United States Patent Office 3,165,822 Patented Jan. 19, 1965

3,165,822

TUNGSTEN CARBIDE TOOL MANUFACTURE

Robert T. Beeghly, Youngstown, Ohio, assignor to Metal Carbides Corporation, Youngstown, Ohio, a corporation of Ohio

No Drawing. Filed Aug. 7, 1963, Ser. No. 300,683
16 Claims. (Cl. 29—182.7)

This invention relates to improvements in carbide tool manufacture and relates in particular to an improved sintered carbide alloy and to the method of obtaining the same.

In the manufacture of carbide tools, hard metal carbide particles of a refractory metal are blended with particles of one or more binder metals of the iron group of the periodic table. The mixture is compressed and sintered to form an unusually hard body that is particularly suitable for use as the working surfaces of tools. Metal cutting tools are commonly provided with inserts of such carbide bodies at their working faces since such carbide alloys are harder and thus resist wear far better than any of the solid metal compositions. Other similar applications of carbide tipped tools include rock bits, percussion bits and other mining tools commonly subjected to considerable shock and abrasion.

Although any of the hard refractory metal carbides, such as the carbides of tungsten, titanium, tantalum, columbium, molybdenum, vanadium, chromium, zirconium and hafnium may conceivably be employed in the manufacture of such hard carbide bodies, tungsten carbide has been found to be, by far, the most satisfactory and available. Consequently, nearly all such sintered carbide products are presently composed mainly of tungsten carbide. This does not imply, however, that the other carbides are not useful for such purpose, and techniques employed in the manufacture of tungsten carbide bodies are equally applicable to the other refractory carbides.

The commercially available carbide products include tungsten carbide plus binders, and tungsten carbide plus additions of one or more of the other refractory carbides mentioned above and the binder. The most common addition carbides are those of titanium and tantalum with some occasional specialized use made of the carbides of columbium, molybdenum, vanadium, chromium, zirconium and hafnium.

The auxiliary, or binder, metal is usually cobalt, nickel or iron or combinations of such metals. Cobalt is by far the most commonly used.

Blending of various carbides with tungsten carbide has the effect of changing the density properties of the resultant carbide body. For example, additions of TiC or TaC will lower the density.

The binder, of course, is necessary to hold the carbide particles together since in the sintering step, the binder metal fuses the fine particles into a cohesive mass. Generally, those carbide bodies that contain a low binder content exhibit higher hardness properties than similar compositions with higher binder content. On the other hand, however, the high binder content compositions exhibit greater ductility. Vibration and shock ordinarily encountered in the use of any tool requires the presence of minimum ductility properties to avoid fracture due to the brittleness of the carbide body. Consequently, the grade or composition of a carbide selected for a given application is a compromise between employing a composition exhibiting sufficient ductility for the tool while having the maximum obtainable hardness for the necessary minimum binder content.

As an example of the above, in the mining industry there is a demand for carbide inserts for tipping percussion bits that are both harder and which possess higher

rupture strength than any of the compositions presently available. Compositions or grades containing relatively high binder contents, i.e. (88% WC—12% Co) exhibit relatively high transverse rupture properties (345,000 lbs./inch^2) and have hardness properties below Rockwell A90 (88.5). Compositions containing relatively low binder additions (92% WC—8% Co), exhibit Rockwell A hardnesses of 90 and above, but have much lower transverse rupture properties (325,000 lbs./inch^2). There is presently a demand for a material for this application which exhibits a hardness of Rockwell A90 and which possesses transverse rupture properties of 350,000 lbs./sq. inch or greater.

I have discovered a method of blending metal carbide-binder compositions in such a manner that a carbide body is obtained that exhibits significantly improved hardness and ductility properties. By employing my method, the quantity of binder employed for a given carbide grade may be significantly lowered so that the hardness of the sintered carbide body is raised while substantially retaining the ductility properties, or conversely, it may be said that by my method, the hardness of a given composition may be maintained while the ductility is significantly increased.

It is, therefore, the object of the present invention to provide a method for obtaining a sintered carbide body having improved hardness and ductility.

It is also the object of the present invention to provide sintered carbide objects which exhibit improved hardness and ductility properties.

Another object of the present invention is to provide a method for raising the transverse rupture properties of a given cemented carbide composition without disturbing its hardness properties.

It is a further object of the present invention to provide a method for effectively lowering the required binder content of sintered metal carbide objects without disturbing the transverse rupture properties.

It is also a further object of the present invention to provide carbide tools that possess given shock resistance properties with improved wear resistance properties.

A still further object of the present invention is to provide a carbide tool that possesses given hardness properties with improved shock resistance.

Other objects and advantageous features will be obvious from the following description.

