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Keat

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[54] **GRAPHITE CONTAINING METAL BONDED DIAMOND ABRASIVE WHEELS**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 227,867, Feb. 22, 1972, abandoned, which is a continuation-in-part of Ser. No. 124,047, March 15, 1971, abandoned.

[52] **U.S. Cl.** **51/309;** 51/298
[51] **Int. Cl.** **C04b 31/16;** C09c 1/68; C23c 5/00
[58] **Field of Search** 51/295, 298, 309

[56] **References Cited**

UNITED STATES PATENTS

3,385,684	5/1968	Voter	51/295
3,402,035	9/1968	Martin	51/295

FOREIGN PATENTS OR APPLICATIONS

1,200,687	7/1970	United Kingdom	51/309

OTHER PUBLICATIONS

Nicodur, The New Diamond Abrasive, Apr. 1966, 4 pages.

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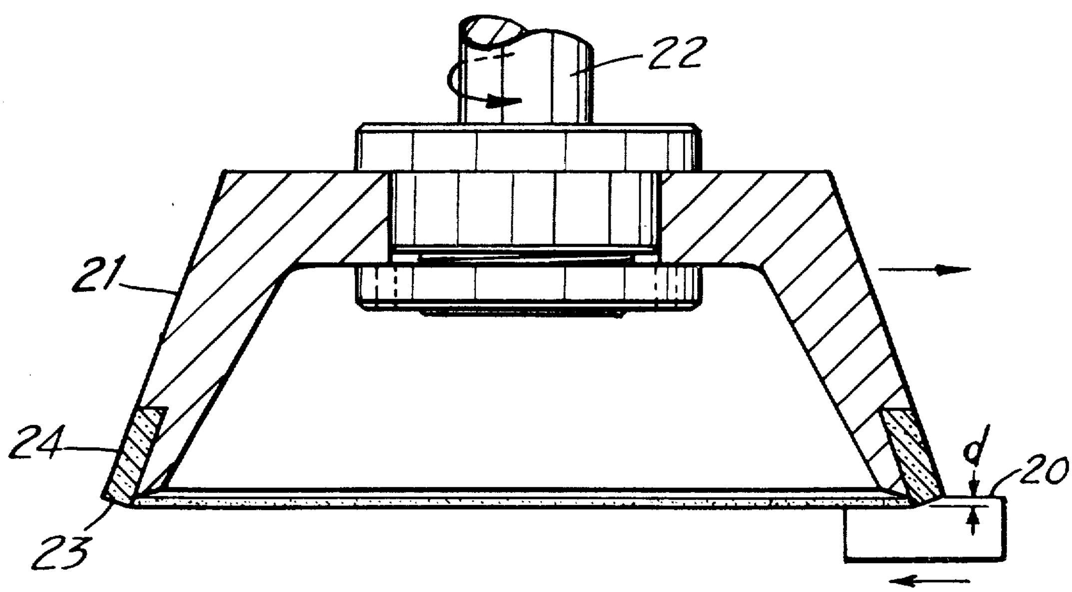
[57] **ABSTRACT**

The addition of graphite or similarly acting inert fillers to metal bonds for diamond abrasive grinding wheels improves performance of cup-type wheels in the dry grinding of cemented carbides. Filler contents of 15 to 50% by volume of the bond, and particle sizes of from 1 micron to 200 microns are useful. Metal coated diamonds show superior performance under many grinding conditions. However under the most severe conditions when localized grinding temperatures are high, uncoated diamonds are superior. Friable type diamond, of the type normally employed in resin bonded wheels must be used. Bonds melt above 300°C. Hardness of bond correlates with amount of filler required, as does bond volume % of filler.

