Aug. 2, 1960 L. COES, JR., ET AL 2,947,616

GRINDING WHEEL STRUCTURE

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Fig. 2

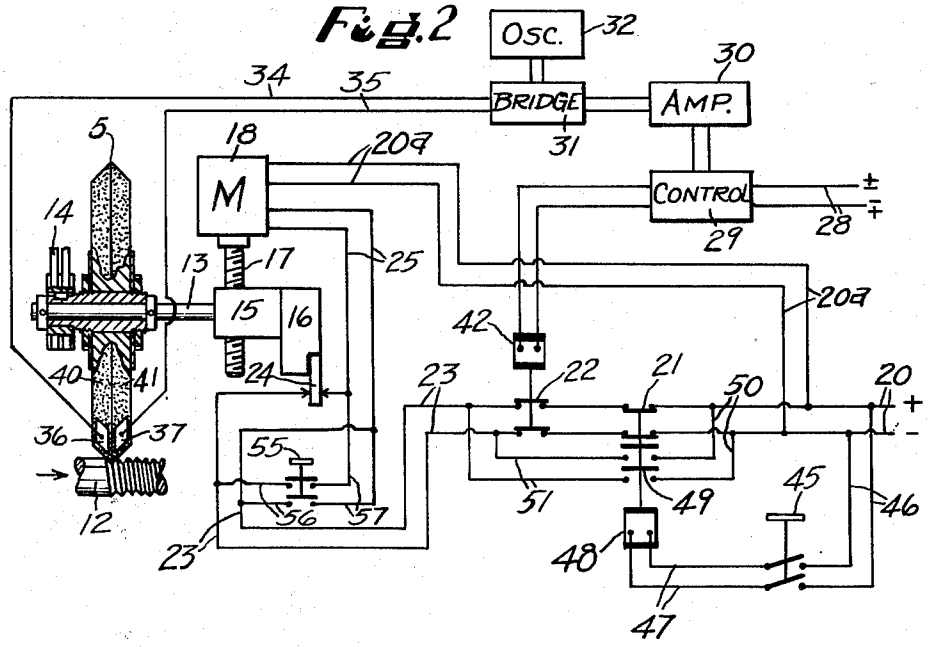


Fig. 3

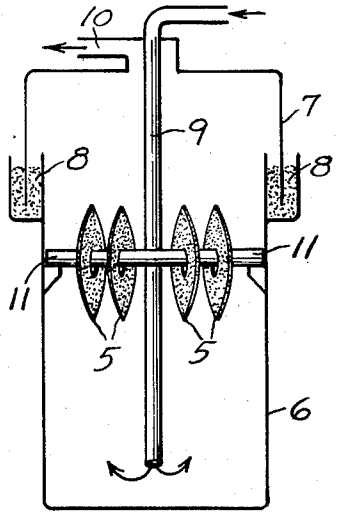
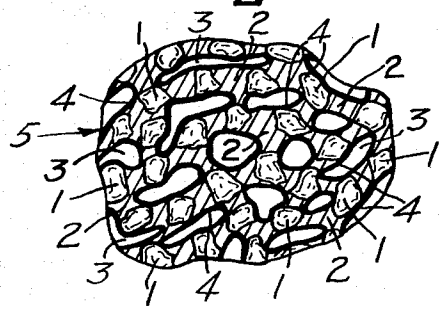


Fig. 1



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GRINDING WHEEL STRUCTURE

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The invention relates to grinding wheel structure.

One object of the invention is to provide a grinding wheel structure that is electrically conductive with an ohmic resistance suitable for certain machine control operations. Another object of the invention is to provide a process for the manufacture of grinding wheels reliably to reproduce wheels having a desired range of electrical conductivity. Another object of the invention is to provide readily practiced processes for the manufacture of such wheels. Another object of the invention is to provide a grinding wheel of abrasive grains bonded with vitrified ceramic bond which is electrically non-conductive but having connecting porous spaces coated with an electrically conductive material readily applied in actual practice, and of relatively high ohmic resistance, whereas such a wheel without the coating of the pore spaces would be for all practical purposes a complete non-conductor. Another object is to provide a grinding wheel having an electrically conductive coating on the pore spaces of interconnected pores which is continuous, and of substantially the same ohmic resistance per cubic centimeter throughout. Another object of the invention is to provide a method of making the kind of grinding wheel structure above indicated which places on the pore space walls of the interconnecting pores of such a wheel a substantial uniform thickness coating without completely filling the pore spaces. Another object of the invention is to provide a method of coating pores of a vitrified bonded grinding wheel with a coating which fills only a small portion of the pores, on the order of 1%, so as to not interfere with the grinding characteristics of the wheel and which coating is electrically conductive within the range desired for certain grinding controlling operations.

