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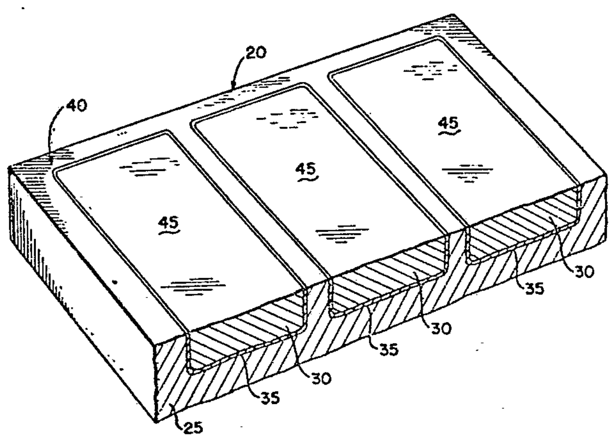
(54) Steel-hard carbide macrostructured tools, compositions and methods of forming.

(57) Composition of matter composed of 30 to 80 weight per cent of a carbide material having a particle size greater than 400 mesh, and 20 to 70 weight per cent of a metallic matrix material, the carbide material which may be a cemented composite (30), being embedded in and bonded to said metallic matrix material (25) by powder metallurgical techniques of compaction and high temperature and high pressure diffusion bonding; and tools having a cemented carbide wear or cutting element (30), these tools also being formed by powder metallurgy techniques.



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BACKGROUND OF THE INVENTION

Since 1940, wear-resistant parts for wear-prone tools and equipment have been made of cemented carbide alloys consisting of a finely-dispersed hard-carbide phase based on metals chosen from Groups IVB, VB and VIB of the Periodic table, cemented by cobalt or nickel or both. Produced by compacting finely-milled powders followed by liquid-phase sintering to achieve consolidation, cemented carbide alloys posses microstructures characterized by hard carbide grains generally in the 1 to 15 micron range.

The use of iron or steel as binder materials has proven difficult because the finely-divided state and high specific surface of the dispersed hard phases promote the formation of comparatively brittle binary interstitial alloys of tungsten and iron with carbon, thus reducing the free binder volume fraction and embrittlingthe sintered body, more or less, depending on the precision maintained in the formulation and sintering parameters and on the free carbon additions made to satisfy the affinity between iron and carbon.

Unlike cobalt and nickel, iron forms a stable carbide, Fe_3C, and has a greater tendency to form brittle binary carbides than cobalt or nickel binder materials. Carbon transfer from the hard carbide phase or phases to iron is promoted by the presence of the liquid or plastic state of an iron or steel binder during liquid-state sintering, carried out at temperatures near to, at, or above the melting point of the binder.

More recently, useful wear parts have been made by casting a liquid steel or cast iron melt into a prepared bed of comparatively coarse particulate, e.g., 1/8 inch to 3/16 inch sintered, cemented carbide.

The present invention may be distinguished from the molten-steel casting method of Charles S. Baum, United States Patent Nos. 4,024,902 and 4,140,170 and the molten-cast iron method of Sven Karl Gustav Ekemar in United States Patent No. 4,119,459 by two main factors: (1) a powder compact of steel or iron and graphite containing dispersed particulates of sintered, cemented carbide, or a number of pieces of dimensioned sintered cemented carbide, or primary, unmilled macrocrystalline carbide crystals is sintered at a temperature below the melting temperature of steel or cast iron, and (2) in place of the use of matrix-alloy melting temperatures to achieve alloy densification, high compaction unit pressures, both before and after sintering, are used, thereby avoiding degradation of the dispersed hard phase particle surfaces by decomposition, melting or carbon diffusion reactions.

Foundry methods, also, lack the well-known economic advantages inherent in powder metallurgy methods, notably, when a multiplicity of wear parts either small or of thin section are to be made. Also, because of the necessarily relatively high processing temperatures and liquidity, excessive amounts of unwanted binary carbides may form despite the use of comparatively coarse, low-surface area carbide particles.

Since both the conventional powder metallurgy method of pressing and sintering finely-milled steel-cemented carbide powders and methods involving casting liquid steel or liquid cast iron into particulate cemented carbide prearranged in molds result in problems hereinbefore described, it is the primary objective of this invention to develop a method by which a steel-cemented hard carbide alloy can be fabricated essentially free of binary interstitial alloys of iron and tungsten with carbon and in which the dispersed hard carbide phase is free of boundary-area decomposition, melting or thermal cracking and is firmly bound in a steel matrix essentially free of macroporosity.

