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# AMIDE IMPREGNATED GRINDING WHEELS

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## ABSTRACT OF THE DISCLOSURE

A novel grinding wheel has been provided which comprises of abrasive grits, a vitrified bond holding said grits together to form the grinding wheel and having its interstitial space filled essentially with an amide of a diamine and a carboxylic acid having a melting point of at least 225° F. and wherein the amine precursor is an aliphatic diamine, a cycloaliphatic diamine or an aromatic diamine. An improved grinding method has also been disclosed.

This invention relates to the treatment and use of abrasive articles such as, grinding wheels, and more particularly, to grinding wheels incorporating a novel and improved impregnant giving superior results in grinding operations.

One widely used type of grinding wheel is essentially composed of abrasive grains or grit bonded in a matrix comprising a vitrified bonding agent. Commonly, this bonding agent is also known as a glass bond or a porcelain bond and consists basically of a clay bonding agent with which other ceramic materials are admixed. In preparing grinding wheels, abrasive grains and the bonding agent are mixed, shaped, dried and finally fired in a kiln to achieve a desired bond strength in a manner well known in the art. It is equally well known that vitrified bonds are strong, rigid, and have various degrees of porosity or denseness.

It has been found by experience that metal chips as well as the abrasive grains are not as readily carried away from the work piece as is desired. Through a combination of factors, metal chips and fractured grains as well as other materials cause such phenomena as loading ,"chatter," dullness and overheating resulting in poorly finished work piece and intolerable power consumption. These phenomena in turn require repeated and severe wheel dress.

Numerous attempts have been made to minimize or eliminate the problems occasioned by the above phenomena, and equally numerous solutions have been proposed for solving the above problems.

A partial, though still unsatisfactory, solution to these problems has been the introducing of various agents such as a beeswax and paraffin mixture as impregnants into the pores or interstices of grinding wheels. However, these impregnants have the tendency during the work cycle to melt and then migrate from the wheel. Another partially satisfactory solution has been to use the above components individually or jointly in admixture with various sulphurized fats. Still another partially satisfactory solution has been the use of sulphur as a grinding wheel impregnant.

While several possible mechanisms have been suggested to account for the improved performance obtained using the last mentioned sulphur impregnant, it is not possible to demonstrate or predict conclusively which, if any, of the mechanisms is in fact responsible for the results. Thus, it has been suggested that chemical action takes place between the metal in the work piece and the sulphur preventing the welding of the metal to the wheel constituents. Another suggestion is that the hot metal chip removed from the work piece contacts the sulphur, melts it, and then the sulphur releases the chip and allows it to be carried away



from the work piece. These phenomena, supposedly, prevent the loading of the wheel and uneven wear. However, it has been found that despite all attempts to introduce thoroughly and uniformly sulphur into a wheel, invariably some spaces of the wheel are not impregnated. Although these spaces may be very small, these often cause excessive loading of the wheel with the consequent buildup of metal and thus the scoring of the work piece and failure to maintain specified tolerances. Moreover, sulphur often causes severe straining of work pieces.

Because of the lack of understanding associated with wheel loading and wear, the utility of a particular compound suitable for filling the pores in a grinding wheel, in general, has to be established by experiment. Accordingly, comparative experiments have been necessary to establish the superiority of one impregnant over another. Generally, a standard has been a sulphur impregnated wheel compared to a wheel having an equivalent wheel structure which wheels are used under identical or standardized conditions.

In the present specification, the following empirical criteria will be used. As one criterion a work-cycle or work-piece output per dress cycle is used when using identical grit wheels. This criterion is defined as the number of work pieces produced having satisfactory dimensions and properties per equivalent dress. The identical operating conditions on the identical material are observed throughout the cycle. Conversely, for the same work-piece cycle, the duration and extent of wheel dress may be measured. Another criterion is the ability to maintain specified tolerances, such as surface finish and part geometry for the work pieces to be ground throughout the work cycle; e.g., under conditions using constant force during grinding. Still another criterion is the improved surface finish and absence of metallurgical damage resulting in less rejects per the same work cycle or less rejects in general. A further criterion is the total work pieces ground per useful life of an equivalent grinding wheel.

It has now been found that using a novel wheel impregnant composition in combination with a porous wheel, in whose interstices the impregnant is more uniformly and thoroughly dispersed than heretofore possible with sulphur impregnated wheels, extended wheel life is achieved, while at the same time specified tolerances of the work piece have been maintained throughout an extended work piece grinding cycle. Moreover, this result has been achieved with improved surface finish. Also, prior art problems associated with using sulphur impregnated wheels, such as sulphur staining of work pieces, wear of diamonds in dressing wheels by interaction with sulphur, sulphur contamination of cutting fluids, and odoriferous gases given off by sulphur, etc., have been eliminated and/or minimized. As a result of the novel impregnant, other benefits have been obtained, such as increased safety factor due to less stress associated with diminished loading of the wheel; e.g., under constant force grinding operations.