Other objects will be in part obvious or in part pointed out hereinafter.

In the accompanying drawings,

Figure 1 is a magnified sectional view of the abrasive structure of the invention.

Figure 2 is a block and wiring diagram of a thread grinding machine to illustrate one application for the grinding wheel of the invention.

Figure 3 is a cross sectional view of a furnace which can be used to produce the grinding wheel structure of the invention.

EXAMPLE I

Best mode

We procured a grinding wheel which was made of white aluminum oxide abrasive grains of a purity of better than 98%, half of it being 280 grit size and the other half (by weight) being 320 grit size, and having a volume percentage of abrasive of 47.3%, a volume percentage of bond of 15.0%, and a volume percentage of pores of 37.7%. These pores were interconnected. The bond formula is given in the following table.

TABLE I

	Parts by weight
Silica, SiO_2	65.13
Alumina, Al_2O_3	16.96
Iron oxide, Fe_2O_3	3.49
Iron oxide, FeO	1.72
Titanium oxide, TiO_2	1.15
Zirconium oxide, ZrO_2	0.06
Phosphorous oxide, P_2O_5	0.07
Calcium oxide, CaO	5.08
Magnesium oxide, MgO	2.73
Sodium oxide, Na_2O	1.03
Potassium oxide, K_2O	2.70

This wheel was 12" in diameter, ¼" thick and had a 3" central hole. It was made in the usual way, by coating the abrasive grains with a water solution of dextrine and then mixing therewith the bond in dry powdered form.

We soaked this wheel in heavy lubricating oil, an SAE 30 oil. This is a well known grade of automobile engine oil. The wheel was completely immersed in the oil and no vacuum or pressure was used. It suffices to leave the wheel in the oil for a few minutes; for assurance in this case we left it in for half an hour. The wheel took up 110 grams of the oil into its pores. The oil was well distributed throughout the pores of the entire wheel. This wheel was then put into a furnace supplied with an atmosphere of pure nitrogen. We heated the furnace to 800° C. which took about three hours. The heating rate is, however, not important. The furnace was then allowed to cool and when the wheel had cooled it was complete.

Figure 1 shows the condition of this wheel. The fused aluminum oxide abrasive grains of 280 and 320 grit size are indicated by the numeral **1**, the bond is indicated by the numeral **2**, the pores by the numeral **3**, the coating of vitreous carbon on the pore spaces is indicated by the numeral **4**, and the wheel as a whole is indicated by the numeral **5**.

Vitreous carbon is a distinct allotropic form of carbon. There are now known to be four allotropic forms of carbon. The common allotropic form of carbon is graphite which has a distinct crystal structure. Another distinctly different crystal form of carbon is diamond. A third form of carbon is amorphous carbon which probably contains some graphitic oxide first identified by Henri Moissan, the French scientist, about half a century ago.

Amorphous carbon is formed when carbon containing gas is burned and when wood is turned to charcoal by burning it with a deficient supply of oxygen. Graphite can be made from amorphous carbon by heating it to high temperatures in the absence of air. How nature made the diamonds is unknown. How man makes diamonds has not been published. It has been indicated by many scientists that there is a probable transition "area" from graphite to diamond at very high pressures and very high temperatures.

The above three forms of carbon have been known for many years and have been differentiated as different forms of carbon for many years. It is only recently that vitreous carbon has been differentiated as a fourth allotropic form of carbon. It is not graphite. It is not amorphous carbon. It is probably a transition form from graphite to diamond but probably only a short way along the road of transition from graphite to diamond. It has an X-ray pattern which is not that of graphite, is not that of diamond but is all its own and the same as that of no other substance. Amorphous carbon has no X-ray pattern.