It is also an object of this invention to produce a composition of matter having dispersed hard carbide material firmly and adherently bonded in a metallic matrix by powder metallurgical techniques of compaction and high temperature and high pressure diffusion bonding.

It is a further object of this invention to manufacture tools having hard carbide wear or cutting inserts embedded in and bonded to a consolidated steel powder matrix or composition of matter according to this invention.

It is a further object of this invention to manufacture parts being substantially nonmachinable and of sufficient impact resistance to make them suitable for use as security plates and padlock components.

BRIEF SUMMARY OF THE INVENTION

The method of the present invention involves blending and mixing sintered, cemented tungsten carbide particles or primary unmilled macrocrystalline (i.e., greater than 400 mesh) tungsten carbide crystals with a matrix of iron and graphite powders or steel powder, cold isostatically pressing the composite in a preform mold to a desired shape, then solid-state sintering at a comparatively low temperature, specifically, at a temperature below the melting temperature of the steel, preferably, between 1900 degrees and 2250 degrees Fahrenheit, then hot isostatically pressing (HIP) the sintered body at a temperature well below the melting point of steel to achieve final densification. A diffusion bond is formed between the hard carbide particles and the surrounding steel powder, which holds the wear-resistant hard carbide particles in place.

A critical factor of the present invention is high-pressure densification, both cold and hot, to avoid process temperatures which produce liquidity of the steel binder phase and, thus, promote the aforementioned undesirable reactions between the steel binder material and hard dispersed phase. The technique is reinforced in this respect by the use of a hard dispersed particle or particles of low specific surface. The method also provides a significant advance in production capability for the manufacture of steel-carbide wear parts of comparatively small size or of thin section or intricate design, as compared with methods as disclosed in United States patents hereinbefore enumerated in which molten steel or molten cast iron are poured into a mold preloaded with particles of cemented carbide.

Further, both chemical control of and compositional flexibility of the matrix alloy are superior to molten-metal casting methods. The avoidance of high processing temperatures required to melt and pour steel or cast iron provides better economy of molds, which may be reused, and matrix metals, which are not subject to pouring loss and recycle cost. The method of the present invention is well suited for the formation of parts that must withstand highly abrasive wear forces as well as impact forces. The process is ideally suited to form wear-resistant parts and cutting tools for equipment for agriculture, road and highway construction and maintenance, crushing, comminuting, excavation, and processing. Since the wear resistance of the products produced by this process is so high, so as to make them practically nonmachinable, they are also ideally suited for use as security plates in safes. This wear resistance in combination with the impact resistance of these compositions makes them also suitable for use in padlocks.

BRIEF DESCRIPTION OF THE DRAWINGS

The exact nature of the present invention will become more clearly apparent upon reference to the following detailed specification taken in connection with the accompanying drawings in which:

Figure 1 is a photomicrograph at 1500 magnification showing a cemented carbide particle having a cobalt binder embedded in and bonded to a consolidated steel powder matrix.

Figure 2 is a cross sectionalized perspective view of a wear plate having cemented carbide inserts embedded in and bonded to a consolidated steel powder matrix.

Figure 3 is a cross sectional view of part of a cutting tool having cemented carbide button embedded in and bonded to a consolidated steel powder matrix.

DETAILED DESCRIPTION OF THE INVENTION

Prealloyed steel matrix powder, or a mixture of iron powder and graphite powder, comprising 20 weight per cent (w/o) to 70 w/o of the final mixture is blended and mixed with 30 w/o to 80 w/o of hard carbide particles of W, Ti, Ta, Nb, or Zr, V, Hf, Mo, B, Si Cr or a mixture of these, either as sintered cemented carbide particles or as primary, uncemented, unsintered, unmilled carbide crystals. About 3 per cent of naphtha or other liquid hydrocarbon is added to the powder blend during mixing to prevent segregation of higher density carbide particles during mixing and mold filling, specifically when the dispersed hard phase is composed of hard carbide particles coarser than about 250 microns.

For dispersed hard phase particles finer than about 250 microns, paraffin wax or a solid lubricant such as zinc stearate may be used, because the possibility of component particle segregation during mixing is then diminished.