It is an object of the present invention to provide an abrasive article giving improved grinding properties. It is another object of the invention to provide a vitrified abrasive grinding wheel whose interstices have been uniformly and thoroughly impregnated with a composition that confers improved grinding properties on the wheel, especially when the wheel is used for grinding operations heretofore requiring sulphur or sulphurized fats as impregnants. It is still another object of the invention to provide a vitrified bond abrasive grinding wheel which exhibits an improved life cycle, provides an improved finish to the work piece surface being ground, prolongs the useful life of a diamond dresser. It is still a further object of this invention to provide an impregnant consisting essentially of N,N'-alkylene bis-stearamide which resists

migration during the work cycle from a vitrified bond, aluminum oxide abrasive grinding wheel which wheel is suitable for internal first grind and finish grind purposes. Other objects of the invention will be in part obvious and in part pointed out hereafter.

The present invention is predicated on the surprising discovery that an N,N'-aliphatic or aromatic diamide of an aliphatic or aromatic carboxylic acid, more specifically N,N'-alkylene bis-stearamide, or more particularly, N,N'-ethylene bis-stearamide possesses exceptionally useful properties as an impregnant in vitrified bond abrasive grinding wheels.

The amides mentioned above and used as the impregnants are derived from a diamine and a carboxylic acid of the acids and amines listed below. As a diamine, the following diamines are useful: aliphatic diamines such as alkylene diamines; e.g., ethylene diamine, propylene diamine, tetramethylene diamine, diethylene triamine, 1,6-hexane diamine; cycloaliphatic diamines; e.g., piperazine, cyclohexyl bis 1,4-methyl diamine; aromatic diamines; e.g., p-phenylene diamine, toluene diamines such as meta-toluene diamine, xylylene diamine such as meta-xylylene diamine; menthane diamine. As a carboxylic acid, the following acids are useful: azelaic, adipic, arachidic, capric, caproic, caprylic, behenic, cerotic, pelargonic, undecanoic, lauric, myristic, palmitic, stearic, lignoceric, oleic, sebacic, succinic, isosebacic, ricinoleic, 12-hydroxystearic. Useful aromatic acids are benzoic acid naphthenic acids, phthalic acids, etc. Of the above amides those derived from alkylene diamines and aliphatic acids are preferred. Of the last, the amides derived from ethylene diamine and fatty acids are most suitable. In all cases the amides still have to possess a melting point of at least 225° F. and preferably a melting point of at least 280° F. The most preferred melting point range which characterizes the most desirable amides is about 290° F. and higher.

Although a number of the above-mentioned carboxylic compounds do not exist in pure state but are associated with different mixtures, it is very easy to determine the melting point of these mixtures and consequently the acceptability of the amides as a novel impregnant. An illustrative list of the amide compounds and mixtures of materials having acceptable melting point properties are: stearic acid and adipic acid amides of ethylene diamine; stearic acid and azelaic acid amides of ethylene diamine; caprylic acid and capric acid amides of ethylene diamine; benzoic acid amide of ethylene diamine; stearic and sebacic amides of ethylene diamine; caproic acid amide of ethylene diamine; a mixture of stearic acid and acetic acid amides of ethylene diamine; pelargonic acid amides of ethylene diamine; myristic acid amide of ethylene diamine; azelaic acid amide of meta-toluene diamine; stearic acid and azelaic acid amine of 1,6 hexanediamine; stearic acid amide of p-phenylene diamine; sebacic acid amide of meta-xylylene diamine and the like.

As a consequence of this invention, prior art impregnants such as sulphur or compositions requiring multiple components can now be replaced by a single component. Moreover, the preferred N,N'-ethylene bis-stearamide, which is a mixture of stearic and palmitic acids, should, in its most desirable form, consist of a mixture removed from its eutectic melting point of 280° F. by at least 10° F. and thus should have a melting point of approximately 290° F. or higher.

In carrying out the present invention, any suitable and well-known abrasive material may be used; e.g., aluminum oxide ($Al_2O_3$), carbides such as silicon carbide (SiC), fused zirconia ($ZrO_2$), mixtures of zirconia and alumina (10–45% $ZrO_2$–90–55% $Al_2O_3$), and the like. Of the above, aluminum oxide is preferred.

