United States Patent

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[54] COMPOSITE MATERIAL FOR MAKING CUTTING AND ABRADING TOOLS

1 Claim, 18 Drawing Figs.

[52] U.S. Cl. **29/103,**
29/95, 51/206, 76/101, 75/200
[51] Int. Cl. **B26d 1/00,**
B24d 5/00, B21k 21/00
[50] Field of Search 76/112, 24, 101 A, 182.5; 29/182.5, 182.8, 103, 95, 95.3, 95.4; 51/206, 209; 75/200

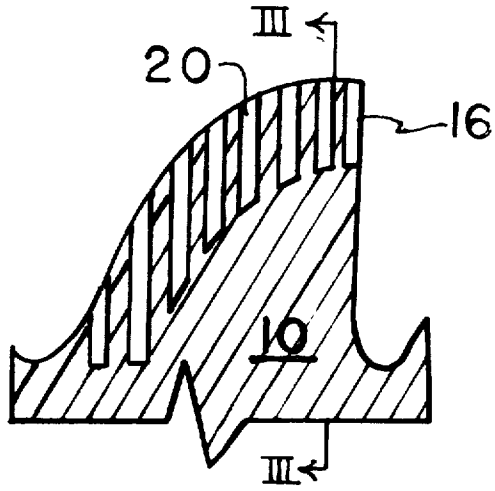
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ABSTRACT: A superindurate, texturally stable abrasive composite material useful in the making of cutting and abrading tools, such as oil well drills, industrial metal cutting bits, mills, planar knives and abrasive grinders. The superficies of the object tool is comprised of the outer face of a tough matrix material and the projecting ends of a preferentially oriented indurate fibers or filaments, such as boron or the indurate intermetallic compounds of boron endowed with a hardness closely approaching that of industrial diamonds, which have been dispersed in collocated array and embodied within a tough matrix material such, for example, as in a sponge iron matrix which has been briquetted in the configuration of the object tool and then heated at temperatures sufficient for incipient fusion to occur to form the composite tool. Other ductile metals such as aluminum, nickel and cobalt, including certain of their alloys, together with steel and titanium are further examples of matrix materials which may be employed. The indurate filaments are so dispersed and collocated that the outer ends of the fibers or filaments are aligned normal to the tool's work-taction surface and consequently to the surface of the object material to be cut or abraded.



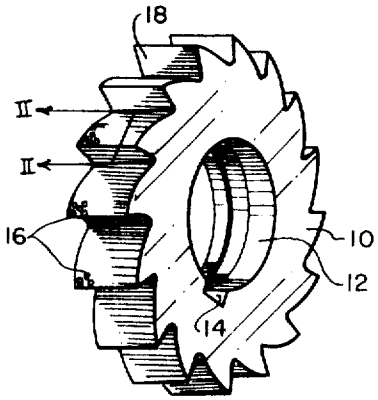


FIG. 1

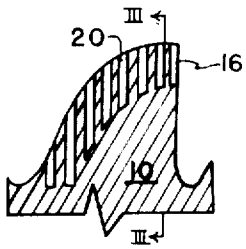


FIG. 2

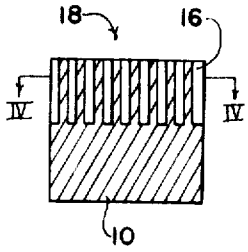


FIG. 3

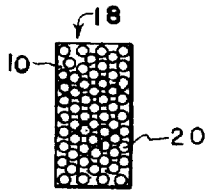


FIG. 4

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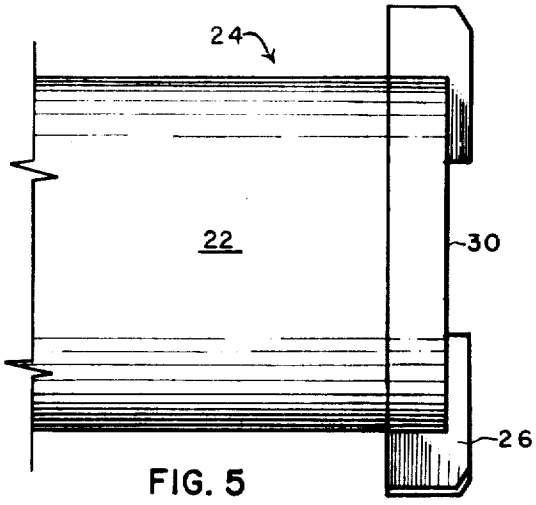