5 Claims, 2 Drawing Figures



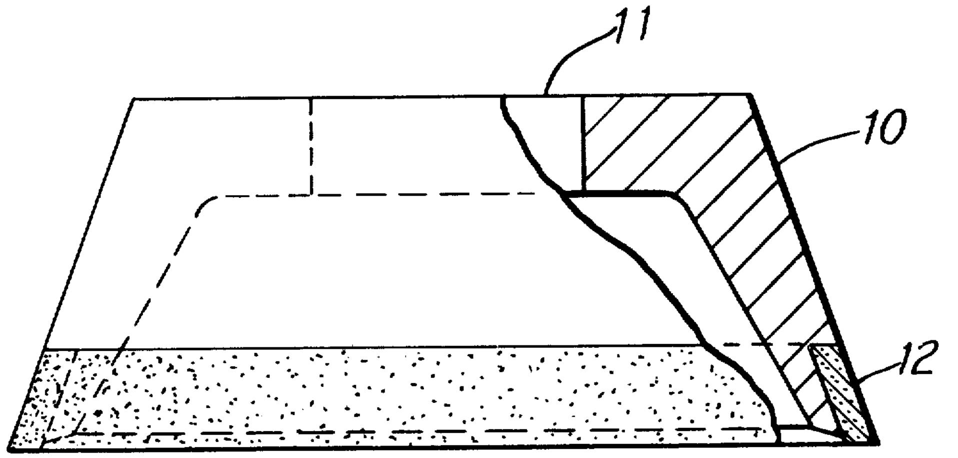


FIG. 1

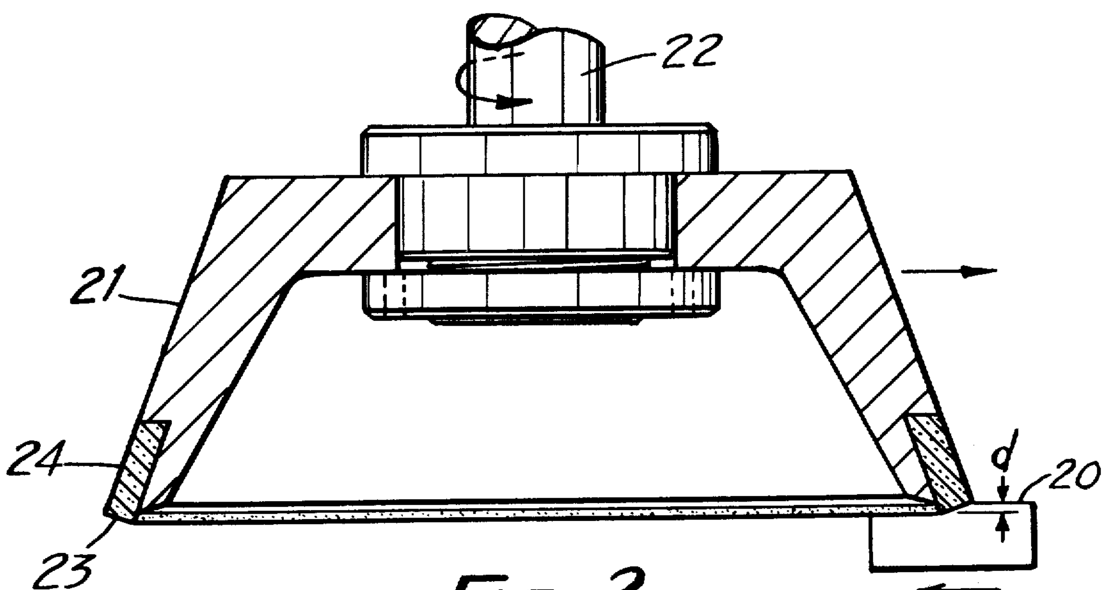


FIG. 2

GRAPHITE CONTAINING METAL BONDED DIAMOND ABRASIVE WHEELS

BACKGROUND OF THE INVENTION

The invention is an improved grinding wheel and method for the dry grinding of cemented carbide materials such as cobalt-bonded tungsten carbide. This application is a continuation-in-part of my copending application Ser. No. 227,867, filed Feb. 22, 1972, and now abandoned, which in turn was a continuation-in-part of my now abandoned application Ser. No. 124,047 filed Mar. 15, 1971. Conventionally, resin-bonded wheels have been used for dry carbide grinding.

British Pat. No. 1,192,475, published May 20, 1970, discloses the use of metal-bonded wheels for dry carbide grinding, wherein the bond is modified by the incorporation of relatively large sized particles of boron nitride, referred to as "granular" particles, in the size range of from 63 to 1000 microns, and in amounts of from 15 to 60 volume % of the total volume of the abrasive section of the wheel. The subject British patent refers to prior British Pat. No. 874,250, published Aug. 2, 1961, which discloses up to 5% of boron nitride in powder (rather than granular) form, and which states that the use of other solid lubricants such as graphite and molybdenum disulfide have not produced any marked improvement in diamond grinding wheel performance. Still earlier British Pat. No. 615,731, to Knowlson, accepted Jan. 11, 1949, discloses the use of up to 5%, but preferably 2–3%, by weight of graphite in a bronze bond, for producing metal bonded diamond wheels for the grinding or lapping of metals. The Knowlson patent teaches the use of graphite, talc, soapstone, slate, or molybdenum disulfide in a fine dispersion, and suggests, for maximum adhesion, that the diamond be coated with a metal, by sputtering or evaporation.