Sintered metal carbide bodies are prepared by blending the fine metal carbide powder with the desired quantity of finely divided binder metal. The mixture is then pressed in hard steel or carbide lined steel molds at pressures usually ranging from 5 to 30 tons per square inch depending on the size and shape of the compact.

Sintering is then performed usually at temperatures ranging from 1400° to 1500° centigrade for times of from about 30 to 60 minutes. Sintering is generally performed in a protective or non-oxidizing atmosphere which may contain sufficient carbon to prevent any decarbonization. Sintering may also be performed in the presence of a substantial vacuum.

It is common practice in the carbide industry to pelletize prepared powdered metal mixes of a single composition so that the material flows more readily into the die while being pressed and the weight may be held within closer limits. The individual pellets would not vary in composition since any blending of the various refractory metal carbides and the carbide or carbides, plus the binder metal, would be accomplished in a ball mill or grinder prior to pelletizing. However, if a difference in composition between the carbide and the binder did exist, it would not be expected to have a noticeable effect on the resultant hardness and ductility since it would be expected

that during sintering the metal binder would migrate to even out the overall composition.

I have discovered that contrary to expectations, the blending of pellets of grades of metal carbides containing different binder metal concentrations does not result in a sintered carbide body with the properties of the average carbide-binder composition of the blend, but instead yields a product with a combination of hardness and ductility which is significantly superior to that of such intermediary product. I have found that by blending pellets of a high binder content carbide grade with a low binder content carbide grade an intermediary grade compact may be created which, when sintered, exhibits significantly greater transverse rupture properties and equivalent or higher hardness than where a compact having a composition similar to the average composition of the blended pellets is prepared and sintered in the usual manner.

For example, I have found that two mining grades of tungsten carbide-cobalt sintered products which had rupture strength properties of 300,000 and 325,000 p.s.i. can be blended in accordance with the method of the present invention to yield a transverse rupture strength of approximately 350,000 p.s.i. while exhibiting a Rockwell A hardness of approximately 90. Such results are surprising since a composition intermediary between the two grades would be expected to exhibit transverse properties between 300,000 and 325,000 p.s.i. and carbide bodies of this type possessing transverse rupture properties in excess of 325,000 p.s.i. would not be expected to have a hardness as great as Rockell A 90.

The sintered alloy prepared in accordance with the present invention has a variable grain structure with areas of hard particles being imbedded in and surrounded by larger areas of softer particles while material mixed together in non-pellet form exhibits a relative uniform grain structure. Hence, it is evident that the individual pellets determine their local structure and physical properties and the mechanical properties of the overall sintered compact exhibit the advantageous features of both structures.

As a specific illustration, there is set forth below a table showing the properties of a tungsten carbide-cobalt body prepared in accordance with the method of the present invention. Two tungsten carbide grades containing different binder contents were pelletized, combined, and then compressed and sintered in accordance with the present invention. For comparison, there is shown the chemical analysis and mechanical properties for each of two grades prepared in accordance with conventional practices. Additionally, there is shown the analysis and properties of a grade containing cobalt in amounts substantially equivalent to that of the intermediary product prepared in accordance with the present invention, the former being prepared in accordance with conventional practices.

The intermediary tungsten carbide-cobalt body prepared in accordance with the present invention is identified in the table below as grade C–90–X. This sintered carbide body was prepared by blending together pellets of the grades identified in the table below as C–93 (95.5% WC–4.5% Co) with the grade identified as C–85 (87% WC–13% Co) in the amount of 25%, by weight, C–93 and 75%, by weight, C–85.

The size of each of the original powdered mixtures before pelletizing was a blend of particles 3–4 microns diameter (4000–6000 mesh) and 1–2 microns (10,000–12,000 mesh).

Each powder mixture of tungsten carbide and cobalt powder was ball milled to obtain a uniform homogeneous mixture.

Each powder mixture (C–93 and C–85) was then pressed into pellets of approximately .0282" diameter #25 mesh U.S.A. standard).

The pellets were then blended (25% C–93 and 75% C–85) pressed and sintered and the resultant sintered body was tested, the results of which are shown below:

Grade	Composition		Density, gms./cm.^{3}	Hardness RA	Transverse Rupture, lb./sq."	Grain Size, Microns
	WC	Co				
C–90–X	90	10	14.45	89.5	370,000	3–4, 1–2
C–93	95.5	4.5	15.15	92.5	240,000	1–2, 3
C–85	87.0	13.0	14.25	88.4	315,000	3–4
C–88	90	10	14.5	89.5	295,000	3–4

It may be readily observed from the above data that the grade C–90–X prepared in accordance with the present method exhibits ductility in the form of Transverse Rupture properties that far exceed that of either of the grades of which it is a mixture. However, the hardness of this material exceeds that of grade C–85. Additionally, the Grade C–90–X possesses equivalent hardness to grade C–88 which has a substantially identical average analysis (90% WC–10% Co) but also exhibits far superior Transverse Rupture properties to this grade.

