Aug. 16, 1949. D. REID, JR 2,479,079

DIAMOND ABRASIVE WHEEL

Filed Oct. 20, 1945

FIG. 1

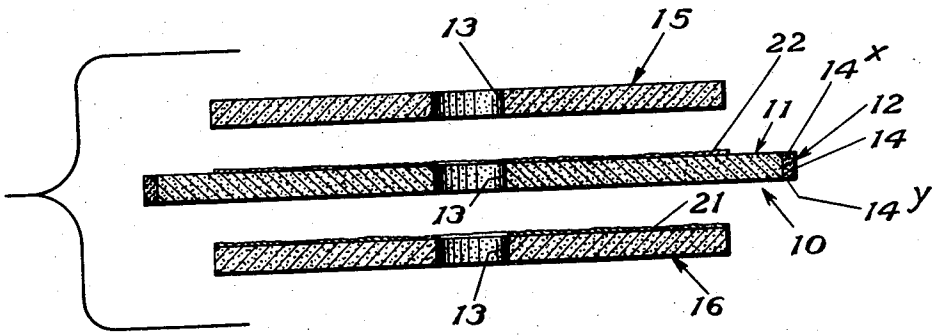


FIG. 2

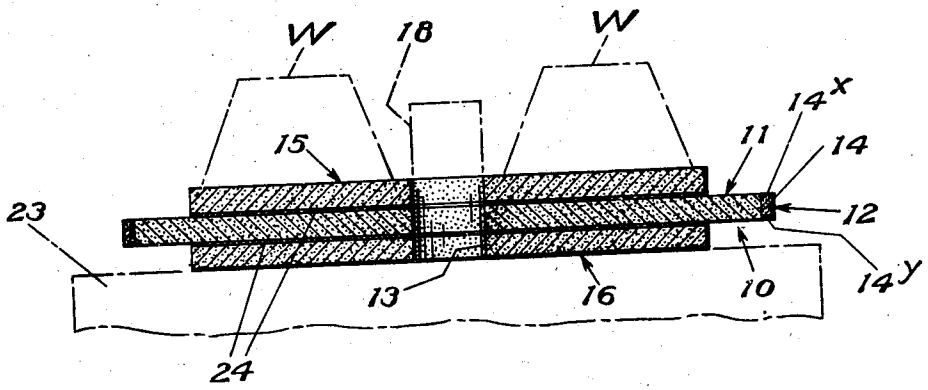
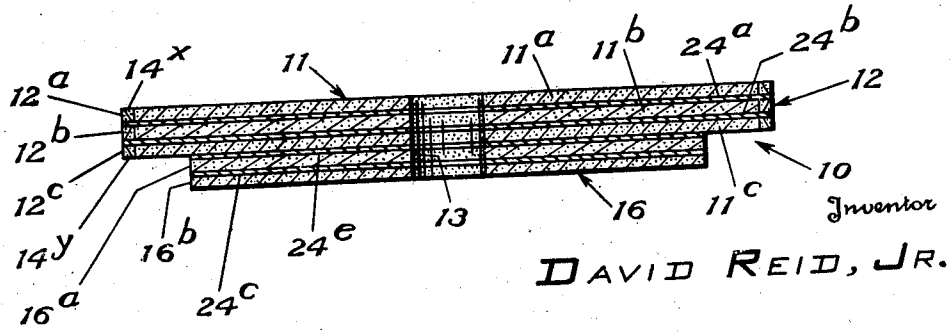


FIG. 3



Inventor

DAVID REID, JR.

By William T. Kinnear

Attorney

Patented Aug. 16, 1949 2,479,079

UNITED STATES PATENT OFFICE

2,479,079

DIAMOND ABRASIVE WHEEL

David Reid, Jr., Holden, Mass., assignor to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application October 20, 1945, Serial No. 623,465

13 Claims. (Cl. 51—206)

1

This invention relates to diamond abrasive wheel construction and to a method achieving the same.

