding aids have not found widespread use in soft grade organic resin bonded grinding wheels, since heretofore the grinding aids have always been incorporated in to the bond as filler. These fillers reinforce the resin which in turn results in a harder grinding grade. Compensating for this increase in hardness by reducing resin content would make the soft grade wheels structurally unsafe. These fillers, therefore, automatically defeat the principal purpose being strived for; namely, the making of a soft grade grinding wheel.

A breakthrough in the development of a soft grade grinding wheel would be to provide soft grinding action with a structural hardness greater than heretofore possible. Additionally, a significant advance would be to provide active grinding aids in soft grade grinding wheels without increasing the grade hardness of the basic soft grade grinding wheel.

It is an object of the invention to provide a resin bond for abrasives which contributes to the increase in physical strength of grinding wheels while retaining a soft grinding action.

It is another object of the invention to provide a resin bond for abrasives which provides for the incorporation of grinding aids into the abrasive articles without the use of additives such as fillers.

It is yet another object of the invention to provide a resin bond for abrasives which provides for the making of soft grade grinding wheels of uniform grade and structure.

It is still another object of the invention to provide a resin bond for abrasives which increases the lot-to-lot uniformity of soft grade grinding wheels.

It is yet another object of the invention to provide a resin bond for abrasives that resists deterioration from coolant attack.

It is still another object of the invention to provide a resin bond for abrasives which provides for the incorporation of grinding aids into the molecular structure of grinding wheel resins as substituents of, for example, epoxides, curing agents of epoxides, and additives or extenders of epoxides.

It is a further object of the invention to provide a resin bond for abrasives which utilizes a brominated glycidyl ether epoxide as the basis of a soft grade grinding wheel having structural hardness greater than conventionally found in the industry, for a comparable grinding grade.

In accordance with the invention, an organic resin bond for abrasives comprises an epoxy resin-based system containing frequently-used grinding aids in the molecular structure (substituents) of the resin system.

Also in accordance with the invention, an organic bond

for abrasives comprises a tetrabromo bisphenol A-based epoxy resin formed by reacting the brominated bisphenol A epoxide with an amine or anhydride curing agent.

The novel features that are considered characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment.

An important consideration of the invention is the provision of grinding aids in soft grade wheels in such a way that the soft grinding action can be maintained and improved. Conceptually, this is done by making the grinding aid a substituent in the molecular structure of the resin bond system. That is to say, the grinding aid substituents, such as sulphur or the halogens, bromine, chlorine, iodine, and fluorine, form part of the internal groups of the epoxides or are substituents of the curing agents such as the amines and the anhydrides. It is also possible to provide extenders and additives such as reactive diluents, which have been halogenated or sulphurated. Examples of epoxides, curing agents and epoxy modifiers and extenders containing halogens and sulphur in their molecular structure are to be found in abundance in the text, Handbook of Epoxy Resins, by Lee and Neville, McGraw-Hill Publishing Company, 1967. Examples of epoxides which would function in accordance with this concept are the glycidyl ethers such as chlorobisphenols and bromobisphenols. Epoxy resins synthesized via the epichlorohydrin route contain chlorine in an active form. Aliphatic-based epoxides are discussed on pages 2-17 and elsewhere in the reference text.

While it is not necessary to use halogenated or sulfonated curing agents, amongst the curing agents that are suitable are the halogenated anhydrides such as tetrabromo phthalic anhydride, chlorindic anhydride, dichloromaleic hydride, and tetrachloro phthalic anhydride.

Other curing agents for epoxides which fall within the inventive concept of providing grinding aids in the molecular structure of the resin system are methylene bis 2,6 dichloro dianiline (commonly known as MOCA). Curing agents derived from acyl halides, alkyl halides, silicon tetra halides, carbon disulphide, hydrogen sulphide contain grinding aid substituents. The Thiokol Corporation has marketed polysulphides for blending with epoxides in proportions which would tend to contain a great deal of sulphur.

In the area of epoxy modifiers and extenders, such compositions as hexafluoro propylene oxide, the chloroprenes, are useful. A chlorinated phenol diluent is discussed on page 13-2 of the reference text. There are others.

Grinding efficiency depends, in part, on the ability of a bond to release a wornout or dull abrasive grain in a timely fashion. In other words, abrasive articles, or grinding wheels, are designed to wear. A hard grade grinding wheel as a bond which holds onto the abrasive grain very tenaciously and gives up the abrasive with great reluctance. On the other hand, a soft grade containing a bond which releases an abrasive grain in a relatively short time. In both cases, the release mechanism is substantially the same. The temperatures in the vicinity of an abrasive grain reaches several hundred to over 1000° F. As the grain becomes dull and must work harder to perform a cutting function, the temperature generated in the grain approaches the higher temperatures in the operating range. The resin bond undergoes thermal degradation. At some point, it weakens sufficiently to release the grain.

The structure of the resin breaks down when it thermally deteriorates when a halogenated or sulfonated epoxy resin system degrades, there are given off hydrogen halides or hydrogen sulphides, in addition to elemental halogen and sulphur. The degradation takes place at the interface of the abrasive grain and the workpiece, precisely where the grinding aids function most efficiently.