FIG. 5

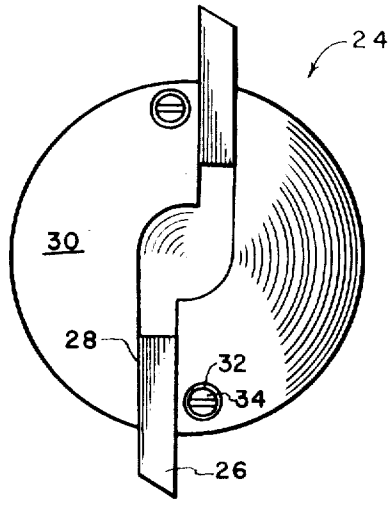


FIG. 6

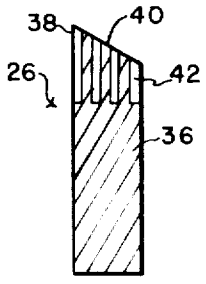


FIG. 8

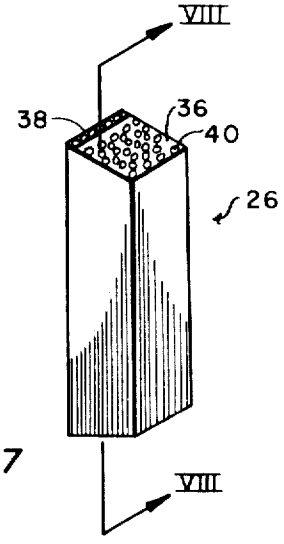


FIG. 7

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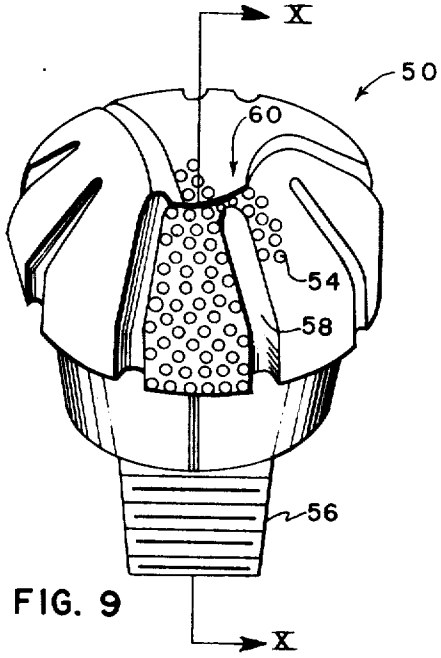