One of the objects of this invention is to provide a strong, efficient, and durable vitrified bonded diamond grinding wheel that will be well adapted to withstand the stresses and strains attendant upon mounting it for rotation and that can be constructed in a manner that will avoid material loss or waste of the costly diamond abrasive material employed. Heretofore, in constructing certain types of vitrified bonded diamond grinding wheels in which the abrasive annulus is of small depth and in which it is desired to have a substantial-sized hub, waste or loss of costly abrasive material has resulted in the course of shaving or shaping the wheel in the green state or otherwise operating upon it to leave the desired thickness of hub, and, as a result, wheels made in that manner are excessively costly. One of the dominant aims of this invention is to avoid this serious obstacle. Another object is to provide a diamond grinding wheel of the desired larger-sized hub and to give the wheel increased capacity to cope with the strains and stresses attendant upon its use in grinding operations, such as stresses imposed by centrifugal forces, temperature changes, and the like. Another object is to provide a method for constructing a diamond grinding wheel of the above-mentioned type that may be economically, speedily, and efficiently carried on in practice, with the use of simple and inexpensive equipment, and capable of being carried on on a quantity production basis. Other objects are, in general, to provide an improved diamond grinding wheel of the above-mentioned kind, and other objects will be in part obvious or in part pointed out hereinafter.

As conducive to a clearer understanding of certain other features of my invention, it might also be noted, particularly where precision grinding operations have to be performed on hard materials, that rigidity of diamond grinding wheel structure and hardness and unyielding characteristic of diamond abrasive surface portions are material desiderata for achieving accuracy and trueness of the parts being ground; vitrified-bonded diamond grinding wheels have, or can be made to have, hardness characteristics superior to diamond grinding wheels employing other types of bonds, and because the vitrified bonded diamond-containing portion thereof can be given a high modulus of elasticity so as to be relatively unyielding under concentrated

2

grinding pressures, particular difficulty is met with in providing such an abrasive annulus with adequate support, particularly in the case of relatively thin wheels, so as to avoid yielding distortion of the wheel under grinding pressures, even though the diamond abrasive portion per se has adequate hardness not to yield in or throughout its grinding surface under the grinding pressure. Moreover, the support for the diamond abrasive annulus should offer adequate resistance to yielding in various directions, the reactions to the grinding pressure being not necessarily uni-directional, but varying in direction with the direction in which the grinding wheel is thrust against the work-piece, or vice versa; thus, the direction might be generally parallel to the axis, or it might be radial, or at various angles to the radius. Another object is to provide a vitrified-bonded diamond grinding wheel and a method of making the same in which adequate or unyielding support for the diamond abrasive portion may be had and the precision and accuracy of grinding operation thereby prevented from being materially impaired.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts, and in the several steps and relation and order of each of the same to one or more of the others, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which are shown, illustratively, several of the various possible embodiments of the mechanical features of my invention,

Fig. 1 is a diametrical sectional view of parts usable in making the grinding wheel;

Fig. 2 is a diametrical sectional view showing the completed wheel and indicating, in broken lines, certain devices that may be employed in carrying out certain of the steps of my method; and

Fig. 3 is a diametrical sectional view showing another possible form of completed wheel that may be made up in accordance with my invention.

Similar reference characters refer to similar parts throughout the several views of the drawing.

Referring, first, to Fig. 1, I first make up a wheel part 10 comprising a cylindrical center 11 having about its periphery an abrasive annulus or zone 12 containing the costly abrasive grain, such as diamond grains, diamond dust, bort, or the like,

using any suitable ceramic or vitrifiable bonding material in each of the parts 11 and 12 suitable or appropriate to firing under conditions or temperatures that will not detrimentally affect the diamond particles employed in the peripheral abrasive part 12. The composite wheel part 10 may be molded and pressed in any suitable way, for example, by the use of molds or mold parts in conjunction with any suitable pressure-applying means, such as a hydraulic press. For example, the mix of which the center 11 is formed may be first molded to the desired diameter, with a hole 13 at its center, and, in the mold, subjected to axial pressure to the desired extent, preferably a low pressure at this stage, whence the mold parts are rearranged or replaced so that the diamond-containing mix, of which the abrasive part 12 is to be formed, may be distributed about the periphery of the center part 11, and the whole then subjected to high pressure to the desired extent, usually several thousand pounds per square inch, the amounts of materials employed being so calculated that, for the final pressure applied, the grinding wheel part 10 has the desired thickness or axial dimension.

The wheel part 10 is in this manner molded at the very outset to give the diamond abrasive annulus 12 the desired final width or axial dimension which its peripheral grinding face 14 is ultimately to have, and to give it the desired uniform thickness or radial dimension so that, as the abrasive part wears down in use, all of its diamond content, down to the innermost layer, may be used in the grinding operation.