These abrasive materials may be selected in various grit sizes or mixtures thereof, preferably of a grit size of 54 and finer and of the grades and structures commonly employed in vitrified grinding wheels.



A number of internal grinding wheels were made incorporating the following compositions of grit types. Conveniently, aluminum oxide was chosen, although the other mentioned abrasives may be used.

The compositions are as follows:

(A) A semi-friable aluminum oxide,
(B) A friable aluminum oxide.
(C) A very friable aluminum oxide (white).
(D) A friable aluminum oxide, less friable than composition B.

These compositions were selected in the following grit sizes:

(A) 80
(B) 120
(D) 54, 60, 80, 100;

and admixed with a ceramic powder comprising a formulation to give the vitreous bond. A suitable ceramic powder comprises, for example, ball clay, feldspar, borosilicate frit or the like components.

From this mixture, "green" grinding wheels of various shapes were formed into desired configurations and fired at a temperature above about 2,000° F. to form a highly porous, hard structure. The pores may typically comprise as much as 40% of the volume of the wheel.

Next, the abrasive wheels, preheated to approximately 350° F. to 375 °F., were partially immersed in melted N,N'-ethylene bis-stearamide and held at about 290° F. to 325° F. or higher, depending on the melting point of the other amides if other amides are used. Capillary action caused a uniform wetting and impregnation of the wheel without entrapping of air into the wheel interstices. Optionally a vacuum was applied to aid the removal of air from the interstices of the wheel, and thus aiding the impregnation. After this, the wheels were removed from the impregnant placed on absorbent paper, inverted and allowed to cool at room temperature. Alternatively, the impregnants in form of a powder and the wheels are placed in a vessel without preheating. The vessel is then heated and held in an oven at 310° F. After allowing the wheels to soak up the amide, they are removed from the amide and allowed to cool. These wheels were compared with the same type of abrasive wheel as further identified herein and impregnated with sulphur.

In order to point out more fully the nature of the present invention, the following specific examples are given of illustrative embodiments of the present impregnant showing the preparation and use of the abrasive article as well as the improved grinding method and results.

## EXAMPLE I

A 6-inch by 12-inch railroad axle bearing cone taper and ribs were ground simultaneously in a microcentric operation using a 20-inch by 2-inch wheel. Two wheels were used having grit composition as indicated above with a grit size of 54; and two wheels were used with the same grit composition and a grit size of 60. One of the identical wheels of the specified grit size had as an impregnant N,N'-ethylene bis-stearamide and the other had as an impregnant sulphur. When using the wheels containing the amide at a stock removal amount of .025 inch on the taper and .007 inch on the ribs of the axle bearing cone, seven work pieces could be ground to satisfactory tolerances before a 45-second diamond dress of .0015 inch was required for the wheel. Contrarywise, only three work pieces could be ground to satisfactory tolerances with the sulphur impregnated wheel before the same dress was required. Moreover, when the number of work pieces was increased from three to more than three for the sulphur impregnated wheel, "chatter," overheating, and excessive power requirements develop.

## EXAMPLE II

A number of the impregnated wheels were picked for grinding of roller or ball bearing tracks and bores of bearing races. These work pieces were roughly finished

with identical abrasive wheels of grit composition D having a grit size of 100 except that for comparison purposes, one group was impregnated with sulphur and the other was impregnated with N,N'-ethylene bis-stearamide. Thereafter, these work pieces were finished with identical wheels made of abrasive grit composition B having a grit size of 120. Finishing efficiencies of the wheels were expresed in R.M.S. defined as the square root of the mean of the sum of the squares of the height in microinches of surface irregularities. In order to obtain a measure of the work piece finishing ability of the two types of wheels, R.M.S. values were taken across the finished bearing track. This value is read from a recording instrument. To show the ability of the wheel to perform in an acceptable manner throughout its grinding life, the finishing efficiency of a new wheel and an old wheel was determined in a similar manner. For this purpose a "new wheel" may be defined as an unused wheel of maximum usable diameter. An "old wheel" may be defined as a used wheel of smallest usable diameter. In the table to follow, the data illustrate the superior work piece finishing ability of the wheel impregnated with the novel impregnant.

TABLE I.—GRINDING OF BEARING SURFACES FINISHING ABILITY

| Wheel | No. of parts per wheel | R.M.S. of 1st Part After Wheel Dress | | R.M.S. of 5th Part After Wheel Dress | |
|---|---|---|---|---|---|
| | | New wheel | Old wheel | New wheel | Old wheel |
| A | 441 | 5.5–6.5 | 5.6 | 5.5–6.5 | 4.5–6.5 |
| B | 400 | 6–7.5 | 7–7 | 6–8 | 6–8 |

Cycle time .399 minutes.
Wheel A was impregnated with N,N'-ethylene bis-stearamide. Wheel B was treated with sulphur which also caused random sulphur staining of the work pieces.