Such results as demonstrated above are surprising since the Transverse Rupture properties of grade C–90–X would be expected to fall somewhere between those of grades C–93 and C–85 so as to correlate with the increased hardness (over grade C–85) in the usual inverse manner.

It may be observed from the last column of the above table that the C–90–X grade exhibits a duplex grain structure (3–4 and 1–2) while, although the conventionally processed materials show varying grain sizes (1, 2 and 3 and 3–4), they do not exhibit the duplex structure indicative of the improved properties attained.

Additionally, quantities of the grade C–90–X have been experimentally applied to the work faces of percussion bits in the mining industry and have been found to perform in a superior manner to the conventionally manufactured materials.

The significance of the data set forth above will be appreciated since it is apparent that any of the known grades of metal carbide-binder compositions may be produced in the manner of the present invention by selecting or creating powders of higher and lower binder content so that when blended will effect the desired grade composition. The individual higher and lower binder content powders are then pelletized prior to blending, compression and sintering. In this manner for any given hardness, the ductility may be significantly increased and, accordingly, grades and compositions, which previously could not be employed in a given application due to a lack of shock resistance, may now be so applied since their ductility for a given hardness may be increased.

Also, it will be appreciated that the binder content of sintered metal carbide tools may be lowered for any given application by employing the method of the present invention so that my process makes it possible to use a cobalt binder or other auxiliary metal in the order of from 2% to 4%, which percentage is lower than generally regarded as practical for applications where shock conditions are encountered. Such compositions are too brittle for commercial applications such as percussion tools, mining tools and other applications where the tools are subjected to shock. The lowered binder metal content is, of course, made possible by the increased ductility so that greater hardness and greater wear resistance of a cemented carbide tool is obtained.

The present method is applicable to cemented carbides of all known binder contents so that the invention encompasses compositions containing from 2% to 25%, by weight, of a binder, preferably a metal from the iron group such as cobalt.

The exact metal carbide employed is not a significant factor in the utilization of the present method so that

any of the refractory metal carbides useable in the manufacture of cemented carbide products, such as WC, TiC, TaC, CbC, CrC, ZrC, VC, Mo_2C and HfC may be employed in the blending of pelletized particles to obtain an intermediary product with improved ductility and hardness properties.

It is obvious that any such blend of two grades prepared in the manner of the present invention will result in an improved intermediary grade, however, we prefer to employ a minimum of at least 10% of one grade and a maximum of 90% by weight, of the other when blending the appropriate pelletized products.

The size carbide particles employed are preferably those sizes ordinarily employed in the manufacture of cemented carbide products, such sizes generally ranging from about ½ to 20 microns in diameter.

In a similar manner it will be appreciated that any sized pellets formed, however large or small, will have some effect on enhancing the resultant properties of the intermediary product, however, practical considerations render an average pellet size of from 10 (.078" mesh) to 100 (.005" mesh) U.S.A. Standard mesh preferable. Pelletizing is well known in the handling and treating of powdered materials. A variety of apparatus is commercially available to compress metal and non-metal powders into pellets. In the utilization of the method of the present invention, the method and apparatus employed to pelletize the metal carbide-binder powders is not of material significance. If the powders are appropiately compressed into a reasonably cohesive mass they may be appropriately blended and utilized in accordance with the present method.

I have had particular success by preparing pelletized powder in lots of 25,000 or 50,000 grams. The size of lots prepared is, of course, dependent on the capacity of equipment used. The usual starting size of the powdered metal mixtures ranges from 1 to 5 micron sizes. The various operational steps are as follows:

(1) Paraffin in an amount of about 1¼%, by weight, is added to the prepared powder mixture and thoroughly mixed together. We have found a "Stokes Blender" manufactured by F. J. Stokes Corporation of Philadelphia, Pennsylvania, to be a satisfactory commercially available apparatus for this step. The blending operation takes 5 to 6 hours and is carried out at a temperature of about 160° F.

(2) Approximately 3% methanol is next added to the powdered metal-paraffin mixture in a blender. A V-cone blender such as a "Patterson-Kelley Blender" manufactured by the Patterson-Kelley Company of East Stroudsburg, Pennsylvania, or a "Dravo Revolving Disc" such as manufactured by the Dravo Company of Pittsburgh, Pennsylvania, are satisfactory equipment for this mixing.

(3) The mixture is then compressed into pellets. The time cycle required to pelletize the powder is approximately 2 minutes. Pellets having an average size of 25 mesh or .028" are most frequently produced.

(4) The pellets are then dried in an oven utilizing electric heating elements at temperatures of 150° F. for a period ranging from 50 to 64 hours.