Illustratively, the same ceramic or vitrifiable bond material may be employed in making up the mixes for the center part 11 and for the abrasive part 12, and, by way of illustration, the bond may be compounded according to the following:

Example I

Frit	Borax	32.2 lbs.	75 parts
	Boric acid	25.4 lbs.	
	Silica	37.6 lbs.	
	Hydrate of alumina	1.0 lbs.	
	Whiting	3.8 lbs.	
Ball clay			30 parts

or the following:

Example II

	Parts
Kentucky ball clay	15
Ground flint	15.5
Borax	19.5

Such a bond material, in powdered form, may be made into an abrasive mix for the part 12 by adding thereto, in suitable proportion, the diamond abrasive grain in desired grit size; for example, diamond grain of 100-mesh grit size, in four parts by weight, may be added to one part by weight of the bond material. Preferably a suitable temporary binder material is also employed, such as glutoline, of which 4% by weight of the whole may be added where the glutoline is a 4% solution; the glutoline plasticizes the mix and also gives it the appropriate strength in the "green" stage.

In similar manner a mix may be made up for the center part 11 of the grinding wheel part 10, but instead of the diamond grit, a suitable body material of suitable grit size is employed, and, illustratively, I may employ vitreous silica (SiO_2), preferably of the same grit size of that of the diamond particles. The proportion by volume of bond material to the vitreous silica is preferably

the same as that of the bond material to the diamond particles of the mix for the diamond annulus 12, and that may, of course, vary from the proportion above set forth. Protective agents such as aluminum, silicon, or boron, or compounds of silicon or compounds of boron, may be employed in both mixes and these materials may also be employed as body materials, according to the teachings of Patents Nos. 2,356,937 and 2,356,938. Likewise the use of mixed glasses in the bond according to the teachings of Patent No. 2,343,218 is often advantageous, and is one means of altering the coefficients of expansion of the reacting parts.

Next I mold, out of suitable mix comprising ceramic or vitrifiable bond material, a hub element, such as the element 15, and where the ultimate wheel structure is to have a hub that projects on each side of the wheel structure, I mold another such hub part 16; these may be made of the same mix that is employed in making the center part 11 of the grinding wheel part 10 as above described, and the same steps of molding may be employed excepting that the hub parts, once and for all, may be pressed axially in the mold to the desired axial dimension, the amount of mix employed being preferably so calculated in relation to the final pressure applied that the volume structure of the hub part or parts and of the wheel center 11 is the same. However, according to certain other features of my invention, I prefer to give the hub part or parts characteristics different from those of the center part 11, so that it or they and the center part 11 will achieve certain co-actions, all as is later described.

The hub part or parts and the wheel part 10 are now coaxially aligned and brought into face-to-face relation as indicated in Fig. 2, and, conveniently, the coaxial relationship may be achieved by the use of a short arbor, indicated in broken lines at 18 in Fig. 2. So assembled, the parts may be fired, the bond material of each fusing together at the face-to-face contact to form an integral union between the wheel part and the hub part or parts. Preferably, however, and particularly where the bonding materials employed do not lend themselves appropriately to fusing together as just described, I apply to one or both of the faces that are brought together a relatively thin layer of bond material, preferably of the same bond composition that is employed in the center part 11 of the wheel part 10. Thus I may apply such a layer, indicated at 21 in Fig. 1, to the upper face of the hub part 16 and a layer, indicated at 22, to the upper face of the wheel part 10 and throughout an area of the latter that matches the area of the underface of the hub part 15. This bond material may be painted or sprayed into position, or, if in dry form, it may be dusted into position.

In firing, the assembly is placed upon the flat face of a suitable support 23 of refractory material, usually called a "batt," and preferably the uppermost element of the assembly is weighted down, as by weights W placed upon it, all as is indicated in broken lines in Fig. 2. Each hub part becomes integrally united to the center part 11 along a junction indicated at 24 in Fig. 2. If two hub parts are employed, and they need not be of the same thickness, the resultant wheel has a mounting hub projecting axially from either side of the wheel; if only one hub element is used, and it may be of any suitable thickness, the wheel structure has a hub that projects

axially only on one side of the wheel, for mounting purposes. In either case, it is not necessary to resort to shaving, shaping, or other removal of material such as would cause material waste or loss of the costly diamond-bearing part; the peripheral and side faces of the diamond abrasive annulus 12 from the very start are properly dimensioned, and at the most, or only if needed, only a truing operation need be given the abrasive annulus and that, because of the facility to give the annulus proper dimension in molding, effects but an inconsequential removal of material. Costly waste or loss of the costly abrasive material is avoided as is also the costly breakage incurred when it is endeavored to shape the wheel by shaving or the like, as in the earlier above-mentioned prior practices.