Next, the matrix powder containing the dispersed hard carbide phase is packed in a preform mold made of polyurethane or other elastomeric plastic. Steel powders of different chemical compositions (such as carbon, alloy or stainless steel powders) or elemental powders such as iron, copper or nickel, may also be packed in the same mold with the main composite steel powder-carbide blend, in any desired location, adjacent to and in contact with the body containing the hard carbide dispersed phase, or surrounding such body, or enveloping a dimensioned, sintered cemented carbide insert. The packed mold with a suitable fitted cover is then sealed and placed in a rubber bag or balloon which is then evacuated, sealed and isostatically pressed,preferably at about 35,000 psi, but not less than 10,000 psi.

The compacted powder preform is then removed from the mold and heated in vacuum or in a protective or reducing gas atmosphere, e.g., hydrogen, to a temperature below the melting temperature of the steel matrix, preferably between 1900 degrees and 2100 degrees Fahrenheit, for between 20 and 90 minutes.

An alternative preforming method consists of packing the composite mixture containing preferably liquid hydrocarbon, e.g., naphtha, preferably 7 w/o and methyl cellulose, preferably 0.5 w/o, as pressing lubricant and green-state binder, respectively, in a steel preform mold. The green preform is then air dried at room temperature, in the mold, then removed from the mold and placed in a rubber bag which is then evacuated and sealed, ready for cold isostatic compaction as hereinbefore described.

Compacts thus solid-state sintered retain some porosity; shrinkage during sintering does not exceed 1 per cent. It has been found, however, that densification achieved by high-pressure isostatic compacting followed by sintering as herein described is sufficient to eliminate any interconnected pore network and that the sintered bodies, therefore, qualify for effective final densification by known hot isostatic pressing (HIP) methods.

Hot isostatic pressing for the purposes of this invention is applied in an inert atmosphere, preferably at 1600 degrees to 2300 degrees Fahrenheit or at any temperature below the melting temperature of the steel for from 20 to 90 minutes at a minimum pressure of 10,000 psi but, preferably at a pressure of about 15,000 psi for 60 minutes. Equally important, an alloy layer is formed at the interfaces of cemented carbide particles and steel matrix. This interfacial alloy bond, which first forms during sintering and is later enhanced during hot isostatic pressing, consists of a thin border area between, for example, a 0.75 per cent carbon steel matrix and dispersed cobalt-cemented carbide particles in a 1/8 inch to 3/16 inch size range. The bond is typically less than 40 microns thick, and no greater than 50 microns thick. The interfacial bonding alloy under these conditions is composed of, principally, cobalt and iron. Bond formation becomes important especially when the hard dispersed phase is of comparatively coarse particles, because these are apt to pull out if not securely anchored in the matrix alloy.

Cemented tungsten carbide particle sizes comprising the dispersed hard phase are selected from within the general size range of 2.5 mesh to 100 mesh, in the U.S. Sieve Series, preferred size ranges being -12 +20 mesh, -6 +12 mesh, and -4 +6 mesh. Specific selected mesh ranges may be prepared by known methods of crushing and sizing sintered, cemented carbide tool components, and which alloys are more commonly of a cobalt or nickel-cemented tungsten carbide (WC) base, sometimes containing also TiC, TaC or NbC or combinations of these hard carbides.

An additional useful aspect in the process of the present invention is to apply a coating of an alloy or metal, preferably Corson bronze or nickel, on the surfaces of a dimensioned sintered cemented tungsten carbide insert of selected shape and size, or a number of such inserts, which are then embedded in a steel or iron-graphite matrix powder at selected locations within a preform mold before the filled mold is isostatically compacted. The corson bronze coating used may be either of the two nominal compositions shown in Table I.

TABLE I

CORSON BRONZE COMPOSITIONS

A	D
2.5 w/o Ni	10 w/o Mn
0.6 w/o Si	4 w/o Co
0.25 w/o Mn	86 w/o Cu
Balance Cu	

Following cold isostatic compaction and during subsequent sintering and hot isostatic pressing of the carbide-steel compact, the coating on the cemented carbide body autogenously forms a diffusion bond, to increase the bonding strength with which dimensioned cemented carbide bodies are held in the matrix. By this method, a cemented carbide body, or a number of them, of specific shape and size may replace a dispersed hard-carbide phase of particulate nature, and thereby form a wear-resistant body or a tool for cutting or drilling metal or rock.