(5) The dried pellets are then screened. A satisfactory screening unit is a "3 Screen Sweco Screening Unit" manufactured by the Southwest Engineering Company of Los Angeles, California. This step separates 60% to 70% of the load into pellets ranging in size from .009" (60 mesh) up to .028" (25 mesh). The majority of pellets are on the coarser size ranging from .020" to .028". The oversize or coarser pellets, those measuring .029" and larger, are separated by screening as well as the undersize or finer pellets measuring .009". The undersize and oversize pellets are subsequently re-processed through the V-cone blender and made into pellets.

(6) The weight of the pellets per square inch varies depending on the composition and the amount of binder metal.

It will be understood that the method of the present invention is applicable to the production of cemented or sintered metal carbides whether such carbides are sintered after compacting or during the compacting step.

In combining pelletized mixtures in accordance with the present invention, it will be appreciated that more than two pelletized combinations may be employed to acquire a single intermediate product. It may well be expedient to combine three or more carbide mixtures each of differing cobalt or binder content to acquire a single desired intermediary.

It is, of course, acknowledged that where the materials of the present invention are said to be compacted and sintered, such terms are meant to include multiple sintering or compacting and sintering treatments where such are employed.

I claim:

1. In the method of making a cemented hard metal carbide wherein a mixture of powdered hard metal carbides and a binder metal are compacted and sintered, the improvement comprising separately pelletizing at least two mixtures of metal carbide powder and binder metal, said binder metals differing in concentration and admixing said pellets prior to compacting and sintering.

2. The improvement as set forth in claim 1 wherein the carbides are refractory metal carbides.

3. The improvement as set forth in claim 1 wherein the binder metals are metals of the iron group.

4. The improvement as set forth in claim 1 wherein the carbides consist of at least one refractory metal carbide selected from the group tungsten carbide, titanium carbide, tantalum carbide, columbium carbide, molybdenum carbide and chromium carbide.

5. The improvement as set forth in claim 3 wherein the binder metal in each of said at least two mixtures is present within the range of from 2% to 25%, by weight.

6. The improvement as set forth in claim 2 wherein the said mixture of pellets contains pellets of each said at least two mixtures within the range of from 10% to 90%, by weight.

7. The method of making a cemented refractory metal carbide body of a preselected binder content comprising admixing a first pelletized mixture of refractory metal carbides and binder, said binder of said first pelletized mixture being present at a concentration that is less than said preselected binder content, with a second pelletized mixture of refractory metal carbides and binder, said binder of said second pelletized mixture being present at a concentration that is greater than said preselected binder content, so that said admixed pelletized mixtures have an average binder content equivalent to said preselected binder content and compressing and sintering said admixed pelletized mixtures.

8. The method as set forth in claim 7 wherein the carbides are at least one refractory metal carbide selected from the group consisting of WC, TiC, TaC, CbC, VC, MoC, ZrC and Cr_2C_3.

9. The method as set forth in claim 8 wherein the binder metal is at least one iron group metal selected from the group cobalt, nickel and iron.

10. The method as set forth in claim 9 wherein the binder metal of each said mixture is present within the range of from 2% to 25%, by weight.

11. The method as set forth in claim 10 wherein said mixture of pellets contains pellets of each said at least two mixtures within the range of from 10% to 90%, by weight.

12. The method of making a cemented refractory metal carbide body having an analysis of approximately 90% tungsten carbide and 10% cobalt comprising:

(*a*) pelletizing a powdered mixture of approximately 87%, by weight, tungsten carbide, and 13%, by weight, cobalt;

(*b*) pelletizing a powdered mixture of approximately 95.5%, by weight, tungsten carbide and 4.5%, by weight, cobalt;

(*c*) mixing the pellets of (*a*) and (*b*) in the proportion of 75%, by weight, mixture (*a*) and 25%, by weight, mixture (*b*), and

(*d*) compacting and sintering said mixture (*c*).

13. A sintered hard metal carbide compact having a variable structure with hard areas being embedded in and surrounded by softer areas, said areas consisting of carbides bonded by a binder metal, said softer areas having a higher binder metal content than said hard areas, said compact being characterized by high hardness and transverse rupture properties.

14. A sintered compact according to claim 13 wherein the hard metal carbide is at least one carbide selected from the group consisting of WC, TiC, TaC, CbC, VC, MoC, ZrC and Cr_2C_3.

15. A sintered compact according to claim 14 wherein the binder is at least one iron group metal selected from the group cobalt, iron and nickel.

16. A sintered compact according to claim 15 wherein the compact is characterized by transverse rupture properties of at least 350,000 lbs./sq. inch.

References Cited in the file of this patent

UNITED STATES PATENTS

2,049,317	Pinta	July 28, 1936
2,553,714	Lucas	May 22, 1951
2,607,676	Kurtz	Aug. 19, 1952