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METHOD OF MAKING ABRASIVE ARTICLES

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This invention relates to powder metallurgy and to the manufacture of metal bodies in which minute grains of nonmetallic abrasive materials are uniformly distributed. Such metallic bodies have many fields of use, including cutting or lapping wheels or stones, friction surfaces used as treads, brake linings, clutch facings and the like, and wear-resisting surfaces of all kinds. In such uses the metallic portion of the body may perform as a structural member or contribute functions closely allied to the use to which the body is placed, but in every case the metal serves as a matrix in which the abrasive is imbedded and held. Often it is only necessary to form a thin surfacing of such a metal-abrasive body. Sometimes, and particularly where the surface may wear away with use, it is desirable that the metal-abrasive body be of substantial depth. However, regardless of the use, it is always desirable that the grains of nonmetallic abrasive be uniformly distributed throughout the metal matrix and securely bonded thereto and that these grains be, within practical limits, of uniform size and quality so that the metal-abrasive body may always present a surface of uniform characteristics.

It is lack of uniformity of the friction, cutting or wearing surface presented by these metal-abrasive bodies and the readiness with which the abrasive grain is removed from the matrix which has been the greatest obstacle to their widespread use and low cost production, and it is the general object of this invention to provide a metal-abrasive body of improved characteristics in these regards. A further object of the invention is the provision of methods by which the components of such bodies may be manufactured.

Previously the art has used two general methods of making metal bodies which embody therein distributed grains of nonmetallic abrasives. One of these methods is based upon casting the molten metal around or on the abrasive grains or, alternatively, mixing the abrasive grains with the molten metal prior to casting. The other, and more flexible, method consists in forming the mixture of abrasive grains and particles of metal powder and compressing and molding this mixture into a body of the desired shape, in accordance with the well known practices used for the molding of metal powders. All such methods possess, in greater or lesser degree, the common fault of non-uniformity of product and insecure bonding of abrasive and matrix. This lack of uniformity is caused in part, and perhaps in greater part, by the differences in density between the nonmetallic abrasives and the metal and, in part, by the difficulties encountered in physically handling and mixing relatively fine sized granular materials and by the insecurity of bonding that is inherent in this method. The present invention relates to those methods of forming metal-abrasive bodies in which the body is constructed by molding and compacting metal powder, and is predicated on the use of a novel product to be used for this purpose, which consists of metal powder the particles of which have nonmetallic abrasive grains attached to their surfaces, the size of these grains being of the order of about 1 to 25 microns. This product may be molded by the known powder metallurgy methods into bodies of proper size and shape and, when so molded, forms a body having a wear-resisting friction or abrasive surface that is not only uniform from the standpoint of distribution of abrasive therein but is also uniform in the sense that the abrasive particles are of even size or are so minute in size that variation thereof is unimportant to many uses to which these metal-abrasive bodies may be put. It is further characterized by the integrity of bond between the abrasive grains and the metallic matrix.

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Therefore, this invention provides as a new product a metal powder the particles of which have attached thereto grains of nonmetallic abrasive, the total size of said grains being in the order of 1 to 25 microns. The invention also provides a novel metallic body composed of a matrix of compressed metal powders in which are uniformly distributed and imbedded grains of nonmetallic abrasive, each grain of which is physically attached to a metal particle. The invention also provides a method of making a metal powder product having nonmetallic abrasive grains attached thereto.

The nonmetallic abrasives to which reference is herein made are the metallic oxides which have, for the purpose of the particular use contemplated, abrasive, cutting, lapping, polishing, wear-resisting or friction producing properties. As is well known, the common characteristic of such oxides is a hardness greater than that of the metals. Common examples are aluminum oxide, silicon oxide and magnesium oxide. Other less used oxide abrasives are zirconium dioxide, boron sequi oxide and titanium dioxide. This listing is not inclusive but represents the more practical substances.

One method of making my new product is described and claimed in the United States Pat-

ent No. 2,404,598 to Julius F. Sachse, issued July 23, 1946. While this method has many advantages, it is somewhat deficient in that the final product is not, from the standpoint of moldability, all that could be desired, and this characteristic may place some limitation upon the use of the above methods of handling and molding metal powders and may be reflected in the characteristics of the finally molded metal-abrasive body. For that reason I prefer to use another method which I have developed and which I will now describe.