Moreover, the hard and relatively non-yielding abrasive portion 12 is given strong and rigid mechanical support to resist yielding or distortion thereof under varying directions of grinding pressure. For example, the pressure with which the grinding wheel, when operating by way of its peripheral or outer grinding surface 14, is pressed against the work-piece, may be principally radial, accompanied frequently by tendencies toward material side or axial thrust tending, particularly where the parts 11—12 are relatively thin, to distort the center part 11 out of its plane and in effect to "dish" it, thus greatly impairing the precision of the grinding operation and running the risk of spoiling the work-piece being ground; however, the built-up hub structure, whether it is built up only on one side face of the center part 11 or on both side faces, resists or acts in opposition to these forces and tendencies and, particularly where one or more layers of glassy bond are employed (as at 21 or 22 in Fig. 1, matured or vitrified into a strong stiffening layer or layers as at 24 in Fig. 2) in the built-up hub structure, the glassy layer not only integrally unites the parts, but forms therewith a composite mechanical structure having greatly improved mechanical action to stresses imposed upon it. The glassy layer 24, being of different composition than the adjacent vitrified parts, functions as a stiffening element that greatly improves the resistance of the structure to compressive stresses acting in the direction of the plane of the layer (radially in Fig. 2), and as against stresses acting at an angle to its plane, as when the abrasive portion 12 operates to grind at either of its side faces alone or simultaneously at one side face and the peripheral face 14, coacts with the adjacent vitrified part or parts as though the glassy layer and one or more of the adjacent parts were a built-up or laminated beam resisting deflection under stress. Where two such glassy layers are present as at 24 in Fig. 2, one of them can function as a tension element and the other as a compression element to oppose the action of stresses exerted through the abrasive annulus 12 tending to dish the center part 11 or tending to cause a portion of it to yield out of its plane. By such coactions as these the action of the grinding wheel under the stresses of performing a grinding operation is greatly improved, precision of grinding can be more efficiently achieved, and the life of the expensive diamond-containing annulus extended.

Turning now to Fig. 3, I have there shown how I am enabled to incorporate directly into the center part 11 of the grinding wheel the structural features and certain unique actions of the above-mentioned stiffening layers of glassy bond.

The center part 11, in Fig. 3, is made up of several thicknesses or elements, illustratively three in number and indicated at 11^a, 11^b, and 11^c, using for each a mix like that above described in making up the center part 11 of Figs. 1 and 2. They may be individually molded, each with a hole at its center, if desired, and each with a diamond abrasive annulus molded thereabout as indicated at 12^a, 12^b, and 12^c respectively, each unit 11^a—12^a, 11^b—12^b, etc., being finally pressed to the desired relatively high pressure, using several thousand pounds per square inch, much in the same manner in which the unit 11—12 of Fig. 1 is molded as above described. The desired number of these relatively thin units is now coaxially aligned, as by the use of a short arbor, and as one is successively superimposed upon the other, a layer of bond material is applied, as by painting, spraying, or molding it into position to the desired thickness, whence the assemblage is fired to mature or vitrify the bond material not only in the parts 11^a, 11^b, etc., and 12^a, 12^b, etc., but also the interposed bond material, which in the fired wheel is indicated in Fig. 3 by the layers 24^a and 24^b. If desired a composite or laminated hub part may in similar manner and at the same time be assembled to the structure and simultaneously fired therewith, and it may comprise several thicknesses or elements 16^a and 16^b joined together by a stiffening layer or glassy bond material 24^c and joined to the built-up wheel center 11 by a similar stiffening layer of vitrified glassy bond, indicated at 24^e, to form the hub element 16.