It is recognized that the comparatively low processing temperatures employed in the process of this invention may, in cases in which steel matrix powder compositions are used which do not bond well to particles of a dispersed hard carbide phase, result in inadequate bond strength at the matrix-carbide particle interface. In such cases, for example when alloy steel powders are used which are known to be less sinterable at the comparatively low solid-state sintering temperatures described in the process of this invention, it has been found beneficial to precoat the hard carbide particles with nickel or copper, for example, by known processes such as electroless metal coating or by vacuum vapor-phase coating. Nickel coatings thus applied to the hard carbide dispersed fraction, prior to blending, have been found to improve carbide particle bonding strength. Such precoating of the hard carbide particles would also be beneficial when stainless steel powders are being used.

A further and useful part of the foregoing method is the incorporation of a dispersed hard carbide phase in a steel or iron-graphite powder compact consisting of unmilled macrocrystalline carbide crystals in size range fractions between 60 mesh and 400 mesh, in the U.S. Sieve Series, and in preferred mesh ranges, e.g., minus 60 plus 100 mesh, minus 80 plus 200 mesh, or minus 150 mesh plus 325 mesh, instead of and in place of particles of cemented carbide. The method of the present invention for formulating and forming macrostructured cemented carbide compositions is exactly as heretofore described.

The relatively low processing temperature practiced results in a macrostructure essentially free of brittle double carbides of iron and tungsten (eta phase) and gross porosity. The tendency for liquid-phase sintered, microstructured, cemented tungsten carbide alloys employing a steel binder, for example, in place of the usual cobalt binder, to develop brittle eta-type phases is well known. It is believed that the avoidance of liquid phase sintering and consequently the avoidance of carbon-transfer that such practice encourages, as well as the uniquely low specific surface of the unmilled macrocrystalline carbide particles comprising the dispersed hard phase are essential for the successful formation of the two-phase, steel-carbide macrostructures produced by this method. It should be understood that liquid phase sintering as referred to herein means sintering at a temperature at which the steel binder is at least partially liquid. The prohibition of liquid phase sintering in this invention, therefore, does not apply to any lower melting point metals or alloys (e.g., copper or corson bronze) which may be added as a powder or coating to promote bonding or densification, and may intentionally become liquid during sintering or hot isostatic pressing.

The use of unmilled macrocrystalline hard carbide crystals as a dispersed hard phase is a preferred embodiment of the method of this invention, as an efficient means of maintaining a hard phase possessing low specific surface. It is recognized, however, that essentially binderless, hard aggregates of finer or milled hard carbides may be so used.

An important aspect of the aforementioned macrostructured bodies is the avoidance of ball milling or other comminution of the matrix-carbide powder mixtures, or of either of these two materials separately, prior to cold isostatic compaction, sintering and HIP. The former practice, widely considered essential to sound commercial cemented carbide structures, leads to enhanced reaction between carbides and iron-base matrix powders with resultant formation of brittle double carbides. Avoidance of powder milling also reduces cost.

The method of the invention may employ any of the macrocrystalline carbides, or combinations or solid solutions of them, specifically WC, TiC, TaC or NbC, all exhibiting the low specific surface and angular, blocky shapes typifying these coarsely-crystalline mono and binary carbides. It is known that primary macrocrystalline carbide materials may be finely milled, together with cobalt or nickel, to form cemented-carbide microstructures by liquid-phase sintering in the temperature range 2400 degrees to 2800 degrees Fahrenheit, in which the resultant dispersed hard carbide phases are typically between one micron and about ten microns. The method of the invention, in contrast, results in dispersed, single macrocrystalline carbide grains in size ranges selected from within the much coarser extremes of 250 microns to about 40 microns.

This invention is further explained by the following examples:

EXAMPLE NO. 1

Wear resistant cutting tips were fabricated for rotary sugar cane shredding machines. A uniformly blended mixture composed of approximately 55 w/o 1/8 inch to 3/16 inch cobalt cemented tungsten carbide granules, approximately 44.67 w/o minus 100 mesh atomized iron powder and 0.33 w/o of minus 325 mesh graphite powder was prepared. During blending 5 w/o of naphtha was added to minimize segregation of the higher-density cemented carbide particles. The damp mixture was manually compacted into an elastomeric polyurethane mold cavity of the desired tool shape, dimensioned to allow for cold isostatic powder compaction plus one per cent sintering shrinkage. Following cold isostatic compaction at 35,000 psi, the compacted preform was removed from the mold and vacuum sintered at 2000 degrees Fahrenheit for 60 minutes, following which the sintered body was isostatically pressed at 2250 degrees Fahrenheit for 60 minutes at 15,000 psi under helium.