Vitreous carbon, is formed when hydrocarbons are

dissociated in the absence of oxygen as in the Example I. This differs from the formation of amorphous carbon which takes place when hydrocarbons, carbohydrates and the like are burned with oxygen but with a deficiency of oxygen. Vitreous carbon was apparently first recognized as a distinctly different allotropic form of carbon by Hoffmann, Ber. 56, page 2071, 1923. Prior to that it was considered to be graphite, which it is not.

The furnace used in making the wheel of Example I is shown in Figure 3. It consisted of a chamber comprising a bottom 6 and a top 7 connected by a sand seal 8 with an inlet pipe 9 an outlet pipe 10 and a bar 11 to hold the wheels 5. The inside diameter of the bottom 6 was 24" and the overall height of the furnace was 44" and the other dimensions were about in proportion thereto as shown in Figure 3. Nitrogen was pumped at the rate of three litres a minute. All parts except the sand were made of stainless steel. The furnace was cylindrical.

The wheel of Example I had an actual ohmic resistance of 100 ohms as measured from side to side of the wheel. Prior to treating wheels in accordance with Example I, for four wheels were actually treated, we piled four wheels of the same specifications in the furnace of Figure 3 with a batt on the bottom of the furnace, batts between the wheels and a batt on top of the top wheel. These batts were conventional silicon carbide refractory batts and they covered the areas of the wheels. The resistance to these wheels from side to side turned out to be about 20,000 ohms which, while usable in accordance with this invention, is nowhere near as satisfactory as the lower resistance of 100 ohms. Incidentally there is not much difference when the actual ohmic resistance is taken from side to side of the wheel, a distance of one-quarter of an inch, or from central hole to periphery a distance of four and one-half inches which seems to be surprising but is undoubtedly due to the spreading of the electric current over the longer distance.

We attribute the improved result obtained when the wheels were free of cover all around to the fact that the vitreous carbon was deposited from hydrocarbon in dilute vapor phase. When the wheel is covered, the gas surrounding the wheel is too rich in hydrocarbon vapor and only soot is deposited, except for a little vitreous carbon under to soot everywhere. Soot is amorphous carbon. Therefore the previous statement that vitreous carbon is formed when hydrocarbons are dissociated in the absence of oxygen is a generalization and the hydrocarbon in the vapor form should not be too rich in the atmosphere. However, vitreous carbon can be deposited from pure hydrocarbon vapor if the vapor is cold while the wheel is hot. This could be done by heating the wheel on one side as with a series of flames and directing a stream of pure hydrocarbon vapor at the other side and the wheel would be impregnated throughout when finally the heat had gone through to where the hydrocarbon vapor was directed. As we can't give any better parameters than this, and as even very dilute hydrocarbon vapor in a gas is capable of depositing vitreous carbon, we shall have to make the broad claim of depositing vitreous carbon from hydrocarbon vapor.

EXAMPLE II

We procured exactly the same kind of a grinding wheel described in Example I. This wheel was then soaked in SAE 30 oil as described in Example I and it took up the same amount of oil into its pores.

We then placed this wheel on a non-porous alumina batt which had an area larger than the wheel and packed petroleum coke (any coke would do and also any other carbonaceous material) on it to about 1" in depth everywhere above and around the wheel. We then placed the batt with the wheel and the coke in a kiln and heated them to 800° C. in an atmosphere of air. The coke effectively prevented the oxygen of the air from reacting

the lubricating oil in the wheel. It is not critical how long the wheel is kept at 800° C., as long as it actually reaches 800° C. that is sufficient. Actually, as soon as we were sure that the wheel had reached 800° C., we shut off the kiln (it was an electric kiln) and allowed it to cool which took a few hours. Then we opened the kiln and removed the batt and wheel and coke and picked out the wheel. The wheel was then complete and had a layer of vitreous carbon 4 on the pore space walls. We have broken apart wheels made in accordance with this invention and find that layers of vitreous carbon are practically everywhere on the walls of the interconnecting pores which are all the pores except for a very small percentage in wheels like those of Examples I and II. In this example the layer 4 was vitreous carbon on the bottom covered with soot. The resistance of the wheels, measured in the same way, was about 40,000 ohms but this wheel is usable for the purpose described herein.