The internal stiffening layers 24^a and 24^b of Fig. 3 directly underlying edgewise the composite abrasive portion 12, can thus directly interpose their resistance of compression and coact with the laminae 11^a, 11^b, etc., to improve their resistance to compressive stresses, thus better to hold the diamond abrasive annulus against radial inward thrusts, and they can coact with the laminae 11^a, 11^b, etc., either as tension elements or compression elements according to the side from which a grinding thrust or component is exerted, to function somewhat like a laminated beam to resist deflection out of its plane. If a hub element is employed on one or both of the faces of the wheel structure, the coactions above described in connection with Fig. 2 also take place, and these may be enhanced if the hub element or elements are laminated as is the element 16 of Fig. 3, thus to provide two or more stiffening and reinforcing glassy layers alternated with the vitrified-bonded parts of the wheel center part and hub part. Thus improved strength and rigidity of support for the hard diamond-containing abrasive portion may be dependably provided and its unique abrasive qualities made to achieve improved precision and accuracy of grinding with improved life of the grinding wheel.

In carrying out my invention I may, however, achieve additional advantages that contribute materially to the functioning of the wheel in use. In the ultimate wheel structure above described, by the use of the same bonding and body ingredients in the center part 11 (either as a whole as in Figs. 1 and 2, or its laminae as at 11^a, 11^b, etc., in Fig. 3) and in the hub element or elements (either as a whole as in Figs. 1 and 2, or laminae thereof as at 16^a and 16^b in Fig. 3), both have identical thermal coefficients of expansion; an excellent wheel structure results, responding evenly and uniformly to changes in temperature, and a mounting hub element is provided that

obviates the difficulties and disadvantages attendant upon cementing the wheel part to a metal hub or back. The wheel structure well withstands the stresses and strains caused by centrifugal forces when the wheel is rotating at its operating speed, but sometimes it is desirable or necessary that the hub element or elements be materially increased in thickness for this purpose, in the endeavor to avoid strain to the breaking point under the tension to which the innermost regions about the hole of the wheel structure are subjected by the centrifugal forces.

These disadvantages I am able to overcome by creating a differential between the thermal expansivities of the center part 11 of the wheel part 10 and the hub element or elements attached or integrally joined thereto. Thus I so compound the mixes for these two parts that, after firing, the hub element, or elements, has a higher thermal coefficient of expansion than that of the center part 11. For example, I may use the same bond material in both and employ different body materials for each, the body materials having physical characteristics such as will appropriately alter or differently fix the thermal expansivities of the two parts. Illustratively, I may employ vitreous silica as the body material for the wheel center part 11, of a grit size on the order of 200 to 300, in an amount of from 5 to 10% by volume, and for the body material of the hub element or elements I may use fused alumina of similar grit size—say, from 200 to 300—and in an amount on the order of from 5 to 10% by volume. As a result the hub element, or elements, has a somewhat higher thermal coefficient of expansion than that of the wheel center part 11. Or I may use both vitreous silica and fused alumina in admixture in each of the two mixes, but with the fused alumina body material present in greater amount in the mix for the hub element or elements than is present in the mix for the wheel center part 11.

Upon conclusion of firing and as the cooling down to ultimate room temperature proceeds, solidification of the glassy or vitreous ceramic bond takes place at some intermediate point in the cooling-off curve. From that point on, due to the different thermal coefficients of expansion, the hub element, or elements, contracts faster than does the part 11, so that, in turn, when room temperature is reached and dimensional changes cease, the center part 11 of the wheel part 10, particularly in the region about the hole 13, is placed under compression in radial inward direction, due to the action of the hub part or parts in having contracted at a greater rate than the center part 11. The hub part or parts 15, 16 are thus in tension, and by their tension impose the above-mentioned forces of compression upon the wheel part 10.

When the wheel is put into use and due to the heat of grinding warms up to reach its operating temperature throughout, frequently controlled or modified with the aid of a coolant liquid, the radially inward compressive forces in the center part 11 and about the hole 13 are still present inasmuch as the operating temperature or the temperature of the parts about the hole as viewed in Fig. 2 does not reach the point or value in the cooling-off portion of the firing at which the glassy or ceramic bond solidified. Centrifugal forces at the operating speed of the grinding wheel therefore have less intense effects for, before they can place the center part 11 of the wheel part 10 in tension to start cracking the wheel radially outwardly from the hole, they must first overcome the radially inward stresses of compression in the wheel part 10. Moreover, the parts can be so proportioned or compounded in relation one to the other to give them such relative thermal coefficients of expansion as will cause the centrifugal forces to overcome the radial inward compressive stresses in the wheel part 10 at any desired speed of the grinding wheel. And in any case the factor of safety can be materially increased. When the grinding operation is finished and the wheel cools off to room temperature, the earlier above-described conditions of stress are restored. Furthermore, when other strains are experienced in use, and it is desired to reinforce the wheel at other points, this differential thermal expansivity relation between hub and center portion can be readily altered in any desired magnitude and direction by adjusting the mixture expansitivies so as to obtain the desired differential relationship.

