

June 28, 1960

W. W. WELLBORN
CARBIDE METAL

2,942,335

Original Filed Feb. 3, 1955

2 Sheets-Sheet 1

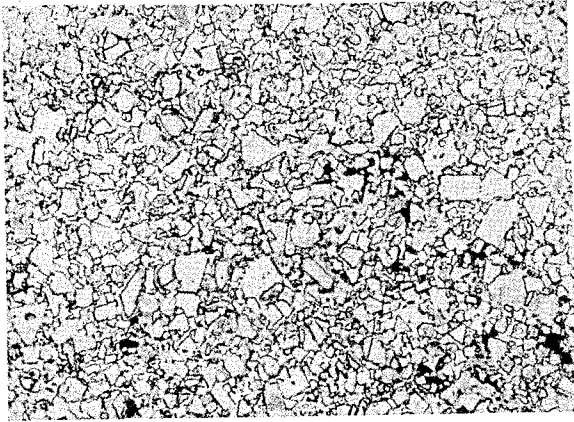


FIG. 1.

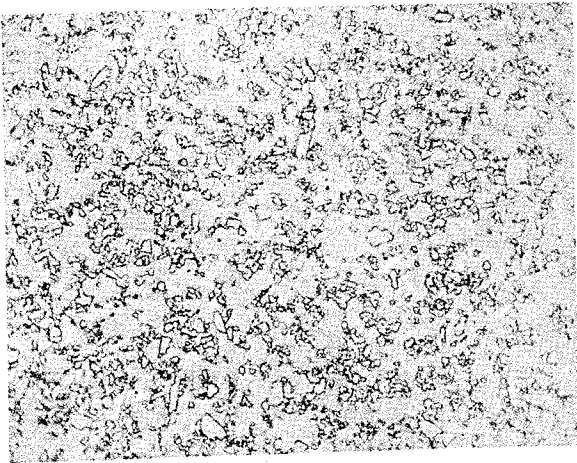


FIG. 2.

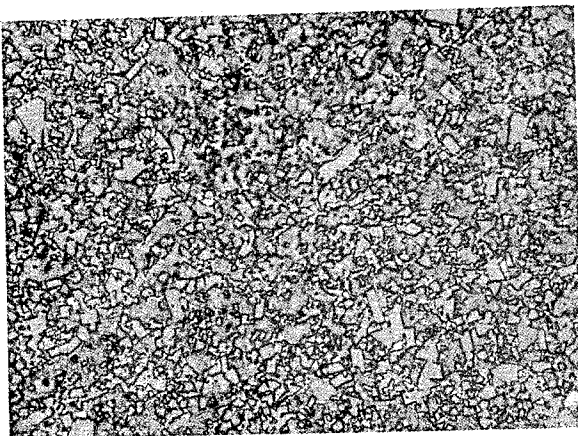


FIG. 3.