Metallographic examination disclosed a matrix structure composed of mostly pearlite and a little ferrite typical of conventional slow-cooled 0.75 per cent carbon steel of low porosity. The cemented carbide-matrix interfaces were occupied by bands of a width of about 5 microns of an alloy believed to be composed of iron and cobalt, principally. The cemented carbide dispersed particles appeared unimpaired by thermal cracking and no evidence of dissolution, melting or decomposition of the dispersed carbide phase existed at or near the interfacial boundaries, such boundaries being sharp except for the aforementioned iron- cobalt alloy diffusion zone. No potentially harmful concentrations of eta phase were observed. Test bodies were manually bent over a mandrel by hammering at room temperature and found to have a high resistance to impact loading and to be essentially free of brittle fracture.

Figure 1 is a photomicrograph of a typical area in a composite produced according to Example 1, except that sintering was done at 2100 degrees Fahrenheit. A cobalt cemented tungsten carbide granule 40 is shown metallurgically bonded to a plain carbon steel having a mostly pearlitic structure 50 by a diffusion zone 45 containing iron and cobalt. The diffusion zone 45 is approximately 3 microns thick.

EXAMPLE NO. 2

A wear-resistant, two inch square by 3/8 inch thick plate was fabricated consisting of 60 w/o of unmilled minus 60 plus 100 mesh macrocrystalline WC cemented by 40 w/o of 0.75 per cent C steel containing 2 w/o Cu. A uniformly dry blended mixture of minus 60 plus 100 mesh macrocrystalline WC crystals, minus 325 mesh graphite powder, minus 100 mesh iron powder, and minus 325 mesh copper powder were dry blended, unmilled, to a uniform mixture, then dampened by blending with liquid naphtha and methyl cellulose equal, respectively, to 7 per cent and 0.5 w/o of the dry mixture, and then packed into a steel preform mold to a firm, green, plate shape of dimensions equal to approximately 102 per cent of the desired final dimension.

Following air drying in the mold at room temperature, the compact was removed from the mold, placed in a rubber bag and further processed by cold isostatic compaction, sintering and HIP as described in Example No. 1. Metallographic examination revealed a macrostructure of macrocrystalline WC evenly dispersed throughout a steel matrix. A 5 micron thick bond layer of unknown composition was observed at WC-steel interfaces.

These interfaces were free of brittle binary carbide phases and cracks.

EXAMPLE NO. 3

A composite 1 1/2 inch cubic wear-resistant body of steel enclosing a dimensioned plate of sintered, cemented 5 w/o cobalt-tungsten carbide was fabricated, purposefully embedding the dimensioned plate of sintered, cemented carbide in the green powder prior to iso-compaction so that its outer surface was flush with the outer surface of the steel cube. A dry unmilled blend comprised of 97.25 w/o minus 100 mesh atomized iron powder, 2 w/o minus 325 Cu powder and 0.75 w/o graphite was made, then blended with naphtha and methyl cellulose equal to, respectively, 5 w/o and 0.3 w/o of the dry blend. This was then packed into an elastomeric mold following which a one inch square by 1/4 inch thick plate of sintered cemented carbide was pressed down into the iron powder mix so that the outer surfaces were congruent.

The mold, after sealing, was placed in a rubber bag, evacuated, sealed and at this point was isostatically compacted, removed from the mold, sintered and hot isostatically compacted as in Example No. 1. Metallographic examination revealed that the prepositioned sintered carbide plate was bonded by a 5 micron interfacial bond phase to the steel matrix surrounding it on three sides and that the entire structure appeared sound and free of cracks.

Figure 2 presents a description of a wear plate 20 manufactured in the manner described in this example, except that three rather one cemented carbide inserts 30 are embedded in the plate 20 such that a surface 45 of each insert 30 is substantially flush with the working end 40 of the tool 20. It will be noted that the interfacial bond 35 is substantially uniform and continuous and forms a tough and adherent bond between the cemented carbide and the consolidated carbon steel and copper matrix 25.