Also, if desired, I may compound the hub element or elements 15, 16 and the wheel part 10 using body materials of the kind above described, and, by applying greater pressure during molding to the hub part or parts than to the wheel part, give the former structure a greater density and less porosity than the latter. In that manner I can give the hub elements greater strength in tension to resist the additive stresses of tension imposed upon them by the centrifugal forces during the operation of the wheel. Also I may for similar reasons employ body materials in the hub element or elements of smaller grit sizes than are employed in making up the mix for the wheel part 10.

It will thus be seen that I am enabled to effect substantial savings in the production of wheels of the character first above mentioned; loss of wastage of costly abrasive grains such as diamonds can be avoided, and a full, useful life of the grinding wheel made possible inasmuch as the wheel construction is better adapted to withstand the stresses to which it is subjected in practical use. Moreover, it will be seen that the various objects above mentioned, together with many thoroughly practical advantages, are successfully achieved.

The invention has been above described and illustrated in the form of a grinding wheel in which the manner of achieving the various features of construction and coaction, and advantages of the invention is best illustrated; however, it is to be understood that many features of the invention are applicable and many advantages thereof attainable in other forms of abrasive articles, such as so-called segments, blocks, sticks, hones and the like, and that therefore my invention is not to be interpreted as limited to grinding wheels alone unless otherwise indicated.

As many possible embodiments may be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A diamond grinding wheel having a peripheral diamond abrasive annulus of lesser axial dimension than the hub portion of the wheel, said

wheel comprising a vitrified-bonded disk-like wheel center part having integrally united therewith a peripheral vitrified-bonded diamond abrasive annulus, said disk-like wheel center part having bonded thereto and flatwise against a face thereof a vitrified-bonded annulus that is coaxial therewith and of lesser diameter than said abrasive annulus, said lesser-diametered annulus having a higher coefficient of thermal expansion than said wheel center part whereby the latter is under compression and the former is in tension and both forming parts of said hub portion.

2. A diamond grinding wheel having a peripheral diamond abrasive annulus of lesser axial dimensions than the supporting center of the wheel, said wheel comprising a vitrified-bonded disk-like wheel center part having integrally united therewith a peripheral vitrified-bonded diamond abrasive annulus, said disk-like wheel center part having bonded thereto and flatwise against a face thereof a vitrified-bonded annulus that is coaxial therewith and of lesser diameter than said abrasive annulus, and a layer of vitrified bond material interposed between and integrally uniting them and forming a strong reinforcing lamination therebetween, said disk-like center part and said second annulus resisting dishing of the grinding wheel in that one of them goes into tension and the other into compression under the reaction of grinding forces tending to dish the wheel, said reinforcing lamination therebetween coacting to prevent tendency to relative movement therebetween under the tension of the one and compression of the other.

3. A diamond grinding wheel having a peripheral diamond abrasive annulus of lesser axial dimension than the hub portion of the wheel, said wheel comprising a vitrified-bonded disk-like wheel center part having integrally united therewith a peripheral vitrified-bonded diamond abrasive annulus, said disk-like wheel center part having parallel thereto a lesser-diametered vitrified-bonded annulus that is coaxial therewith and that is compounded and formed to have greater structural density than that of said wheel center part and presenting a substantial area of surface toward a side face of said wheel center part, and a layer of vitrified bond material interposed between said surface and said face and integrally uniting said lesser-diametered vitrified-bonded annulus and said wheel center part throughout said relatively large area.

4. A diamond grinding wheel comprising a vitrified-bonded diamond abrasive annulus supported by a disk-like wheel center part comprising a plurality of coaxial relatively thin disk-like vitrified-bonded elements integrally united to give them greater resistance to bending out of their respective planes than the sum of their individual resistances, by vitrified-bond material interposed between adjacent faces thereof in layer-like form of a thickness to form a stiffening laminus therebetween.