The time-honored problem of providing a soft grade grinding wheel with structural hardness greater than heretofore available has been answered through the use of a tetrabromobisphenol A epoxide system. Grade for grade, structure for structure, such epoxy formulations containing 50% more bond than found in phenolic resin bonding systems will produce wheels of grinding grades equivalent to phenolic resin bonded wheels. Previously, it was pointed out that the physical grade hardness increases with the amount of resin present in a formulation. It was also pointed out that greater uniformity within a lot and from lot to lot can be obtained when the amount of resin is increased.

In comparison with conventional phenolic systems, an equivalent grinding grade can be obtained in the bisphenol A epoxy system with 50% more resin. This is a very significant contribution to the art of making soft grade grinding wheels.

The following examples will serve to illustrate several ways in which the tetrabromo bisphenol A system has been used to construct soft grade grinding wheels.

EXAMPLE NO. 1

In one soft grade application a new standard of performance was achieved, with a grinding wheel containing 52% abrasive, 12% of a brominated bisphenol bond and 36% pores, all by volume. The bond was formulated using a dry segment comprising 80-85% of the total resin batch with the remainder a liquid segment.

The powdered resin/hardener relationship can range from 90/10 to 60/40 without any significant effect being encountered.

The dry segment of the resin system is formed by mixing 80-85 parts by weight of solid tetrabromo bisphenol A, sold as Epo-Tuf 90-165 with 20-15 parts by weight of diamino-diphenyl-sulphone, sold as Eporal. The liquid formulation is 65 parts by weight of a lower molecular weight tetrabromo bisphenol A sold as Epi-Rez 5163, mixed with 25 parts by weight of low molecular weight epoxy derivative of bisphenol A sold as Epi-Rez 510 and 10 parts by weight tetra-hydro-furfuryl-alcohol. The alcohol acts to reduce the viscosity of the batch. It also acts as a weak solvent to aid in wetting the abrasive grain.

The abrasive is first wetted with the liquid portion of the resin, then the dry resin ingredients are added and mixed until the dry resin has all adhered to the wetted abrasive.

The resultant mix is loaded into the mold and is cold pressed at a pressure of about two tons/in.². The wheel is taken from the mold and is then oven-cured in a curing cycle which starts at 150° F., rises to 390° F. in nine hours, and holds at 390° F. for an additional twenty-four hours.

The grinding wheels will tolerate some variation in curing temperature. For best results, the end curing temperatures should be between 375°-450° F. Below 375° F., the resin does not cure completely. Above 450° F., the resin system begins to deteriorate. Previously, for this same application, a phenolic resin bonded abrasive was used. The phenolic contained 56% abrasive, 8% bond, and 36% pores, all by volume. In spite of the 50% increase in bond in the epoxy system over the phenolic system, the grinding grades were substantially identical and the cutting action about the same. It is clear from the foregoing that with the added bond, greater uniformity in product is possible, and an increase in mechanical strength is available. The average metal removal rate was 224.3 pounds per pair of wheels for the epoxy, as against 179.6 pounds per pair of wheels for the phenolic.

In a standard mechanical grading test where a drill bit is reciprocated, under a loading, the penetration into the example wheel was about half of the normal penetration experienced with the phenolic wheel of similar grinding grade. The physical grade hardness, i.e., the mechanical strength, is inversely related to the depth of penetration.

In a second test, the amount of abrasive in the phenolic and the epoxy was kept constant at 54%. The amount of bond in the epoxy was increased to 16% over the bond content of 14% in the phenolic. A much harder physical grade evolved in the epoxy, yet it gave a softer grinding action by about two thirds.

The epoxy resin system described is totally reactive. The components become part of the finished bond with little or not volatilization taking place. Previous phenolic resin systems were plagued with considerable volatilization or plasticizers, which tended to disrupt and alter the bonding mechanism of the resin system to the abrasive, producing a nonuniform bond abrasive relationship whenever the bond distribution in the mix was less than perfect.

EXAMPLE NO. 2

Qualitatively, it has been determined that the epoxy resin system described provides a significant increase in the water and coolant resistance. However, the problem of cooling and water deterioration in test wheels was eliminated with grinding wheels which employed the brominated bisphenol resin system in conjunction with vinyl polysiloxane coated abrasives. The coated abrasive is described in U.S. Pat. 2,878,111. Such an abrasive is commercially available from the General Abrasives Corporation.

All of the preceding has dealt with the application of the resin system to high porosity wheels. This includes a grade range from G-N (26 to 40% porosity). All the constituents of the grinding wheel include only the resin bond and abrasive.

It is always desirable to be able to apply a bond system over the entire range of grinding wheel grades and this particular tetrabromo bisphenol system is easily adapted to provide grinding wheels with less porosity from 0 to ZZ grade (24% to 0% porosity). The porosity is reduced by adding inert fillers, such as an alumina-zirconia composition known as AZ40 fines, iron pyrites, kryolite, etc.