The invention is not at all limited to the kind of wheel which is lined with vitreous carbon as to the abrasive thereof or the size thereof or the porosity thereof provided it has interconnecting pores so that an electric current can be passed through it through the vitreous carbon but the bond of the wheel, although it may vary widely in composition is vitrified ceramic bond, of which Table I is an example. The following are additional examples of how to impregnate the pores of vitrified bonded grinding wheels with a coating of vitreous carbon.

EXAMPLE III

Heat the wheel in a furnace held between 700° C. and 1,000° C. in an atmosphere of an inert gas such as nitrogen, hydrogen, argon, krypton, helium, xenon containing hydrocarbon vapor. In this process nitrogen and hydrogen are inert and the others mentioned are the truly inert gases. This can be done as follows: Put the wheel in the furnace, put also a quantity of gasoline in a sagar in the furnace say equal in weight to the weight of the wheel, and then raise the temperature of the furnace to 800° C. The furnace used to make wheels according to this example can be the furnace of Figure 3 with the inert gas flowing at the same rate, but it must be understood that such specifications are merely illustrative in all of the examples, as many different types of furnaces and kilns can be used and the rate of flow of the inert gas can vary widely. Wheels treated in accordance with this example have an ohmic resistance of about 100 ohms, raising the temperature to 800° C. in three hours, the wheels being 12" x ¼ x 3" wheels. The wheels should be uncovered in the furnace as in Example I.

EXAMPLE IV

Heat the wheel in any furnace having an atmosphere of carbon monoxide to a temperature above 500° C., 1,000° C. is recommended. At temperatures above 1,300° C. many vitrified bonded grinding wheels would be damaged but in the case of some wheels even this temperature could be used. The carbon monoxide dissociates into carbon dioxide and carbon and the carbon is deposited in the pores of the wheel as a layer in all of the interconnecting pores of vitreous carbon. In this example the carbon monoxide is kept flowing through the furnace during the entire process after the wheel reaches some minimum temperature which typically is 500° C. Of course the carbon dioxide with some of the carbon monoxide flows out of the furnace and this keeps the percentage of carbon dioxide low and the percentage of carbon monoxide high. As a more detailed specification of this example, use the furnace of Figure 3 with the carbon monoxide flowing at 3 litres a minute and raise the temperature to 1000° C. in four hours. Wheels of the same size, 12" x ¼" x 3" have a resistance of about 20,000 ohms. The wheels should be uncovered in the furnace.

Wheels according to the invention are useful for controlling grinding operations as illustrated in the diagram of Figure 2. In Figure 2 the work piece **12** is being ground by a grinding wheel **5** made in accordance with the invention. In Example I the manufacture of a cylindrical disc wheel was described, but this can be trued to a shape like that shown in Figure 2 and this is the way to make such a shape. The wheel **5** is mounted on a spindle **13** which is rotated as by means of belts **14**. As Figure 2 is simply a diagram, a feed nut **15** is represented which is connected to a slide **16** to move the spindle **13** forward and back in the direction of the work, the spindle **13** being journalled on the slide **13**. The nut **15** is moved by a screw shaft **17** driven by an electric motor **18**. Referring now to the lower right of Figure 2 and working to the left and up, the armature of the motor **18** is energized by power lines **20** through a double relay switch **21**, another double relay switch **22**, lines **23**, a slide controlled switch **24** and lines **25**. The slide controlled switch **24** has an insulated element attached to the slide itself which, when it withdraws to a certain point, opens the circuit as diagrammatically indicated.