## EXAMPLE III

Wheel of various sizes and configurations were used for grinding bearing cups and cones. These wheels were of composition D and of a grit size of 80. A number of wheels were impregnated with the novel grinding wheel impregnant and a number with sulphur. These wheels were run on a variety of grinding machines, such as Heald machines Model Nos. 1CF90, 290A, 180, 188A and 81 made by the Heald Machine Co., Worcester, Mass. Operating conditions were identical for grinding wheels having both types of impregnants. In Table II to follow, the finish was measured and recorded for the high R.M.S. reading across the bearing track. Different machine parts were ground with the different wheels, but both types of impregnants were tested on the same machine. Both controlled feed rate and controlled force conditions were used. Surface finish and part geometry were maintained well within print specifications. Representative results are illustrated below. Wheels designated by A are impregnated with N,N'-ethylene bis-stearamide, while those designated by B are sulphur impregnated.

TABLE II.—COMPARISON OF GRINDING PERFORMANCE OF NOVEL WHEELS AND WHEELS IMPREGNATED WITH SULPHUR UNDER IDENTICAL OPERATING CONDITIONS

| Heald type machine | Wheel type | Wheel size, inches | Total work pieces per wheel | Finish R.M.S.-high reading |
|---|---|---|---|---|
| 1CF90 | A | 2½ x 1¼ x ⅝ | 260 | 12 |
| 1CF90 | B | 2½ x 1¼ x ⅝ | 200 | 30 |
| 290-A | A | 4¼ x 1½ x ⅞ | 532 | 18 |
| 290-A | A | 4¼ x 1½ x ⅞ | 550 | 17 |
| 290-A | B | 4¼ x 1½ x ⅞ | 305 | 27 |
| 290-A | B | 4¼ x 1½ x ⅞ | 213 | 20 |
| 180 | A | 1¼ x ¾ x ⅜ | 190 | 20 |
| 180 | B | 1¼ x ¾ x ⅜ | 187 | 25 |
| 180 | A | 1⅜ x 1⅛ x ⅜ | 416 | 25 |
| 180 | A | 1⅜ x 1⅛ x ⅜ | 246 | 18 |
| 180 | A | 1⅜ x 1⅛ x ⅜ | 400 | 18 |
| 180 | B | 1⅜ x 1⅛ x ⅜ | 155 | 38 |
| 180 | B | 1⅜ x 1⅛ x ⅜ | 174 | 25 |
| 180 | B | 1⅜ x 1⅛ x ⅜ | 140 | 30 |

## EXAMPLE IV

Another procedure was carried out whereby the performance of different impregnants was compared when grinding outer bearing races of 52100 steel with an internal grinder (Heald 1CF91) with a low force value of 20 lbs. and with a high force value of 80 lbs. An untreated standard was also used. These wheels were of grit composition D (previously mentioned) with a grit size of 100 of medium grade and structure having a vitrified bond. Used as impregnants were: (a) sulphur, (b) N,N'-ethylene bis-stearamide and (c) a mixture of about 80% sulphurized fat, 10% mineral oil and 10% of a composition as in (b). The sulphurized fat is obtained by heating a quantity of unsaturated organic natural fat (generally an ester of glycerine) and sulphur until complete reaction between the sulphur and fat takes place leaving no free fat. About 20% reacted sulphur on basis of fat is the maximum which can be achieved.

For each composition compared, fifty work pieces were ground. Each wheel was dressed at the beginning of the operation and after twenty-five work pieces. Stock removal was about .005 inch on the diameter. Finish on the work pieces was obtained in R.M.S. using a profilometer while the surface finish range (high reading) was determined for the first ten work pieces. Metal damage was obtained using Nytal etch test.

Results of these tests are summarized in the following table:

TABLE III.—COMPARISON OF IMPREGNANTS

| Impregnant | Surface finish Range 1 to 10 parts, micro-inches, R.M.S. | Metallurgical damage, Nytal test |
|---|---|---|
| With grinding fluid A: | | |
| Control (unimpregnated) | 8–13 | Severe. |
| Sulphur | 11–12 | None. |
| Composition (b) | 7–9 | Do. |
| Composition (c) | 8–11 | Severe. |

Grinding fluid A is a heavy duty cutting and grinding fluid of soluble oil emulsion containing fat, sulphur and chlorine conventionally employed in the industry.