Until the present invention, however, no significant application of metal-bonded wheels in the dry grinding of hard carbides has been known. The present invention provides a metal bonded diamond wheel which can outperform standard resin bonded wheels by an order of magnitude or more, in terms of the ratio of carbide removed to wheel wear, and which can operate at lower power inputs, with less heating of the work, in the dry grinding of carbides.

SUMMARY OF THE INVENTION

Whereas the prior art suggests the use of large amounts of coarse solid lubricant (such as British Pat. No. 1,192,475), or small amounts of finer solid lubricant (such as British Pat. Nos. 615,731 and 874,520) the discovery of the present invention is that relatively large amounts of fine graphite in closely controlled sizes and amounts, result in an order of magnitude improvement in the efficiency of metal-bonded diamond cup-wheels in the dry grinding of cemented carbides, when weak or friable type diamond is employed. Specifically it has been discovered that, depending upon the particular metal bond employed, the graphite content may range from 15% of the total bond volume to 50%, and the particle size may range from under 10 microns to 200 microns, the coarser graphite being employed at the higher concentrations and vice versa. The graphite particles normally being flaky or plate like, when so shaped, are measured in terms of the average diameter of their face. Other fillers, specifically polytetrafluoroethylene, hexagonal boron nitride, and molybdenum disulfide may be substituted in whole or in part for the graphite.

The grinding element of the wheel is fabricated by conventional hot pressing techniques by placing the prepared mixture of graphite, metal powders, and diamond grit in a suitable mold and pressing while simultaneously heating. The term cup-wheel is well understood in the art to refer to wheels in which the grinding face is an essentially planar radial face, as distinguished from the cylindrical, curved grinding face of the so called "straight" wheels. Although referred to as "planar" the grinding face, in operation may tend to assume a conical form as more clearly explained in connection with the drawing discussed below.

THE DRAWING

FIG. 1 of the drawing shows a cross-section of a typical cup-type grinding wheel of the present invention, having a support element **10** of suitable material such as metal or metal filled synthetic resin, a mounting hole **11**, and a grinding element **12**.

FIG. 2 shows the wheel during a grinding operation, the relative movement of the work and the wheel being indicated by the arrows. A workpiece **20** is being ground with a downfeed, on each pass of the wheel, **21**, driven by shaft **22**, equal to *d*, as indicated in the drawing. For purposes of clarity the downfeed is shown exaggerated in amount, resulting in wear on the working surface **23** of the grinding element **24** such that the thickness of the element decreases, by an amount *d* from its outside diameter to its inside diameter. Since such wear is measured in a few thousandths of an inch, the working face can be referred to as substantially planar, and perpendicular to the axis of wheel rotation.

DESCRIPTION OF PREFERRED EMBODIMENTS

The raw materials required for the production of the grinding elements of the invention are metal powder for the bond, finely divided natural or synthetic graphite, as the preferred filler, and diamond abrasive grits. The raw materials are thoroughly mixed, in the desired proportions, placed into a mold cavity of the required size, and hot-pressed by conventional techniques well-known in the art of powder metallurgy.

The metal may be selected from the practically infinite number of stable metals, metal alloys, and intermetallic compounds and mixtures thereof known to the art and commercially available, having melting points above 300°C and a hardness equal to or greater than silver at 300° to 500°C. For example, tin is inoperative as an elemental metal bond. Particularly useful are intermetallic or alloy compositions which can be formed at low temperatures but which react to form higher melting metal matrices. Under severe grinding conditions when localized grinding temperatures are high, uncoated diamonds are superior. Under less severe grinding conditions metal clad diamonds are preferred. Other fillers, in addition to the graphite may be incorporated into the metal bond, such as secondary abrasives or solid lubricants.