In the preferred method of making the novel product of my invention, once the abrasive oxide to be used is selected, there is then selected as a matrix metal a metal the oxide of which has a lower heat of formation than the heat of formation of the abrasive oxide. The abrasive oxide and the matrix metal having been selected, an alloy is then formed between the metal of the abrasive oxide and the metal of the matrix. This alloy is disintegrated by atomizing, pulverizing or the like, is screened to proper size and is mixed with a calculated quantity of the oxide of the matrix metal. The mixture is then heated under substantially non-oxidizing conditions and maintained at temperature until the desired degree of reaction is completed between the oxide of the matrix metal and the metal in the alloy which is intended to form the abrasive oxide. The reaction being complete, the reaction mass is cooled, pulverized and screened and the result is a free flowing readily moldable metal powder having grains of the desired abrasive attached thereto, and is thus the product which my invention contemplates. The determination of the heat of formation of any particular metal oxide may be from standard published data or by actual determination based on known standard methods. The following list is only exemplary: Al_2O_3, SiO_2, ZrO_2, TiO_2, B_2O_3, MgO with Fe, Ni, Cu, Co, Zn, Sn, Mo, W, Pb, singly or in combination.

The calculation of the proper charge is a simple one. For instance, if it is desired to make a metal powder which in mass contains 25 per cent. Al_2O_3 and 75 per cent. nickel, each 100 parts of charge should contain 13.3 parts of aluminum, 31.9 parts of nickel, all in the form of a powdered alloy composed of 70.5 per cent. by weight nickel and 29.5 per cent. by weight aluminum which composes 45.2 parts of the charge. The remainder of the charge will be powdered nickel oxide (NiO).

Since fusion or melting of the components of the charge will often prevent production of a free flowing moldable powder product, the reaction temperature must be maintained below that at which melting or fusion takes place. Moreover, since many of the charges which are processed are very exothermic during reaction, the starting temperature may suddenly increase beyond the desired point. With these considerations in mind, it will be apparent that the most efficient temperature, from the standpoint of completion of the reaction may not always be used with success where a free flowing metal powder product is desired. However, by manipulation of the size of the charged materials or by dilution of the reactants, or both, control of temperature and reaction efficiency may often be achieved. By way of example, I cite the results of runs on a mixture of iron, aluminum and iron oxide which is strongly exothermic and often somewhat difficult to handle under commercial conditions in the practice of this invention. The starting

mixture or charge of these comparable runs was in each case calculated to yield as a product a moldable iron powder to which was attached particles of aluminum oxide (Al_2O_3), the total amount of the latter constituting 30.2 per cent. by weight of the charge. To this end the charge consisted of 55 parts of an iron-aluminum alloy containing 44.8 per cent. by weight of aluminum and 100 parts of iron oxide (FeO). In all of these runs the reaction was carried out in a non-oxidizing atmosphere composed of approximately 16 per cent. hydrogen, 30 percent. carbon monoxide and 54 per cent. nitrogen by volume.

Run No. 1

The mixture was made up of materials ground to pass a 100 mesh screen. The mixture was heated to 1000° C. for 1 hour. The reaction was only 64 per cent. complete, the product containing only 19 per cent. Al_2O_3.

Run No. 2

The conditions of Run No. 1 were repeated with the exception that the mixture was heated 3 hours. The same result was obtained.

Run No. 3

The conditions of Run No. 2 were repeated with the exception that the temperature was raised to 1200° C. This resulted in a violent exothermic reaction and fusion of the charge took place.

Run No. 4

In this run the conditions of Run No. 2 were duplicated except that the starting materials were ground to pass a 200 mesh screen. The resultant reaction was 93 per cent. complete, the powdered iron-abrasive product containing 28 per cent. by weight of Al_2O_3.

Run No. 5

Run No. 4 was repeated with the exception that the starting materials were ground to pass a 325 mesh screen. The result was a violent exothermic reaction with consequent fusion of the charge.