Referring now to the upper middle right of Figure 2 and working to the left and up, the stopping and starting of the motor **18** is controlled by lines **28** through an off and on control **29** energized by an amplifier **30** which receives its signal from a capacitance bridge **31** energized by an oscillator **32**. The capacitance bridge **31** is connected by wires **34** and **35** to condenser plates **36** and **37**. The other elements of the condensers of which the plates **36** and **37** are parts are the faces **40** and **41** of the wheel **5**. When the capacity of the circuit of the bridge **31**, wire **34**, plate **36**, face **40**, wheel **5**, face **41**, plate **37** and wire **35** rises to a certain high value during the feeding of the wheel **5** into the work piece **12**, the signal from the bridge **31** through the amplifier **30** to the control **29** opens the switch **22** by means of relay solenoid **42** which stops the infeed. But when the wheel **5** has been worn away some or trued, thus becoming of less diameter, the capacitances between **36** and **40** and **37** and **41** are lowered and the wheel is fed again toward the work piece to maintain the same depth of cut.

The arrangement shown in Figure 2 is particularly useful for thread grinding of all kinds and can also be used for surface grinding and cylindrical traverse grinding. Since this invention is in a grinding wheel structure and a method of producing it we don't need completely to describe the machine, since the above description is merely to show the utility of the wheel and such machines actually exist.

However the machine should have a circuit to cause the slide **24** to withdraw at the end of a grinding operation. Referring to the lower right of Figure 2, a push button switch **45** is connected by lines **46** to the power lines **20** and when closed, through lines **47** energizes a relay solenoid **48** which closes a double relay switch **49** and opens the double relay switch **21**. The double relay switch **49** is connected by lines **50** to the power lines **20** and by lines **51** to the lines **23**, and it will be seen that the direction of the current is reversed through the double relay switch **49** as compared with through the double relay switch **21**. The motor **18** is a reversible motor since the current through its field coils is not reversed as they are connected by lines **20***a* to the lines **20** not through the switch **49**, so when the push button switch **45** is closed the slide **16** retreats, and when it gets to a certain position the switch **24** opens the circuit and the motor **18** stops thus stopping the withdrawal of the slide. Referring to the bottom middle left of Figure 2, to start the machine up again the operator momentarily presses a push button switch **55** which connects lines **56** to lines **57**, the former being connected to lines **23** and the latter to lines **25**. Later the circuit is re-established through the slide switch **24**.

The ohmic resistance between the faces **40** and **41** of the wheel **5** is still about 100 ohms where it is one of the wheels that has a resistance of 100 ohms from side face to side face and, in general, the ohmic resistance between the faces **40** and **41** will be about the same as that from side face to side face of the wheel.

The lining of vitreous carbon should not be too thin, or the ohmic resistance will be too great for the best results in controlling the machine as described. The lining of vitreous carbon should not be too thick or the grinding performance of the wheel will suffer. For the best results the lining everywhere in the electrical path should be not less than .01 mil thick and not more than 10 mils thick but usable wheels can have linings outside of these limits as our wheels can be used in other machines.

Any wheel that has interconnecting pore spaces will also have surface pores. When the interconnecting pore spaces are coated with vitreous carbon, so also will be coated the surface pores.

Preferred grinding wheels according to the invention will have an ohmic resistance of less than 500 ohms from one surface to another surface, such as from the surface **40** to the surface **41**. But in the case of use of the wheels for cylindrical grinding, the two surfaces will be two parts of the same surface, the cylindrical peripheral surface; however a wheel so used will have two opposite side surfaces between which the resistance can be measured. There is no lower limit to the ohmic resistance for use of the wheel as described, as from surface to surface it could have a resistance of zero ohms if such were possible and the condensers **36—40**, **37—41** would still operate properly, in fact they would be more sensitive.

What is "vitrified ceramic bond" is very well understood. It excludes all forms of organic bond and all metal bonds and metal carbide bonds. Invariably on analysis it shows a major portion of oxides, a major portion of the wheel being metal oxide, silica being taken to be metal oxide. In the usual case it consists of a complex silicate. "Vitrified" means that the bond has been fused to flow around the grains thus to bond them together.

Although the examples show the use of aluminum oxide abrasive any abrasive can be used. Aluminum oxide abrasive is usually preferred for grinding steel. Next in order by amount of use comes silicon carbide and next after that comes diamond. These three abrasives are used for the manufacture of well over 99% of all grinding wheels made today, but zirconia abrasive has been tried and found useful for certain grinding operations, so also have mixtures of zirconia and titania. Various other oxides and also the carbides and the borides of the transition metals of groups IV, V, and VI can be used. These transition metals are Ti, Zr, Hf, V, Nb, Ta, Cr, Mo and W. All kinds of mixtures can be used. The invention is therefore not limited to the use of any particular abrasive.