Diamond which is useful in the present invention is that known to the art as "resin bond type" diamond. Such diamond was introduced to the industry subsequent to the announcement in 1955 of the synthesis of diamond by the General Electric Company. After commercialization of the synthetic resin bond type diamond in 1959, together with a synthetic metal bond type in 1960, the suppliers of natural diamond also offered diamond to wheelmakers in two basic types, the resin bond and the metal bond types. In the synthetic diamond classification, the resin bond types are distinguished primarily by their multicrystallinity, irregular surfaces including re-entrant angles, and by their irregular, weak shape, as compared to the stronger, blockier, more perfect single crystal metal bond type synthetic diamond grits (with smooth and regular surfaces). The natural resin bond type diamonds are characterized, on the other hand, as distinguished from natural metal bond types, by their splintery shape or flat, platelike shape; the natural metal bond type being blocky and strong shaped, but both natural diamond types being monocrystalline in the grit sizes suitable for the invention. All diamond now on the market for use in the production of grinding wheels is specified by the seller as either a metal bond type or a resin bond type; except for a synthetic type sold by DeBeers Consolidated Mines and referred to as DXDA-MC, which is a blocky, strong shape sold for use in resin bonded wheels designed for grinding steel or steel and carbide combinations. This type diamond is not considered to be a "resin type diamond" in the sense defined above, nor is it classified in the art, except for its special application, as a resin bond type diamond.

For the purpose of this application the resin bond type diamonds can be divided into two classes: (1) synthetic and (2) natural. The useful synthetic diamond can be fully characterized by the term resin bond type diamond (synthetic) or simply by reference to it as multicrystalline (weak) diamond grit. While there is available a strong polycrystalline natural diamond type called ballas and another called carbonado, both of these, although they are polycrystalline, are very strong and not suitable for the present invention. The individual crystals in the ballas or carbonado are around 20 microns and finer, while the crystals in the grits of synthetic resin bond type diamond are more coarse and instead of producing a grit of higher strength than a comparably shaped monocrystalline grit (as in the carbonado and ballas types) it results in a weaker grit. There is also a rare natural diamond, framesite, which is coarsely polycrystalline, but very strong. It is also not intended to be included in what we refer to as "weak multicrystalline" diamond.

Aside from the industry classification of the diamond as resin bond type (RB) or metal bond type (MB), physical measurement of friability, bulk density, and aspect ratio can be employed to define the diamond type coming within the present invention. For synthetic diamond, the friability index, F, for grit sizes of 130 and coarser is to be equal to or less than: $0.0052\ x^2$, and equal to or less than $1.07x^{0.9}$, for grit sizes finer than 130 mesh when x is the average of the larger and smaller nominal screen size of the screens used to obtain the sample, in the U.S. Sieve series; i.e. for 60/80 grit, x is 70.

For natural diamond of the RB type the friability is equal to or less than $11.3x^{0.43}$, where x is the average of the number designation of upper and lower U.S. sieve size screens used in obtaining the sample. For natural RB type diamond the bulk density, as measured by the A.N.S.I. (American National Standards Institute) method B74.17-1971 (obtainable from American National Standards Institute 1430 Broadway, New York, N. Y. 10018) should be 1.7 grams per cubic centimeter

or less in the 140/170 size, and 1.6 grams per cubic centimeter or less in the 200/230 size grit.

Another parameter which is satisfied by natural RB type diamond is the three dimensional aspect ratio, defined as the longest particle dimension in the horizontal plane, divided by the height of the particle. The average value of this parameter, for RB diamond in the 60/80 grit size, should be larger than 1.4, as measured by conventional optical microscopy with the grains resting randomly on a flat surface.

Another parameter, commonly measured is the two dimensional aspect ratio, which is the ratio of the maximum projected dimension of a grit particle to the maximum dimension of the particle perpendicular to the first dimension in a plane, parallel to the plane of the slide on which the particles are resting. For resin bond type natural diamond this ratio is found to be greater than **1.4.** Friatest Model 500 machine, obtainable from Boart and Hard Metal Products S. A. Ltd., Friatest division, P.O. Box 104, Crown Mines, Johannesburg, Transvaal, Republic of South Africa is used in determining friability index F.