FIG. 9

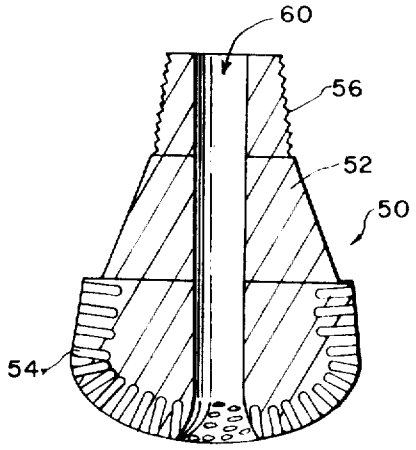


FIG. 10

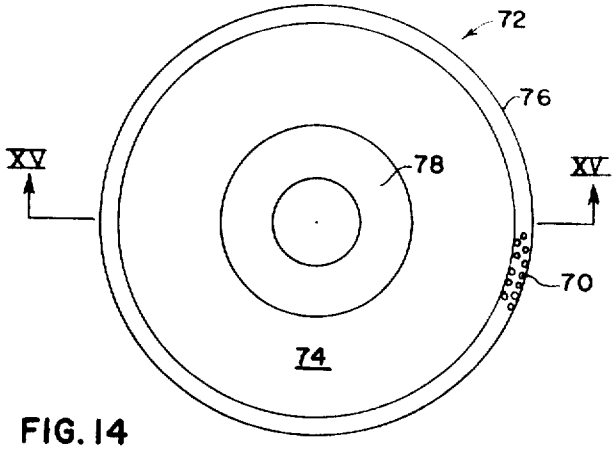


FIG. 14

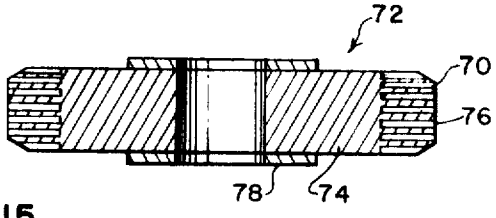


FIG. 15

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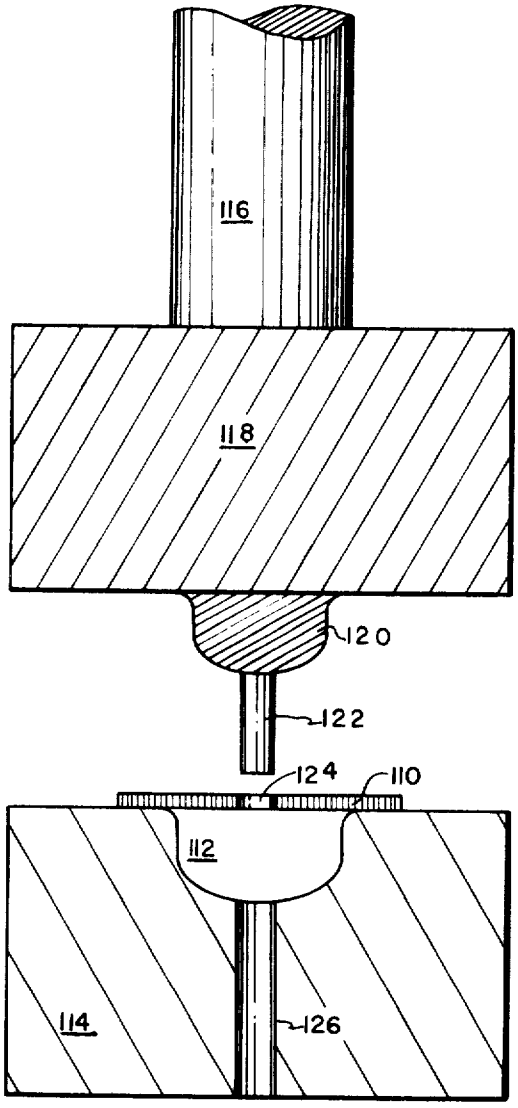


FIG. 11

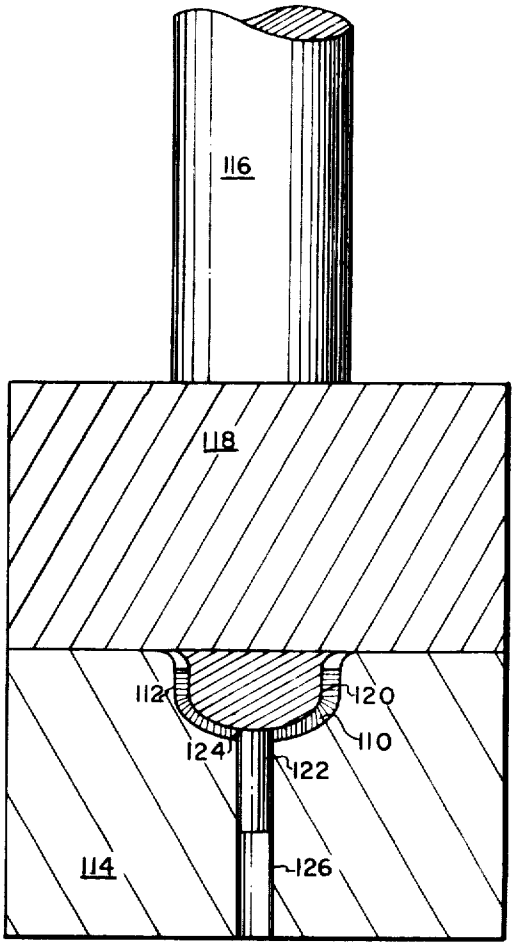
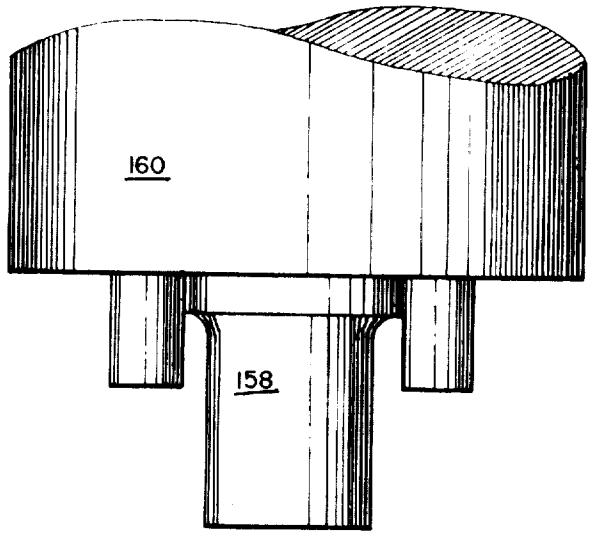