Typical examples of inert gases have been given. In this invention any gas is inert that is inert to hydrocarbon vapor and which does not itself dissociate at the top temperature used. The gases mentioned are all elemental gases so they can't dissociate and all of them are inert to hydrocarbon vapor at any temperature.

In Figure 1 the pores appear to be blocked but this is because Figure 1 represents a cross section and in any cross section the pores will appear to be blocked. The connections are through the third dimension, but not necessarily at right angles to the plane of the paper.

With regard to the firing temperature to impregnate the wheels with vitreous carbon, temperatures down to 450° C. can be used with some results and may be preferred where expense is the major consideration. Although most grinding wheels are fired at temperatures which do not much, if any, exceed 1300° C. a vitrified ceramic bonded grinding wheel could be made out of a

composition to be fired at cone 35 involving a top temperature of 1780° C. Just use the aluminum oxide bond mixture now used for making highly refractory furnace bricks and shape it into a wheel with a central hole and fire it at cone 35. It will grind although it will not grind most steels very well, but therefore we claim up to 1780° C. as the firing temperature for impregnating the wheel because any wheel can be treated according to this invention at any temperature up to the firing temperature at which it was matured.

The only utility we know of for electrically conductive grinding wheels is for use in machine tools. Nothing but vitrified ceramic bonded grinding wheels are used in machine tools, except in the case of diamond wheels. But probably the only machine tools which will use electrically conductive wheels of ohmic resistance over 50 are precision grinders and they use practically nothing but vitrified ceramic bonded wheels. Also metal bonded wheels are highly conducting and are only suitable for a limited number of grinding operations. Organic bonded grinding wheels are practically never used on precision grinders and they would be destroyed at 450° C. anyway. So our invention must be embodied in or in the manufacture of a vitrfied ceramic bonded grinding wheel.

It will thus be seen that there has been provided by this invention a grinding wheel structure and a method of making it in accordance with which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiments above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. A grinding wheel consisting of abrasive grains bonded together by electrically non-conductive vitrified ceramic bond leaving interconnecting pore spaces in the wheel, and a continuous lining of vitreous carbon on the walls of the interconnecting pore spaces said vitreous carbon being electrically conductive and said lining forming a continuous electrical path through the wheel, said wheel having surfaces and said path extending from one surface to another surface and said continuous lining being also on the walls of the surface pores of said surfaces.

2. A grinding wheel according to claim 1, said wheel having a resistance of less than 500 ohms from one of said surfaces to the other thereof.

3. A grinding wheel according to claim 2, said lining being everywhere in the path not less than .01 mil thick and not more than 10 mils thick.

4. A grinding wheel according to claim 1, said lining being everywhere in the path not less than .01 mil thick and not more than 10 mils thick.

5. Method of making electrically conductive a vitrified ceramic bonded grinding wheel having interconnecting pore spaces and surface pores which consists in heating the wheel to a temperature of between 450° and 1780° C. in an oxygen free atmosphere of hydrocarbon vapor, dissociating the hydrocarbon vapor and depositing carbon in a continuous lining of vitreous carbon in said interconnecting pore spaces and surface pores and forming a continuous electrically conductive path through the wheel from one surface thereof to another.

6. Method according to claim 5 in which the atmosphere is also an atmosphere of a gas that is inert to hydrocarbon vapor and which does not itself dissociate at the top temperature used.

7. Method according to claim 6 in which the hydrocarbon vapor is produced by first filling the pore spaces of the wheel with liquid hydrocarbon and thereafter heating the wheel uncovered in the atmosphere thereby generating the hydrocarbon atmosphere but allowing it to become diluted by the inert gas by escape of the hydrocarbon vapor from the pore spaces and entry of the inert gas therein.

8. Method according to claim 7 in which the inert gas is kept flowing adjacent the wheel to keep out oxygen and to promote dilution of the hydrocarbon vapor with the inert gas.

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