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2 Sheets-Sheet 2

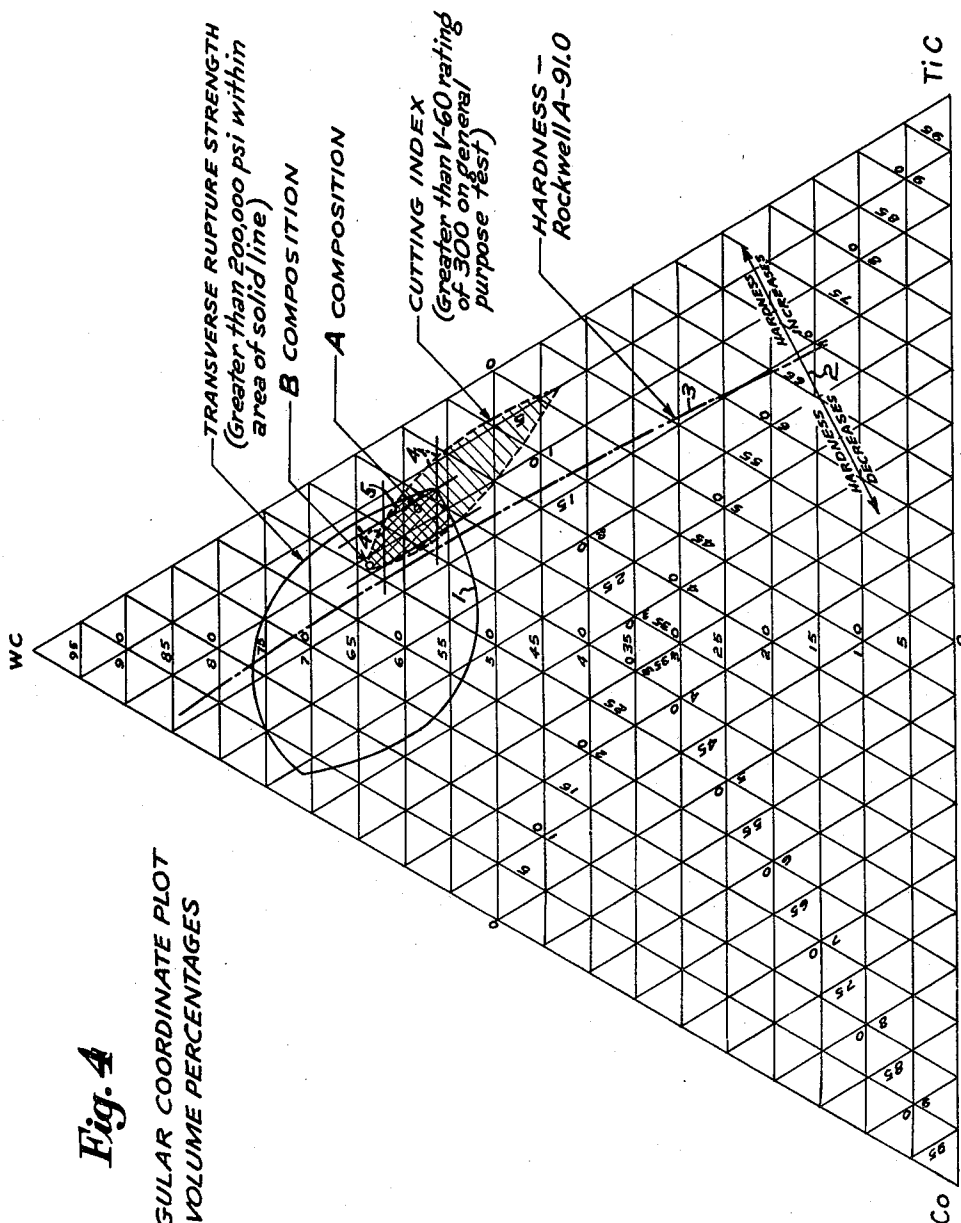


Fig. 4

TRIANGULAR COORDINATE PLOT
BY VOLUME PERCENTAGES

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2,942,335

CARBIDE METAL

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Original application Feb. 3, 1955, Ser. No. 485,876.
Divided and this application June 23, 1959, Ser. No. 822,354

10 Claims. (Cl. 29—182.7)

This invention relates to an improved hard cemented carbide composition or product and to procedure for making such a product. It deals particularly with a compacted and sintered titanium carbide, tungsten carbide and cobalt composition that has general purpose characteristics.

Previous to my present invention, various types of metal carbides have been employed in making sintered compositions and employing various types of binders including iron, nickel and cobalt. In the prior art, it has been conventional practice to intimately mix various compositions of carbide and binder powders, compact them and then sinter to form suitable hard metal alloys. Various combinations of metal carbides and binders have been employed in endeavoring to obtain a better carbide product.

In the field of tool cutting elements, there has been a long-standing need for a so-called general purpose type of carbide composition or alloy product. Those products or compositions produced in the art before my invention, however, have only approached a so-called general purpose type, since it has been determined that certain desired properties could only be obtained by compromising other desired properties. That is, a better type of property or analogous group of properties could only be obtained by sacrificing or lowering another property or non-analogous group of properties.

More specifically, I have determined that there are three properties in combination which are needed to produce a good general purpose product, namely, transverse rupture strength, hardness and cutting index. Heretofore, the first could be obtained in the neighborhood of 190,000 p.s.i., but with a lowering of hardness (Rockwell A) to below 91 and of cutting index (V-60) to below 225. On the other hand, a hardness of above 91 with a cutting index of 225 could be obtained, but with a lowering of transverse rupture strength to below 190,000 p.s.i.

There has thus been a critical need for a new and improved cemented carbide composition which will make possible a relatively high combination of strength, hardness and cutting index properties.

In studying the problem presented, I determined that it was necessary to provide sufficient carbon to avoid an eta (carbon deficient) type of carbide. Also, grain size should be decreased and its growth limited and properly controlled. At the same time, it is necessary that carbide introduced at a later procedural stage with the binder be converted into a limited or minimum volume phase to assure a porous-free compact.

Limiting time and temperature of the sintering operation will avoid decomposition of impurities and thus, an increase in porosity of the product or composition. Limiting time and temperature will also avoid excessive grain growth. I discovered that it is highly important to provide a proper type of action of one of the initially employed carbides, within which the other carbide will dissolve, from the standpoint of avoiding excessive grain

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growth and porosity and of limiting temperature and time required in processing. In analyzing the problem, I found that the particular type and utilization of carbides and binder and their volume contents are highly important.

In a mix employing compositions of tungsten carbide powder and cobalt powder which are compacted and sintered, it is well known that hardness will be decreased in substantially direct proportion to an increase in cobalt and that strength will be also increased up to about 16% or 25% cobalt (depending upon tungsten carbide grain size), after which it will tend to fall off. However, in the final sintering operation, a low amount of cobalt tends to produce a non-uniform but relatively small amount of grain growth. On the other hand, a higher content tends to produce a uniform growth but with a relatively coarse structure. Ordinarily, an increase in grain size produces an increase of transverse rupture strength, toughness, and resistance to shock but with a decrease of resistance to wear. With a decrease of grain size, the opposite effect is ordinarily produced.