FIG. 12

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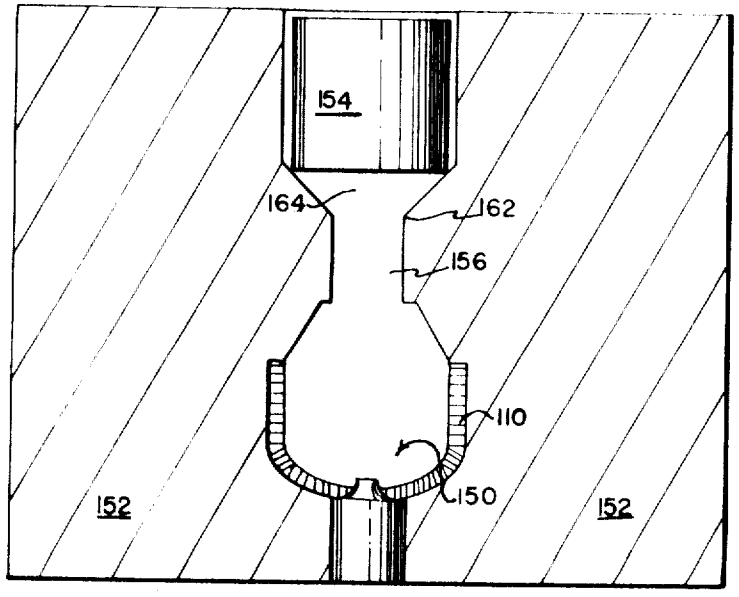


FIG. 13

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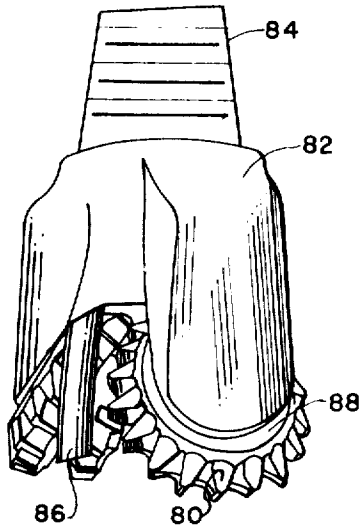


FIG. 16

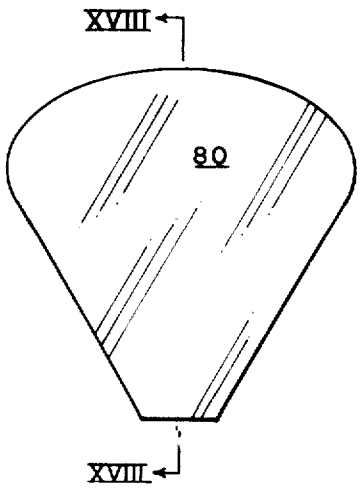


FIG. 17

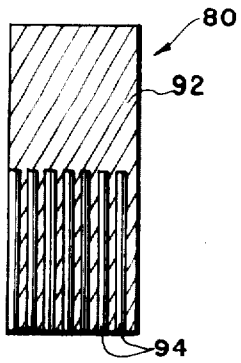


FIG. 18

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COMPOSITE MATERIAL FOR MAKING CUTTING AND ABRADING TOOLS

The present invention relates generally to a very hard composite material for cutting or abrading hard and obdurate substances and the methods of forming the composite. More particularly the invention relates to a novel and unique material combination referred to herein as a superindurate composite structure which can be readily fabricated into useful and efficient tool shapes for the cutting or abrading of very hard substances such as the most obdurate metals, rock, other lapideous matter and the like. Such cutting and abrading tools may be any of several varieties having either rotary or planar cutting or abrading action such as end mills, boring mill cutters, drills, augers, planing mill cutters, lathe cutters, turning mill cutters, abrasive discs, grinding or polishing wheels and the like. Further examples include oil well rock bits, roller bits, coring bits and similar geological boring and scraping tools.