5. A diamond grinding wheel comprising a vitrified-bonded disk-like wheel center part having integrally united therewith and throughout an outer surface portion thereof a vitrified-bonded diamond abrasive annulus, said disk-like wheel center part comprising a plurality of vitrified-bonded substantially disk-like elements of which at least one has a higher coefficient of thermal expansion than another and which are integrally united to each other by interposed

layers of vitrified bond material forming strong reinforcing laminations therebetween, the disk-like element that is of higher coefficient of thermal expansion being in tension and said other disk-like element being in compression.

6. A diamond grinding wheel comprising a vitrified bonded disk-like wheel center part having integrally united therewith and throughout an outer surface portion thereof a vitrified-bonded diamond abrasive annulus, said disk-like wheel center part having coaxial therewith a disk-like vitrified-bonded element integrally united thereto throughout their adjacent faces, said element having a higher coefficient of thermal expansion than said wheel center part whereby the latter is under compression and said element is in tension.

7. A grinding wheel comprising a plurality of disk-like laminae of vitrified-bonded granular material of which at least one lamination has a higher coefficient of thermal expansion than another lamination, and means integrally uniting said laminations in substantially face to face relation whereby the lamination of higher thermal coefficient is in tension and the other is in compression.

8. A diamond grinding wheel having a vitrified-bonded abrasive annulus supported by and integrally united with a vitrified-bonded disk-like wheel center part and a vitrified-bonded hub part, said center part and said hub part comprising a plurality of laminae of vitrified-bonded granular material integrally united in substantially face to face relation, certain of said laminae having a higher coefficient of thermal expansion than others whereby the latter are under compression and the former in tension.

9. A diamond grinding wheel having a vitrified-bonded abrasive annulus supported by and integrally united with a vitrified-bonded disk-like wheel center part and a vitrified-bonded hub part, said center part and said hub part comprising a plurality of laminae of vitrified-bonded granular material integrally united in substantially face to face relation by interposed matured layers of glassy material forming stiffening layers therebetween, certain of said laminae having a higher coefficient of thermal expansion than others whereby the latter are under compression and the former in tension.

10. A diamond grinding wheel having a vitrified-bonded abrasive annulus supported by and integrally united with a vitrified-bonded disk-like wheel center part and a vitrified-bonded hub part, said center part and said hub part comprising a plurality of laminae of vitrified-bonded granular material integrally united in substantially face to face relation, certain of said laminae being compounded and formed to have greater structural density and hence greater tensile strength than others and having a higher coefficient of thermal expansion than others whereby the latter are under compression and the former in tension.

11. A diamond grinding wheel having a vitrified-bonded abrasive annulus supported by and integrally united with a vitrified-bonded disk-like wheel center part and a vitrified-bonded hub part, said center part and said hub part comprising a plurality of laminae of vitrified-bonded granular material integrally united in substantially face to face relation, certain of said laminae being compounded with granular material of smaller grit size than the granular material of others and thereby to have greater

tensile strength and having a higher coefficient of thermal expansion than others whereby the latter are under compression and the former in tension.

12. A diamond abrasive article comprising a plurality of rigid vitrified-bonded parts of which at least one carries a hard vitrified-bonded diamond-grain-containing layer to provide it with an external abrasive face, said vitrified-bonded parts being stiffened and integrally united at their adjacent faces by vitrified bond material in layer-like form, at least one of said parts being in tension and at least one other of said parts being in compression and having different thermal coefficients of expansion.

13. A diamond abrasive article comprising a relatively hard vitrified-bonded diamond-grain-containing abrasive layer integrally united with and supported by a support that comprises a plurality of vitrified-bonded disk-like parts integrally united in face to face relation, at least one of said disk-like parts being in tension and

at least one other being in compression and having a different thermal coefficient of expansion.

DAVID REID, JR.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
687,962	Hyde	Dec. 3, 1901
1,336,751	Linbarger	Apr. 13, 1920
1,422,200	Harris	July 11, 1922
1,501,720	Siegel	July 15, 1924
1,709,820	Gammeter	Apr. 16, 1929
2,033,263	Tone	Mar. 10, 1936
2,034,721	Howe	Mar. 24, 1936
2,281,525	Milligan et al.	Apr. 28, 1942

FOREIGN PATENTS

Number	Country	Date
451,781	Great Britain	Aug. 11, 1936