The friability index F is determined from the relation

$$F = \frac{t}{ln\ (100/R)},$$

where t is the time in seconds and R is the fraction of diamond "residue" from the Friatest, in which a sample of diamond grit of a given grit size is placed in a capsule with a hard steel ball and shaken for a measured amount of time. The diamond grit is then carefully removed from the capsule. It is screened through the next smaller screen size (smaller in linear size by a factor of 1.19) than was used as the smaller of the two screens in making the tested sample. The term R is then determined by weighing the amount retained on the screen and dividing that weight by the original weight of the sample of diamond.

Although the Friatest method is available to the industry and is a proposed standard for the industry, the following is a detailed description enabling a duplication of the test.

DETAIL OF FRIATEST METHOD

An accurately sized 140/170 sample of the grit to be tested is placed in a cylindrical steel capsule (Friatest Mark IV) having an inside diameter of 0.5 inches and a length of 0.75 inches. Covers are provided for each end of the capsule; the cap on one end is flat, the cap on the other end is spherically concave with a radius of curvature of 9/32 inches and an inside diameter, measured perpendicular to the axis of the capsule, of 0.5 inches, to exactly cover the cylinder.

An accurately weighed 0.4 gram portion of the diamond sample is placed in the capsule with an alloy steel ball 5/16 inches in diameter, and weighing 2.025 to 2.4 grams. The cylinder is capped and clamped on an oscillating holder on the Friatest machine (Model 500). The machine oscillates the capsules, in the direction of the axis of the capsules, at a rate of 2400 cycles per minute with an amplitude of 0.325 ±0.015 inches. The machine is turned on for a timed period of 50 seconds. The sample is removed and weighed as described above. From the known values of t (50 seconds) and R, the value of F can then be calculated.

The following examples illustrates preferred embodiments of the invention:

EXAMPLE I

The following materials were mixed to form a homogeneous blend:

Graphite powder, natural, 65 micron particle size (through 400 on 500 mesh): 3.13 grams

Bronze powder: 70 Cu (15 to 20 microns), 20 Sn (2–3 microns) 10 Ag (2–3 microns): 22.30 grams

Diamond (150 grit, copper clad, 50 wt. % of Cu) Friatest Friability: 50 to 60: 5.66 grams

The mixture of the above powders was cold pressed at 10 tons/in ^{2}, pressure released, heated to 500°C, soaked for 5 min. at 500°, hot pressed at 6 tons/in^2 at 500°C, for 10 minutes, and removed from the mold to give a grinding element containing 15.25% by volume of diamond. The graphite represented 35% of the bond volume (metal plus graphite), ignoring in this case, a pore volume of 4% by volume. The pore volume is not critical and may typically range from 0 to 8%.

EXAMPLE II

A similar grinding element was made up of 15.5 volume % diamond, of the same type, the same metal bond, and 40% of the total bond volume was through 325 mesh on 400 mesh natural graphite (average size 80 microns). The grinding element had a porosity of 2.8%.

Wheels were made by cementing the grinding element with a metal filled epoxy resin on an aluminum filled resin wheel center to produce a standard 6A9 straight cup-wheel having a 4 inch outside diameter, 1.75 inches high with a 1.25 inch mounting hole.

In the dry grinding of carbide cutter material at a relatively heavy infeed rate of 2.4 mils per pass, and a total rate of cut of 0.037 cubic inches per minute, the wheel made from the grinding element of Example I drew the same power as a conventional standard phenolic bonded commercial wheel containing the same kind and amount of diamond (nickel clad diamond was employed for the phenolic wheels) but had a volumetric ratio of material removed to wheel wear (G ratio) of over 16 times that of the standard wheel. The wheel of Example II, in the same test, drew 25% less power and had a G ratio of over 14 times that of the standard. Thus the wheel made from the element of Example I, under these conditions, could do the work of more than 16 standard wheels, while the wheel of Example II could do the work of 14 of the standard wheels at 25% less power draw. The diamond was 150 grit size, before cladding.

The peculiar effect of graphite when employed with resin bond type diamonds in producing the order-of-magnitude, or greater, efficiency of performance of the grinding elements of the invention is shown by the fact that many other materials also sometimes considered to be solid lubricants are ineffective in producing improved grinding results. Such materials which have been tested and found ineffective in this invention are: mica, CaF_2, LiF, WS_2, WSe_2, $NbSe_2$, lamp black, and cryolite. Aluminum oxide was also tried and found ineffective.