In the present art and with particular reference to the petroleum industry and related geological activities, many types of drill bits are presently being employed. Hardened tool-steel bits and carbide insert cutters are in widespread use for general drilling through low and medium hardness geological formations. Diamond tipped bits are employed when penetration of very hard, lapidified formations is desired. Several disadvantages are inherent in the use of separate cutting, boring and abrasive tools of the known art. Drilling oil wells requires the use of different bits when passing through the changing geological formations and therefore the long articulated drill stem must be pulled from the hole, disassembled in sections and stacked until the entire length is withdrawn and the cutting bit changed, before proceeding into the next formation. This is a slow, laborious and very costly procedure which must be repeated many times during the course of drilling a well. This is particularly true in offshore drilling because of the extreme depths of the wells.

Further, the commonly used hardened tool steels employed in making such drills wear out very rapidly, also requiring the costly pullout operation described above, to permit the drill bit to be replaced. Rock drills having cemented-on tips of industrial diamonds become unusable when the diamond chips become loosened or disengaged from the drill bit's face, again requiring costly pullout of the entire stem system and replacement of the bit.

High-speed steel, from which the efficient design of the well-known general purpose roller bit is made, wears very rapidly when this bit is employed for drilling in very hard formations, thus requiring pullout of the drill stem in order to make the change to a diamond studded hard rock bit, which, from necessity is limited to a relatively inefficient pestlelike design. With the present invention, a roller bit of the same general configuration as those presently employed, but having its roller teeth fabricated from the present superindurate composite material has the dual capability of serving as an efficient all-purpose drill bit, thus retaining the efficiency of the roller bit configuration yet also attaining the effectivity of the diamond studded-hard rock bit for drilling in the very hard formations. Thus, the present invention permits continuous drilling without pullout for bit change when passing from one formation to the other.

Industrial metal-working milling tools, grinders, boring bits, drills, sanders and the like also wear very rapidly when the harder metals such as tungsten, tantalum, titanium, molybdenum, the high carbon steels, etc. are machined or ground with abrasive tools and also in some of the more advanced steel alloys such as D6ac, martensitic stainless, maraging steel, and H-11 tool steel.

The presently invented composite material effectively obviates most of the above-described deficiencies and disadvantages inherent in the use of cutting and abrading tools of the present art by providing a very economical, easy to manufacture, superindurate composite material for the making of such tools. Superindurate fibers and filaments are defined for purposes of this disclosure as having a hardness in the range of 9.3—9.99 inclusive, on the Mohs' hardness scale for inorganic materials.

It is an object of the present invention to provide a superindurate composite material for the manufacture of cutting and abrading tools.

Another object of the invention is to provide a superindurate composite material for the manufacture of cutting and abrading tools which has an exceptionally long wear life in respect to that of conventional tools employed for similar purposes.

Other and further objects and advantages of the invention will be more readily apparent to those skilled in the art upon a consideration of the appended drawings and the following description wherein several constructional forms of the invention are disclosed, and wherein:

FIG. 1 is an isometric view of a milling cutter embodying the present invention;

FIG. 2 is an enlarged sectional detail view in elevation of a typical cutting tooth taken at II–II in the cutter shown in FIG. 1;

FIG. 3 is a cross-sectional elevational view of the milling cutter tooth taken at line III–III of FIG. 2;

FIG. 4 is a sectional plan view near the cutting edge of the milling cutter tooth as taken at line IV–IV in FIG. 3;

FIG. 5 is a side elevational view of the metal cutting end of a boring bar with typical cutting inserts affixed in their cutting position;

FIG. 6 is an end view from the front of the boring bar of FIG. 5;

FIG. 7 is an enlarged detail isometric view of one of the cutting inserts shown in FIGS. 1 and 2;

FIG. 8 is a sectional view through the cutting insert taken at line VIII–VIII of FIG. 7 and particularly showing boron filaments, in collocated and aligned array embodied within a metal matrix according to the present invention to provide a superindurate composite material for the cutting portion of the insert;

FIG. 9 is a pictorial view of a detachable oil well hard-rock bit of conventional configuration embodying the superindurate composite material of the present invention in lieu of forged steel having industrial diamonds adhered to its cutting face as in the present practice in conventional devices having this configuration and for this purpose.