In certain wear applications, depending on the corrosion nature of the environment in which the wear plate will be used, stainless steel or alloy steel powders may be advantageously substituted for the iron, carbon and copper powders utilized in this example.

Figure 3 provides a cross sectional view of another embodiment of a tool according to the present invention. This tool 1 can be manufactured substantially as described in Example 3, except that the cemented carbide insert 5 is allowed to have its working end 2 extend outward and beyond the steel body 10 of tool 1. As shown in this figure, the insert 5 bonded to the steel body 10 by a diffusion zone 15 which was formed by the interdiffusion of cobalt from the insert 5 and iron from the steel body 10 during high temperature and high pressure sintering operations.

Modifications may be made within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A composition of matter comprising: 30 to 80 weight per cent of a carbide material having a size greater than 400 mesh; said carbide material selected from the group of hard carbides consisting of tungsten carbide, titanium carbide, tantalum carbide, niobium carbide, zirconium carbide, vanadium carbide, hafnium carbide, molybdenum carbide, chromium carbide, boron carbide, silicon carbide, their mixtures, their solid solutions, and their cemented composites; 20 to 70 weight per cent of a matrix material selected from the group consisting of steel, steel and iron, steel and copper, and steel and nickel; said carbide material embedded in and bonded to said matrix; and an interface between said carbide material and said matrix no greater than 50 microns in thickness.

2. A composition of matter according to Claim 1 further characterized in that said interface has a thickness of 0 to 40 microns.

3. A composition of matter according to Claim 1 wherein said carbide material is a cemented composite having a cobalt binder; and further characterized in that said interface has iron and cobalt and a thickness of 0 to 40 microns.

4. A composition of matter according to Claim 3 further characterized in that said cemented composite contains tungsten carbide.

5. A composition of matter according to Claim 1 further characterized in that said hard carbide is tungsten carbide.

6. A composition of matter according to Claim 1 further characterized in that said composition is ductile at room temperature.

7. A composition of matter according to Claims 1, 3 or 5 further characterized in that said steel is an alloy steel.

8. A composition of matter according to Claims 1, 3 or 5 further characterized in that said steel is a stainless steel.

9. A composition of matter comprising: 30 to 80 weight per cent of a carbide material having a size greater than 400 mesh and having a metallic coating; said carbide material selected from the group of hard carbides consisting of tungsten carbide, titanium carbide, tantalum carbide, niobium carbide, zirconium carbide, vanadium carbide, hafnium carbide, molybdenum carbide, chromium carbide, boron carbide, silicon carbide, their mixtures, their solid solutions and their cemented composites; 20 to 70 weight per cent of a matrix material selected from the group consisting of steel, steel and iron, steel and copper, and steel and nickel; and said metallic coating forming a tough and adherent bond between said carbide material and said matrix.

10. A composition of matter according to Claim 9 further characterized in that said steel is selected from the group consisting of alloy steels and stainless steels.

11. A method for manufacturing steel hard carbide composite wear resistant bodies comprising: blending 20 to 70 weight per cent of steel forming powders with 30 to 80 weight per cent of hard carbide particles having a particle size between 2.5 and 400 mesh to produce a mixture; cold pressing said mixture to produce a compacted preform; and densifying said compacted preform via a high temperature and high pressure diffusion bonding and sintering process, and said high temperature being below the melting temperature of said steel.

12. A method for manufacturing steel hard carbide composite wear resistant bodies according to Claim 11 further characterized by coating said hard carbide particles with a metallic coating prior to said blending with said steel forming powders.

13. A method for manufacturing steel hard carbide composite wear resistant bodies according to Claims 11 or 12 wherein said densifying of said compacted preform via diffusion bonding characterized by sintering said compacted preform at a temperature above 1900 degrees Fahrenheit and below the solidus temperature of said steel to minimize interconnected porosity in the preform and then hot isostatically pressing said preform at a pressure above 10,000 psi and a temperature between 1600 degrees Fahrenheit and the melting temperature of the steel.