The following examples show a comparison of grinding results for variations in filler content metal bond composition with a standard resinoid bonded diamond wheel, under identical grinding conditions, in the dry grinding of cemented carbide. The column marked "Grinding Efficiency % of Standard" reports the G ratio of the test wheel based on 100% as the value of G ratio for the standard resin bonded wheel of the same diamond type and concentration; the G ratio of a given wheel being the ratio of the volume of material removed from the workpiece by the grinding action divided by the volume of the grinding element worn away. The average power draw is the average peak power drawn by the motor which rotates the wheel during grinding measured by a watt-meter connected to a recording instrument, during the last quarter of the run.

Four wheels were made up using the same metal bond as in Examples I and II, but with varying amounts and particle size of graphite. The diamond in all cases was copper clad, 150 grit, except in the case of the resinoid standard wheel in which nickel clad diamond was employed, such diamond being superior to copper clad diamond in the type of standard resin wheels employed in this test. Metal clad diamonds are known commercial items; the cladding metals, as indicated in British Pat. No. 615,731 should melt above 500°C, and should be compatible with the bond metal. The diamond concentration, 15 volume percent of the grinding element, was the same in all cases. The wheels were compared in the dry grinding of cemented tungsten carbide as in Examples I and II, under the identical grinding conditions. The results are shown in Table I. The wheels were made as in Examples I and II.

Table I

Example	Graphite Size and Vol. %	Grinding Efficiency % of Standard	Power Draw % of Standard
III	5 micron 35 vol. %	480%	76%
IV	5 micron 25 vol. %	1100%	80%
V	100 micron 40 vol. %	700%	76%
VI	170 micron (230/325) 40 vol. %	80%	98%

From the above and other tests it has been shown that, in this bond, optimum performance is obtained for very fine graphite with a graphite content of 25% to 35%, and that the graphite size should be less than 170 microns at higher graphite contents. However, excellent performance is achieved at the 40% level with 100 micron graphite.

EXAMPLE VII

A similar wheel was made with a copper-cadmium bond, Cu_5Cd_8 containing 74% cadmium and 26% copper, by weight. The wheel was compared, in the same test as reported above, with a standard resinoid wheel. The diamond content in both wheels was 15 volume %

and the diamond was metal clad as in the previous tests. The copper-cadmium wheel contained 25 volume %, of the bond, of 10 micron graphite. The grinding efficiency was 650% as compared to 100% for the standard, and the power draw was only 64% of the standard. This low power draw is characteristic of the brittle intermetallic compounds, such as Cu_5Cd_8.

EXAMPLE VIII*a*

As in the previous examples, a wheel was made employing a copper tin bond corresponding closely to the intermetallic compound Cu_3Sn, containing 66% copper (a slight excess over the theoretical Cu_3Sn which exists as a separate phase), and 34% tin. The graphite content was 20% by volume of the bond, and the graphite was 10 microns in size. In the same test method against the standard wheel as reported above, the grinding efficiency was 770% as compared to 100% for the standard, and the power draw was 72% of the standard. The low power draw, again, being characteristic of the intermetallics such as Cu_3Sn.

EXAMPLE VIII*b*

To show that metal cladding of the diamond is not essential, a wheel identical to that of Example VIII*a* was made except that the diamond was not metal clad. In the standard test it showed a grinding efficiency of 370% as compared to 100% for the standard resinoid wheel containing nickel clad diamond. The power draw was 60% of the standard. Thus, although not as efficient as the graphite filled wheel containing copper clad diamond, the wheel of this example was almost four times as efficient as the standard wheel in terms of volume of metal removed per unit volume of wheel wear, and was better than the wheel of Example VIII*a* in terms of power.

EXAMPLE IX

A grinding element formed form a copper-tin bond, Cu_3Sn, as in the previous example, but containing 25% graphite, 10 micron particle size and employing copper clad diamond, was tested in the same manner against the standard. The grinding efficiency of this wheel was 1100%, as compared to 100% for the standard, and the power draw was 56% of the standard. This example illustrates our finding that with the brittle intermetallic bonds, the optimum graphite content is between 20 and 28%, by volume.