FIG. 10 is a cross section elevational view of the bit of FIG. 9 taken along line X–X of FIG. 9;

FIG. 11 is a cross-sectional elevational view of an open punch press showing a disc of superindurate composite material placed over the press die concavity prior to forming;

FIG. 12 is a view similar to that of FIG. 11, but showing the punch press closed and the disc formed into shape in the press die concavity;

FIG. 13 is a cross-sectional view of the apparatus employed for the present invention when formed by a closed cavity, hot extrusion molding process;

FIG. 14 is a front elevational view of an industrial metal grinding and polishing wheel embodying the present invention;

FIG. 15 is a cross-sectional view taken along line XV–XV of FIG. 14;

FIG. 16 is a pictorial view of a general purpose oil well roller bit embodying the invention;

FIG. 17 is an enlarged pictorial detail view of one of the teeth or lug elements of the bit shown in FIG. 16; and

FIG. 18 is a sectional, elevational view taken at line XVII–XVIII of FIG. 17.

Referring now to FIG. 1 of the drawings, there is shown an industrial straight-tooth, plane milling cutter of conventional configuration for metal working having a matrix 10, a bore 12 and key-way 14 for conventional mounting on a mill arbor (not shown). Such milling cutters are usually made for forged,

high-speed, homogeneous steel and are therefore subject to progressive dulling and wear by attrition of the cutting edge when used for milling other hard metals and like substances. Hence only a comparatively short wear-life is realized in the use of such homogenous metal tools.

In the present invention a tough yet ductile matrix metal **10**, such as iron, aluminum, steel, nickel, cobalt and the like embodies preferentially orientated, aligned and collected boron or other superindurate filaments **16**, dispersed within cutting teeth **18** in such manner that the outer face of the cutting portion of the tooth is comprised of the projecting ends **20** of the filaments and the intimately interspersed matrix material **10**. This is better illustrated in FIGS. **2**, **3** and **4** wherein cutting tooth **18** is shown enlarged for clarity, as is the dispersion of boron filaments **16** or other superindurate filaments within matrix material **10**, to form cutting tooth **18** from the superindurate composite material of the invention in lieu of homogeneous high-speed steel or other conventional metals from which such milling cutters are normally formed in the present art.

The preferred process for making the above-described plain, straight-tooth milling cutter may be generally referred to as a modified cold slurry extrusion process. For example, a predetermined amount of sponge iron power is mechanically mixed into a hopper containing an aqueous solution having a deflocculant to suspend it in a dispersed state. Boron filaments of selected length and quantity are then admixed into this aqueous solution to form a slurry. The resultant viscous fluid slurry is then cold extruded through an orifice having a ratio of 14:1 or greater to the hopper diameter into a permeable mold or die of the object milling cutter's configuration, thus molding the slurry into the desired size and shape of the tool while simultaneously collocating and otherwise selectively orienting the boron fibers in the desired pattern by the resultant fluid dispersion as the slurry enters the die. The wet-mold composite form is then dried in a drying oven or otherwise dehydrated by exposing it to drying heat in order to evaporate and drive out substantially all water and moisture. The molded composite milling cutter is next sintered by subjecting it to a temperature sufficient only to permit incipient fusion to occur throughout the granular constituency of the composite's matrix and metallic substrata, resulting in a finished mill cutter with a superindurate composition for each of its cutting teeth.

Referring now to FIG. **5**, there is shown the lower portion or cutting head **22** of a boring bar **24** of conventional configuration and having dual insert type cutters **26**, also of conventional American Standard configuration. Cutters **26**, as best seen in FIG. **6**, are fitted into retainer slots **28** of bar end **30** and fixedly held in position by flattened bushings **32** and screws **34** inserted at an angle for secure a wedging effect. For purposes of clarity, an enlarged detail of one of the insert cutters **26** is shown in FIG. **7**. Dispersed in a collocated pattern within matrix material **36** and extending across the superficies of the cutting end **38** thereof are the projecting ends **40** of a plurality of boron superindurate filaments **42**, FIG. **8**. Preferably fibers **42** are spaced one diameter of less apart in order to achieve a desired dispersal density of about 30 percent by volume or greater of filament ends at matrix material exposure in any given surface to be employed for cutting or abrasion.