14. A composition of matter comprising: 30 to 80 weight per cent of a carbide material having a size greater than 400 mesh; said carbide material selected from the group of hard carbides consisting of tungsten carbide, titanium carbide, tantalum carbide, niobium carbide, zirconium carbide, vanadium carbide, hafnium carbide, molybdenum carbide, chromium carbide, boron carbide, silicon carbide, their mixtures, their solid solutions and their cemented composites; 20 to 70 weight per cent of a matrix material selected from the group consisting of steel, steel and iron, steel and copper, and steel and nickel; characterized in that said carbide material is embedded in and bonded to said matrix by powder metallurgical techniques of compaction and diffusion bonding below the melting temperature of the steel.

15. A tool comprising: a working end having a hard wear resistant cemented carbide insert; a body having steel; a bond region joining said insert to said body; characterized in that said bond region comprises an alloy having iron and cobalt.

16. A tool comprising: a working end having a hard wear resistant cobalt cemented carbide insert; a body having steel; said insert powder metallurgically bonded to said body by a diffusion zone formed during high temperature sintering below the melting point of said steel; and said diffusion zone having iron and cobalt.

17. A method of forming a cemented carbide tool characterized by embedding a predimensioned cobalt cemented carbide insert in a predetermined location in a blend of steel forming powder; consolidating said powder around said insert to form a preform; and interdiffusing cobalt from said insert with iron from said consolidated steel forming powder adjacent the insert at a high temperature below the melting point of said steel and, simultaneously at a high pressure, to form a metallurgical bond between said insert and said steel.