EXAMPLE X*a*

A grinding element using the same metal bond and graphite mix as in Example IX was made into a flaring-cup wheel, **11V9** shape, with a 3.75 inch diameter, 1.5 inches high, and a 1.25 inch mounting hole. The wheel was made by molding an aluminum filled resin wheel center to the pre-formed grinding element, which element included a bronze ring at the face opposite the grinding face of the diamond section to aid in the dissipation of heat and to improve bonding to the resin center. The wheel showed a grinding efficiency of 1600% and a power of 52% in the standard test.

EXAMPLE X*b*

The same bond as in Example X*a*, but with 30% by volume of graphite was used to make a grinding element. The element was cemented to an aluminum metal wheel center to produce a straight cup as in Examples I through IX. In the standard grinding test this wheel had a grinding efficiency of 3600% as compared to 100% for the standard. The power draw was 92% of the standard. Although the wheel showed essentially no improvement in power, in terms of volume of carbide removed by grinding under the test conditions, it was shown to be the equivalent of 36 standard resinoid bonded wheels, each of the same diamond content as the test wheel.

EXAMPLE XI, XII and XIII

A variety of metal bonds, filler contents, and diamond types were employed to make various wheels with resin centers which were then compared against the standard. The variations are shown in Table II.

Table II

Example	Diamond	Graphite Content	Bond	Wheel Type
XI	copper clad	25 (10 micron)	silver-indium (Ag_3In; 76 In 24 Ag)	Straight cup 6A9
XII	nickel clad	20 (10 micron)	silver	Straight cup 6A9
XIII	unclad	33 (10 micron)	bronze (85 Cu, 15Sn)	Straight cup 6A9

In these examples the grinding element was mounted to form a straight cup wheel as in Examples I through IX.

The grinding results against the standard resinoid wheel were obtained as before, except that in Examples XII and XIII, the infeed rate was 2.0 mils instead of 2.4 mils (for both the test wheel and the standard). The results are given in Table III.

Table III

Example	Grinding Efficiency % of Standard	Power % of Standard
XI	1000%	84%
XII	300%	64%
XIII	500%	48%

Example XI shows, again, the excellent results obtained with brittle intermetallic bonds. This bond can be fabricated from the elemental metals at temperatures as low as 200°C which permits the inclusion of organic or inorganic fillers having low thermal stability, if desired. In this connection it is also pointed out that the Cu_3Sn bond, described above, can also be fabricated at temperatures as low as 250°C when made from mixes including the elemental metals. The intermetallic compounds formed in the fabrication process have, of course, melting points well in excess of 300°C. In all cases the metal powder used in fabrication preferably should be relatively fine, being preferably about 2 to 15 microns.

To show the effect of friability of the diamond on its performance in graphite filled metal bonds a series of wheels were made employing a bronze bond containing 25% by volume of graphite. The diamond, 140/170 grit size was present at a concentration of 18.7 volume %. Several different diamond types were used having friability values (F) of from 50 to 159. The grinding test was performed dry on a ¼ by ½ inch cemented tungsten carbide surface, Carboloy 370, with a 2 mil infeed; the wheels were 3 ¾ inch diameter 11V9 (flaring cup) wheels. The results are as follows:

Table IV

Example	Diamond Type	Cladding	Friability Index	Wheel Wear (mils)	Grinding Ratio	Power (Watts)
XIV	General Electric RVG-D Synthetic	Copper 50% by Wt.	51	0.5	220	760
XVa	"	"	51	0.7	160	760
XVb	"	Same as above but surface of coating acid etched	51	1.7	59	720
XVI	"	Unclad	51	3.8	23	320
XVII	"	Nickel 55% by Wt.	51	4.4	21	840
XVIII	DeBeers Synthetic	Copper 50% by Wt.	58	5.1	20	800
XIX	DeBeers Natural	Unclad	125	13.0	5.8	440
XX	DeBeers Natural	Unclad	159	15.0	4.5	400
XXI	MB-Saw General Electric MD	Unclad	143	18.1	3.5	360

In all of Examples I through XIII, the diamond was synthetic polycrystalline resin bond type diamond. Characteristic of such diamond type, it had a friability index, F, for the 150 grit size of less than 97 when tested by the method described above, in its uncoated condition, and had an irregular surface including reentrant angles and an irregular weak shape.