The preferred process for fabricating the type of insert cutter exemplified by the above-described boring bar cutter may be generally referred to as a modified dry-powder metallurgical process wherein predetermined porportions of boron filaments of selected length, or other superindurate fibers are funneled through a first hopper, preferably of the 14:1 ratio described above, onto a troughlike receptacle whose base defines an inclined plate. From a second hopper a predetermined proportionate amount of metal matrix granules or powder, such as sponge iron, is simultaneously funneled onto the inclined trough and admixed with the deposited filaments as a result of a vibratory motion imparted to the inclined trough by conventional means (not shown). This vibration causes a predetermined, proportionate mixing of the filaments with the matrix powder, on the order of approximately 30 percent, or greater, by volume, of filaments to matrix material, while also causing the dry mixture to flow or slide evenly down the inclined plane of the trough and to be deposited into a die cavity formed by a depression, of the size and shape desired, in the floor of the inclined chute. The boron filaments are dispersed and longitudinally aligned in the desired collocated pattern by passing the dry mixture through one of more funnel flues or gates mounted upon the trough, athwart the flow path of the mixture and upon the inclined plane above the die cavity. The die cavity, when full, is subjected to compaction by conventional means, such as by mechanical presses or by the know isostatic pressing process sufficient to cause the dry powder and filament mixture to coalesce into a briquette of the desired dimensions and configuration. This briquette is then sintered by subjecting it to a temperature sufficient only for incipient fusion to occur between its metallic granules, resulting in a permeant encasement of the aligned and collocated boron strands into the sintered powder matrix to form the object insert into a superindurate composite structure.

The pestle-shaped hard-rock bit **50**, shown in FIGS. **9** and **10**, is presently employed in geological drilling, particularly in the petroleum industry for drilling through very hard formations, and is also exemplary of the type of abrasive cutting tool whose working superficies may be readily fabricated from the superindurate composite material of the present invention. Conventionally, the working face of this bit is studded with industrial diamonds which are cemented or otherwise adhered to the work traction surface by a very strong adhesive. This diamond studded face serves as the abrading medium for drilling through rock formations or other very hard geological substances.

The present invention integrally combines the conventional hardened tool steel **52** employed in this hard-rock bit design with work taction superficies of superindurate composite material **54** to provide a bit which does not need to be withdrawn from the hole. The advantage obtained in the use of boron and other superindurate fibers **54** in a tough matrix **52** to provide a working face composite as a direct replacement for cemented diamond chips is obvious since they cannot be pulled out, dislodged or otherwise degraded by hard use because of their firmly embedded length. Other portions of the tool **50**, such as the threaded shank portion **56** as well as its general configuration, including relief channels **58** and drilling fluid orifice **60** remain consistent with those of the conventional diamond studded bit.

This bit, when fabricated to embody a work surface of superindurate composite material is made by the closed cavity hot extrusion process described above but employing two phases in the process. In the first phase a cylindrical superindurate composite having a central bore therethrough and with its filaments oriented and collocated in a longitudinal direction is formed by the modified cold slurry extrusion process hereinabove described. From this cylindrical shape a washerlike disc segment having a thickness as required to effect the superindurate working face of the bit is removed or in effect sliced from the parent extrusion.

Referring to FIGS. **11**, **12** and **13**, a circular washerlike segment **110**, FIG. **11**, is concentrically positioned over concavity **112** of conventional punch press die **114**, the cavity having the shape and configuration of the work taction face of the object bit to be formed. Segment **110** is pressed into concavity **112** and shaped by the lowering of press ram **116**, upper platen **118** and convex or male die **120**; convex die **120** nesting into concavity **112** and punch **122** being passed through central aperture **124** of segment **110** and into orifice **126** of die **114** as shown in FIG. **12**.

The preformed cup-shaped segment **110** of superindurate material is next placed into closed cavity die **150**, FIG. **13**, which is preferably of the split die type **152** as currently employed in closed cavity extrusion molding using high-energy-rate pneumatic-mechanical forming techniques and equip-

ment (not shown) such as the commercial "Dynapak" apparatus. However, appropriate dies in large hydraulic presses will also provide adequate capability for making the object bit.

A heated billet of matrix metal **154**, such as steel, iron, nickel, or aluminum is next positioned in the upper part of cavity **150** above neck portion **156** and punch die **158** of punch ram **160** is released under high pneumatic or hydraulic pressure to impact billet **154** at very high pressure, thus causing the metal billet to extrude through neck **156**, completely filling cavity **150** and coalescing this extruding metal with superindurate composite material **110**, thus forming the drill bit body into the configuration of the walls of cavity **150** and capping the superficies thereof with the superindurate composite material **110** to provide the abrasive work taction face of the bit. The drill bit is then removed from the die and finished in a conventional manner by cutting at the **162** and removing flared portion **164**. Drilling fluid orifice **60**, FIG. **10**, is bored through the center and coupling shank **56** appropriately threaded to complete the object rock bit.