Throughout the grading system the grinding action of the epoxy resin system, bonds will give a softer grinding action than an equivalent phenolic grade.

EXAMPLE NO. 3

To obtain a fully close grade ZZ grinding wheel, it was necessary to hot press and to change the curing agent. Two curing agents have been found to be satisfactory. These are tri-mellitic anhydride and pyro-mellitic anhydride.

In the hot pressing process 25.5 parts by weight of tetrabromo bisphenol A is mixed with 5.1 parts by weight of a curing agent, tri-mellitic anhydride, for example, and 69.4 parts of a filler. Twenty to forty cubic centimeters of tetrahydro furfuryl alcohol is added as a wetting agent per pound resin. The mixture is placed in a mold. The mold is held under a pressure of about 2-3 tons per square inch and at about 320° F. for 30-45 minutes until the resin is advanced to a non-fusible state, i.e., partially cured. This step is followed by an oven cure at 375° F.-450° F. for up to twenty-four hours.

In summary, the discovery that substituents comprising grinding grades may be incorporated into the molecular structure of epoxy resin systems has made it possible to provide these grinding aids in soft grade grinding wheels. The prior art attempts to provide grinding aids as fillers in soft grade grinding wheels have not been commercially successful because of the incompatibility of added fillers, while at the same time, maintaining soft grinding action.

The specific brominated bisphenol A system has resulted in the bond structure which provides soft grinding action while at the same time providing a more uniform structure having greater strength than prior art grinding wheels which perform similar soft grinding applications.

The various features and advantages of the invention are thought to be clear from the foregoing description.

Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as likewise will many variations and modifications of the preferred embodiment illustrated, all of which may be achieved without departing from the spirit and scope of the invention as defined by the following claims.

What is claimed is:

1. A grinding wheel consisting essentially of an epoxy-based bond formed by reacting an epoxide with a curing agent, at least one, the epoxide or curing agent, containing a grinding aid in its molecular structure selected from the group consisting of sulphur and the halogens, chlorine, bromine, and fluorine, and abrasive particles distributed in the resin system.

2. A grinding wheel as defined in claim 1 in which the grinding aid forms part of the molecular structure of the epoxide.

3. A grinding wheel as defined in claim 1 in which the grinding aid forms part of the molecular structure of the curing agent.

4. A grinding wheel as defined in claim 1 which includes, in addition, modifiers of epoxies and extenders of epoxies having said grinding aids in their molecular structure.

5. A grinding wheel as defined in claim 1 wherein the epoxy-based resin system is formed from a brominated bisphenol A epoxide.

6. A grinding wheel as defined in claim 5 wherein the epoxide is tetrabromo bisphenol A.

7. A grinding wheel consisting essentially of an epoxy-based resin system formed from the reaction of tetrabromo bisphenol A with a curing agent selected from the group consisting of an amine and an anhydride, and abrasive particles distributed through the resin system.

8. A grinding wheel as defined in claim 7 wherein the amine is a diamino-disphenyl sulfone and the anhydride is trimellitic anhydride.

9. A grinding wheel consisting essentially of an epoxy-based resin system formed from the reaction of a dry resin segment consisting essentially of tetrabromo bisphenol A and a curing agent with a liquid segment consisting essentially of tetrabromo bisphenol A, bisphenol A, and tetrahydro furfuryl alcohol, and abrasive particles distributed in the resin system.

10. A grinding wheel as defined in claim 9 wherein the dry segment comprises about 80%-85% by weight of the total resin batch and the liquid segment comprises about 20%-15% by weight.

11. A grinding wheel as defined in claim 9 wherein the dry tetrabromo bisphenol A comprises 90-60 parts by weight and the curing agent comprises 10-40 parts by weight of the dry segment of the resin batch.

12. A grinding wheel as defined in claim 9 wherein the dry segment comprises 80-85 parts by weight epoxide and 20-15 parts by weight curing agent and the liquid segment comprises 65 parts brominated epoxide, 25 parts bisphenol A epoxide, and 10 parts tetrahydro furfuryl alcohol, all by weight.

13. A grinding wheel as defined in claim 9 wherein a hot-pressed bond is formed from 25.5 parts of tetrabromo bisphenol A, 5.1 parts trimellitic anhydride, and 69.4 parts filler, all by weight.

References Cited

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DONALD J. ARNOLD, Primary Examiner

U.S. Cl. X.R.

51-295

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,560,176

Dated February 2, 1971

Inventor(s) John R. Thompson

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 13, for "abrasive" read--abrasives--; line 20, for "eliminated" read--eliminate--; line 56, for "proved" read --proven--; Column 2, line 15, for "frade" read--grade--; Column 3, line 1, for "bisphonal" read--bisphenol--; line 21, for "sulphuried" read--sulphurized--; line 57, after "abrasive" read --grain--; line 58, for "containing" read--contains--; Column 4, line 44, for "weted" read--wetted--; Column 5, line 9, for "not" read --no--; line 27, for "preceeding" read --preceding--; line 6: for "grades" read--aids--; Column 6, line 56, for "bromonated" --brominated--.

Signed and sealed this 6th day of July 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
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