The following results further show the influence of diamond type in a test in which the resinoid standard control wheel, which gave a G ratio of 8, was compared against a group of wheels having the same bronze bond as used in Examples XIV through XXI, containing 25 volume % graphite, and 140/170 diamond (not metal clad). The work was a ¼ inch by ½ inch surface of 370 Carbolay; the unit infeed was 2 mils; the traverse rate was 72 inches per minute; the wheel speed was 3600 revolutions per minute; and the wheels were 3 ¾ inch cup wheels in the standard 11V9 shape, with the grinding section mounted on an epoxy resin core. The results were as follows:

Example	Diamond Type	Friability Index	G Ratio	Power (Watts)
XXII	Synthetic Diamond Resin bond type	53	112	667
XXIII	Natural Diamond Resin bond type 2 dimensional aspect ratio 1.47	95	93	820
XXIV	Natural Diamond Resin bond type 2 dimensional aspect ratio 1.56	76	43	620
XXV	Monocrystalline Synthetic Diamond Metal bond type 2 dimensional aspect ratio 1.38	159	14	500

-continued

Example	Diamond Type	Friability Index	G Ratio	Power (Watts)
XXVI	Same as XXV but thermally weakened	60	15	500

The above results show that monocrystalline metal bond type diamond is not useful in this invention even if it is thermally weakened to give it a low F value. Thus in order to properly characterize monocrystalline diamond in this invention, other than by type classification (i.e. metal bond or resin bond), it is necessary to specify bulk density or aspect ratio in addition to the friability index. Since natural diamond is essentially monocrystalline, definition of operable diamond by the physical characteristic of strength in terms of friability alone, is thus not sufficient.

Although only about one half as effective as graphite when used as the sole filler, hexagonal boron nitride may be used in the present invention at the same volume % levels as graphite. The boron nitride is preferably used in admixture with graphite.

Molybdenum disulfide, while not as good, by itself, as boron nitride is also effective within the same volume % levels as graphite. By combining MoS_2 with 20% graphite, as a % of the total filler content, the combined filler achieves performance levels in terms of G value of as much as 75% of the value achieved by the use of graphite alone, in a volume % equal to the total MoS_2 and graphite. Thus the addition of MoS_2 to graphite results in a kind of synergistic effect.

BN and MoS_2 may be combined with each other and with graphite according to the present invention, to produce significantly improved grinding performance.

Polytetrafluoroethylene, although not as effective as graphite, may be employed when the hot pressing temperature required to manufacture the wheel is not excessive. Good results, for example, have been achieved at the 40 and 50% filler levels when employing a low temperature bond such as a Cu_3Sn bond with 10% added tin to allow hot pressing at 200°C to 350°C such that degradation of the PTFE is avoided.

What is claimed is:

1. A cup-type dry grinding wheel having an abrasive section consisting of resin bond type diamond abrasive grains bonded in a metal matrix having a melting point above 300°C, said metal matrix including a filler selected from the group consisting of particulate polytetrafluoroethylene, graphite, hexagonal boron nitride, molybdenum disulfide, and mixtures thereof in the amount of from 15 to 50%, by volume of the bond, said filler having a particle size of between 1 micron and 200 microns, the smaller size filler being present at the lower concentrations of filler, the larger size filler being present at the higher filler concentrations, said diamond abrasive grit being defined by one of the following lists (a), and (b) of characteristics: (a) synthetic multicrystalline diamond having an irregular surface and a friability index F, for grit sizes of 130 and coarser equal to or less than $0.0052s^2$, and equal to or less than $1.07s^{0.9}$, for grit sizes finer than 130, wherein *s* is the arithmetic average of the number designations of the U.S. Standard sieve series screens used to obtain a sized sample of the diamond, and (b) natural monocrystalline diamond with a friability index of less than $11.3s^{0.43}$ and is selected from a population having a bulk density of 1.7 or less in the 140/170 grit size and 1.6 or less in the 200/230 grit size as measured by the American National Standards Institute method.

2. A grinding wheel as in claim 1 in which a continuous film of a metal having a melting point above 500°C coats the diamond abrasive grains.

3. A grinding wheel as in claim 1 in which the metal matrix has a hardness at 300° to 500°C equal to or greater than that of silver at 300° to 500°C.

4. A grinding wheel as in claim 1, in which the matrix material includes an intermetallic compound.

5. A grinding wheel as in claim 1 in which the filler is graphite.

* * * * *