In the formation of cutting, grinding or abrasive tools which define bodies of revolution, the die may be simultaneously rotated while the metal extrusion is being effected in order to take advantage of centrifugal force to better position the filaments and thus assure increased exactness in collocation and alignment thereof. Further, prior to admixing boron or other superindurate filaments with the matrix material the former may be precoated with a very light magnetic film. Thereafter, conventional application of a magnetic field of force about the compacting die will help assure that the filaments are aligned and collocated with exactness. This magnetic force alignment may be applied during either the cold slurry extrusion or immediately following the admixing of dry metallic powder with superindurate filaments as heretofore described.

The grinding wheel shown in FIGS. **14** and **15** is exemplary of abrading tools that may be fabricated to employ superindurate composites by dry powder metallurgy wherein superindurate filaments **70** may be aligned and collocated by first applying a magnetic film thereon, admixing with a powdered metal matrix material and subjecting the admixture to a magnetic field while lying uncongealed in the die cavity prior to compaction into a briquette or billet for eventual sintering to form finished wheel **72** having matrix **74** with aligned and collocated superindurate filaments **70** embodied peripherally therein; the outer ends of which define abrasive surface **76**. Conventional bushing or bearing insert **78**, subsequently fitted about the central axis completes the construction to provide grinding wheel end product **72**.

The general lugs drill bit illustrated in FIGS. **16**, **17** and **18** may be fabricated in a manner closely correlated to that employed for making the hard rock bit shown in FIG. **9** and generally described above, to embody superindurate composite material of the present invention in abrasive lugs or teeth **80**. Three-legged bit body **82** including threaded coupling shank **84** and drilling fluid nozzle **86** are made of conventional material and are of known construction and thus need not be further described herein.

Cutting tooth or lug **80** is fabricated by the dry powder metallurgy process generally analogous to the described above for making the boring bit insert cutter shown in FIG. **8**. Preferably the filaments to be employed are first metallized so that they may be precisely aligned and collocated upon the admixture of metallic matrix powder and these filaments being loosely deposited in the compaction die immediately prior to their compaction into a billet or briquette which is subsequently sintered to finish the tooth. In the second phase of the process teeth or lugs **80** are fitted into notches cut radially into the periphery of a circular positioning plate (not shown) and evenly dispersed thereabout. Only that convergent portion extending downwardly from the tangent point on each shouldered radius protrudes beyond the notches. This protrusion fits snugly into tooth cavities provided in the wall of the closed end split extrusion die to prevent the former from being covered or damaged by the flow-in of metal during the subsequent extrusion of a billet. With all lugs or teeth **80** being properly spaced and retained by the slotted die ring and also properly disposed with relation to the appropriate die wall cavities, a billet of tough matrix material such as hot steel is extruded into the closed die cavity, much in the manner exemplified in FIG. **13**, to cause hot metal to flow into and around the shouldered radii being retained within the slot of the die ring, thereby firmly securing teeth **80** by coalescence with extruding metal and forming rotatably disc element **88**, FIG. **16**, so that teeth or lugs **80** become an integral part of rotatable disc element **88**.

From the foregoing, it will be readily apparent that the present invention is characterized as a superindurate composite material and method of making same comprising a plurality of superindurate filaments such as boron and its intermetallic compounds fixedly embedded in a tough, ductile matrix material and aligned and collocated in such manner that the filament ends and the exposed surface of the matrix provide the cutting edge or abrasive surface of the work taction part of the object tool into which it is shaped, embodied or incorporated.

We claim:

1. A superindurate composite cutting and abrading material for application to very hard substances, comprising in combination:

a. a matrix material having the characteristics of toughness and a uniform wearability less than the abrading elements embedded therein:

b. a plurality of superindurate filaments having a hardness on the Mohs' scale of 9.3 to 9.99 aligned substantially normal to a work surface defined by said matrix and collocated within said matrix the ends of substantially the major portion of said filaments exposed on said surface to define a cutting edge of abrading surface upon said composite, the remainder of the length of said filaments embedded in said matrix.

Notice of Adverse Decision in Interference

In Interference No. 98,064, involving Patent No. 3,590,472, J. R. Nix, M. R. Sargent and W. T. Kaarlea, COMPOSITE MATERIAL FOR MAKING CUTTING AND ABRADING TOOLS, final judgment adverse to the patentees was rendered Dec. 9, 1974, as to claim 1.

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