These experiments (Runs 1 to 5, inclusive) demonstrate that selected combinations of temperature and particle size of the charge will produce high efficiency without fusion. The conditions will, of course, vary with the reacting materials, and the above described runs are but exemplary of the conditions which by simple trial may be determined in each case to give the best results. High efficiency at low non-fusing temperatures may likewise be obtained by diluting the charge with a material which is not harmful to the final product or is dissipated in gaseous form during the reaction.

Run No. 6

An example of such dilution practice is found in this run in which the charge consisted of 50 parts of iron oxide (FeO), 25 parts of iron-aluminum alloy containing 44.6 per cent. by weight of aluminum, and 75 parts of a cast iron containing 3 per cent. by weight of carbon and 1.4 per cent. by weight of silicon. In this mixture the aluminum, silicon and carbon will on reaction be oxidized in the order named, the carbon oxide passing off as gas and the aluminum and silicon oxides forming the abrasive. The materials were ground to pass a 100 mesh screen and the mixture was heated for 1 hour at 1000° C. The charge reacted quietly without fusion and the reaction proceeded to completion. The dilution of the charge with the

excess non-reactive iron allowed dissipation of excess heat without fusion of the final product.

As previously stated, the product of this invention consists of metal powder particles to which are attached very minute grains of abrasive, their grain size being of the order of 1 to 25 microns. From observations I have made of this product, I believe that the abrasive particles are only attached to those matrix metal particles which found origin in the alloy of matrix metal and abrasive forming metal originally added to the charge.

To determine the size of the abrasive grains which are attached to these metal particles I dissolve from the metal-abrasive mass all of the metal and determine the particle size of the residue. For instance, the product of Runs Nos. 1 and 4 above described was heated at about 600° C. in a stream of chlorine until all of the iron matrix metal was converted to ferric chloride and volatilized from the mass. Any unoxidized aluminum is also converted to its chloride and similarly volatilized, the Al_2O_3 being refractory with respect to chlorine and remaining in the residue. Measurements of the size of the residual abrasive grains showed the following:

Size	Run No. 1	Run No. 4
	Per cent	*Per cent*
Grains under 5 microns	41.4	21.4
Grains between 5 and 10 microns	3.4	7.1
Grains between 10 and 20 microns	55.2	71.5

From observation of the abrasive grains isolated by such procedures as above described, I have concluded that these grains are actually physically attached to the particles of metal powder since the grains appear to be crystalline in compact form and not in the form of shells, envelopes or fragments thereof, such as might be expected if the abrasive merely formed a layer surrounding a metal powder particle. In any event, physical tests such as flotation, air elutriation and, where the matrix metal is magnetic, magnetic separation, fail to effect any separation or division between the abrasive grains and the metal particles and, therefore, demonstrate that actual physical attachment between grain and particle exists, a conclusion which is further confirmed by the fact that despite the difference in density between the abrasive grains and the metal powder particles, the novel material which is the subject of this invention, when molded and compressed into a body (which, if desired, may then be sintered), produces a metal-abrasive body in which the abrasive grains are uniformly distributed and firmly bonded to the metallic matrix.

I claim:

1. The method of making a metal powder product having grains of metal oxide abrasive attached to particles of said powder, which comprises selecting a metal from which the abrasive oxide is to be formed, alloying said metal in predetermined amount with matrix metal the oxide of which has a lower heat of formation than said abrasive oxide, reducing said alloy to powder form, mixing said powdered alloy with a predetermined quantity of the oxide of the matrix metal, said quantity containing sufficient oxygen to react with the abrasive forming metal to form the desired amount of abrasive oxide, and heating said mixture to cause said reaction at a temperature below the fusion point of the reaction mixture.

2. The method of making a metal powder product having grains of metal oxide abrasive attached to particles of said powder, comprising selecting metal from which the abrasive oxide is to be formed, selecting metal from which the metal powder is to be formed, said powder metal being composed of at least one metal the oxide of which has a heat of formation lower than the heat of formation of the abrasive metal oxide, forming an alloy of the selected metals, reducing said alloy to powder form and reacting said powdered alloy with a quantity of oxide of said powder metal at temperatures below the point at which any component of the reacting charge fuses.

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