FIG-1

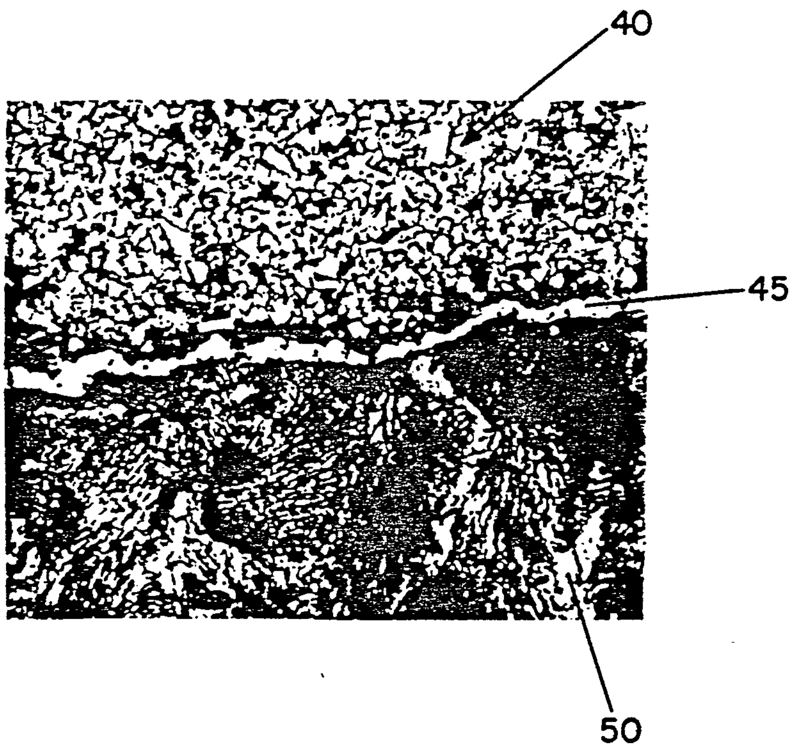


FIG-2

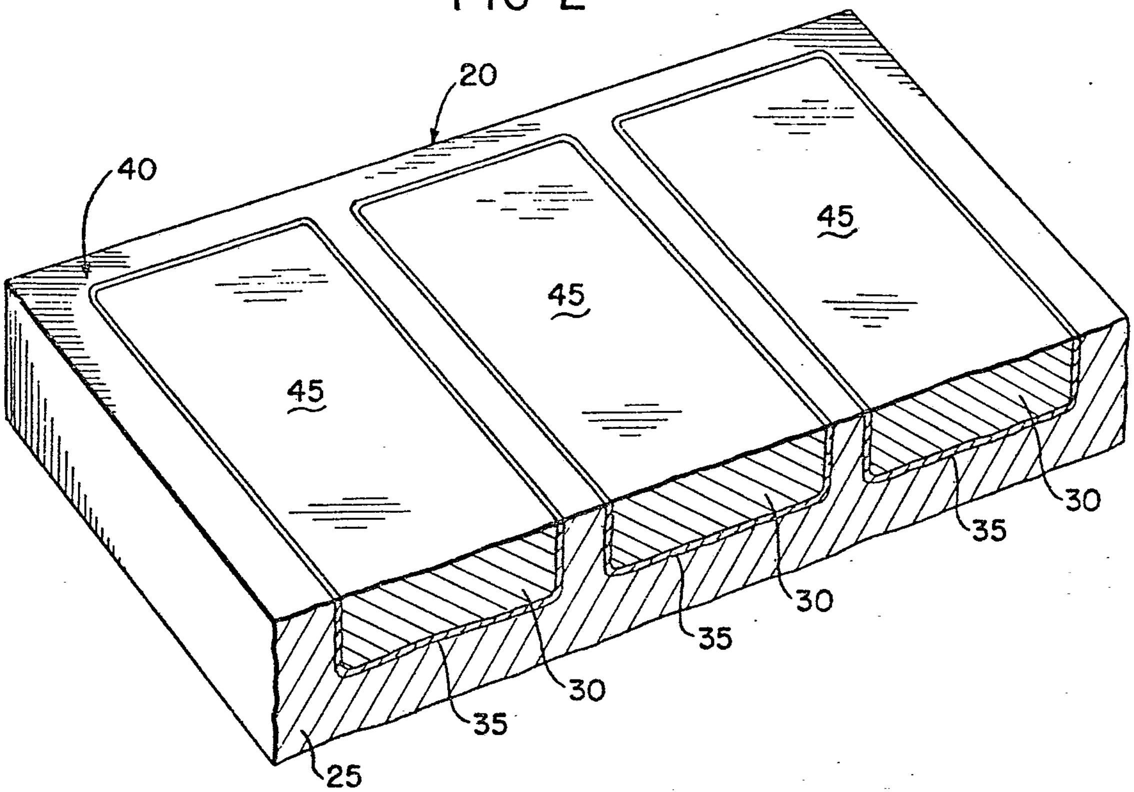
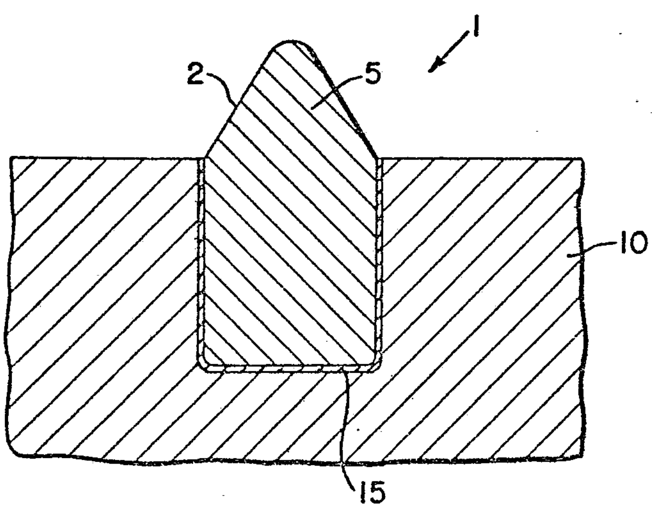


FIG-3



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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 81 10 57.

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int Cl)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	CH - A - 215 453 (F. KRUPP) * Whole document *	1-17	B 22 F 7/06 C 22 C 1/02 29/00 B 23 B 27/14
	GB - A - 530 639 (MEUTSCH, VOIGTLANDER & CO) * Whole document *	1-17	
	GB - A - 2 007 720 (NIPPON TUNGSTEN CO) * Claims 1,2,5,7,9,15; page 1, lines 85-98 *	1-2, 4-12, 14	TECHNICAL FIELDS SEARCHED (Int. Cl)
	DE - A - 2 722 271 (THYSSEN EDELSTAHLWERKE A.G.) * Claims 1,3 * & US - A - 4 198 233	11,13, 14	B 22 F C 22 C
	GB - A - 1 300 864 (ASEA) * Claims 1,6,7; page 2, lines 4-59 *	11,13	
P	DE - A - 2 916 709 (SINTER-METALLWERK KREBSOGE) * Claims 1,4,6 *	11,13	CATEGORY OF CITED DOCUMENTS X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons &: member of the same patent family, corresponding document
⌿	The present search report has been drawn up for all claims		

Place of search	Date of completion of the search	Examiner
The Hague	18-11-1981	SCHRUERS

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