In a similar manner, the same work pieces were ground with a conventional heavy duty grinding oil having a viscosity of 100 SUS at 100° F. and similarly containing sulphur, chlorine and fat. The surface finish of the work pieces were superior when ground with wheels impregnated with composition (b) as against the unimpregnated control and wheels impregnated with sulphur and composition (c).

Similar, acceptable results were obtained using amides of ethylene diamine and caprylic acid and ethylene diamine and pelargonic acid.

Subjecting the work pieces to a staining test also showed the novel impregnant to possess superior properties. For example, when immersing work pieces in a grinding-coolant fluid of the conventional type which fluid contained the solid material from each of the pulverized grinding wheels having as impregnants sulphur and the compositions (b) and (c), the work piece in fluid containing the novel impregnant did not stain, while the sulphur-containing wheel material and the wheel material of composition (c) stained the work pieces after a two-week immersion. Staining was evident by the development of a tan to brown color.

The novel wheel and impregnant combination is suitable in most grinding operations, such as internal, centerless, plain, surface, disk, centertype, shoe-type centerless, etc.

From the above examples, such as Example I, it is evident that the novel impregnant extends wheel life and thus allows production of more work pieces per dress. Specified print tolerances can be easily maintained as demonstrated by the data in Tables I and II. For given surface finish, greater operating safety margins are obtained; e.g., at constant force conditions less stress is set up in the wheel, such as when surface loading is absent (characterized also by metallurgical damage). Conversely, less rejects are produced because surface finishes are improved. Sulphur staining of parts and metallurgical damage to

parts is absent when using the novel impregnant as demonstrated in Example IV. These results are surprising, because the impregnant consists essentially of N,N'-ethylene bis-stearamide. Other unexpected advantages are the ability to "stub down"; i.e., reduce the wheel size, or use wheels of reduced size on other machines or other applications. As a consequence a large inventory of wheels of different sizes can be reduced.

Moreover, the different grinding methods illustrated herein are improved by the use of the novel wheels impregnated with the N,N'-ethylene bis-stearamide when this impregnant is presented to the work piece during a grinding operation.

It is, of course, to be understood that the foregoing examples are illustrative only, and that numerous changes can be made in the ingredients and properties described therein without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

**1.** A grinding wheel comprising abrasive grits, a vitrified bond holding said grits together to form the grinding wheel, said wheel having an interstitial space which space contains essentially an amide of a diamine and carboxylic acid having a melting point of at least 225° F. and wherein the diamine is an aliphatic diamine, a cycloaliphatic diamine, or an aromatic diamine.

**2.** A grinding wheel according to claim **1** wherein the amide melts at above 280° F. and is derived from a cycloaliphatic diamine and an aliphatic acid.

**3.** A grinding wheel according to claim **1** wherein the amide melts above 280° F. and is derived from an alkylene diamine and an aliphatic acid.

**4.** A grinding wheel according to claim **1** wherein the amide melts above 280° F. and is derived from an aromatic diamine and an aliphatic acid.

**5.** A grinding wheel comprising abrasive grits, a vitrified bond holding said grits together to form the wheel according to claim **1**, said wheel having an interstitial space which space contains essentially N,N'-ethylene bis-stearamide.

**6.** A grinding wheel according to claim **1** comprising aluminum oxide abrasive grains, a vitrified bond holding the grains together to form a wheel, said wheel having an interstitial space containing essentially N,N'-ethylene bis-stearamide.

**7.** A grinding wheel according to claim **1** comprising aluminum oxide abrasive grains, a vitrified bond holding the grains together to form a wheel, said wheel having an interstitial space containing essentially N,N'-ethylene bis-stearamide of a melting point in excess of about 290° F.

**8.** In an improved grinding method wherein an abrasive wheel has an interstitial space constituent and wherein said wheel is presented to a work piece and engaged therewith, the work piece ground, and the wheel dressed after a work cycle during which at least one work piece is ground, the improvement comprising the step of maintaining in the work cycle the abrasive wheel in contact with the work piece in presence of an amide of a diamine and a carboxylic acid as the major essential interstitial space constituent of said wheel wherein the diamine is an aliphatic diamine, a cycloaliphatic diamine, or an aromatic diamine, and wherein the amide has a melting point of higher than 225° F.

**9.** In an improved grinding method according to claim **8**, wherein the amide melts above 280° F. and is derived from an alkylene diamine and a fatty acid.

**10.** In an improved grinding method according to claim **8** wherein the interstitial space constituent is N,N'-ethylene bis-stearamide which is characterized as having a melting point of 290° F.

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