For steel cutting utilizations, it has become common practice to use a composition containing titanium carbide (TiC) in making the cutting tools. The relatively hard titanium carbide particles have been found to have a greater resistance to wear and to cratering and, in general, tend to improve tool life. It was determined that the use of a mixed crystal of tungsten carbide (WC) and titanium carbide (TiC) produces a better product than one in which the composition is made up of individual components of titanium carbide, tungsten carbide, and cobalt. In the second part of procedure employing a mixed crystal with other ingredients such as tungsten carbide and cobalt, relatively long sintering times have been required to fully sinter and densify the ingredients and, at relatively high temperatures, with a resultant increase in grain growth of individual tungsten carbide grains as well as of solution areas.

After considerable work in this particular connection in endeavoring to find a true general purpose type of carbide composition, I discovered that it could be accomplished by a controlled use of titanium and tungsten carbides with a cobalt binder and that from the standpoint of the processing, by the preliminary making and the later employment of a so-called solid solution type of mixed crystal. I discovered and developed highly important criteria, both from the standpoint of a new and improved composition product to be produced as well as from the standpoint of procedure for providing such a product or composition.

It has thus been an object of my invention to solve the problem involved in producing an improved carbide composition or product which will have genuine general purpose attributes;

Another object of my invention has been to produce a sintered carbide product or composition having a new and improved relationship of properties and in combination and such that one desirable property does not have to be obtained at the sacrifice of another desirable property;

A further object of my invention has been to devise procedure in accordance with which an improved sintered or cemented carbide metal composition or product may be obtained;

A further object has been to obtain an improved metallographic relationship or pattern in a sintered carbide product;

And a still further object has been to provide a volume balanced carbide composition.

These and many other objects will appear to those skilled in the art from the drawings and the description of the invention.

In the drawings, Figure 1 is a micrograph showing

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structure under 1500 magnification of a composition, alloy or product made from an unsaturated solid solution of TiC and WC and sintered as a mixed crystal with cobalt and tungsten carbide;

Figure 2 is a micrograph showing structure under 1500 magnification of an exemplary composition, alloy or product of my invention and produced in accordance with my invention and thus, essentially employing a saturated and as an optimum, a super-saturated solid solution of titanium and tungsten carbides as a mixed crystal and as comminuted, admixed and sintered with tungsten carbide and cobalt;

Figure 3 is a micrograph showing structure under 1500 magnification of another exemplary composition, alloy or product of my invention and produced in accordance with my invention; it will be noted that Figure 2 relates to alloy A of Figure 4 and that Figure 3 relates to alloy B of the same figure;

Figure 4 is a triangular co-ordinate plot or graph by total volume percentages of tungsten and titanium carbides with cobalt that are employed in accordance with my invention and within the critical contents required for such invention.

The area defined by enclosed solid line or envelope 1 of Figure 4 represents an alloy composition content such that the product has a transverse rupture strength of greater than 200,000 p.s.i. Solid line 2, by its arrows, indicates the effect of cobalt, and dot and dash line 3 indicates the content of cobalt required to produce a Rockwell A hardness of 91. Dotted line 4 defines, encloses or envelopes an area (shown with cross lines) within which a cutting index of greater than a 300 (V-60) rating on a general purpose test is attained. The shaded (cross hatched) area defined by dotted line portion 4' within overlapping portions of curves 1 and 4 represents an area of volume content of my invention, wherein the three properties represented by curves or lines 1, 3 and 4 are obtained, as a minimum, and in combination. Points A and B indicate representative alloys of my invention which are hereinafter discussed in some detail. The area defined by the solid lines of the parallelogram 5 lies fully within the area of 4' and thus, is an easily defined area within which the properties of my invention are attained. By way of example, the parallelogram 5 represents an area containing about 56.5% to 62.0% WC, about 26.5% to 36.0% TiC and about 7.5% to 11.5% Co by volume, whereas the cross-hatched area 4' of Figure 4 represents a content of about 54.5 to 63.7% of WC, 25.5 to 36.0% of TiC, and 6.3 to 12.0% of Co, by volume.

It should be noted that the two compositions illustrated in Figures 1 and 2 were produced by employing the same crushed sizes of ingredients in both cases and involving the same total volumes of WC, TiC and Co.

In determining the composition of my solid metal carbide alloy, I recognized that a cobalt binder normally clings closely when fused to tungsten carbide, but has less affinity for titanium carbide. It has thus been customary to use nickel as a binder for a titanium carbide composition, product or tool.

Another factor which had to be considered is that the strength of a solid metal carbide ordinarily depends on its type of boundary, since the latter is considered stronger than the individual crystals. Thus, it is ordinarily easier to break a coarse grain structure because the proportioning of boundary to crystal is less. However, tungsten carbide, itself, has a peculiar characteristic in that the boundary is first broken before the crystal structure is pulled apart.

Taking the above and other factors into consideration, I have been able to produce a composition employing both titanium and tungsten carbides and of such a type that the boundaries are strengthened and depend essentially on the use of cobalt. The composition or product

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is such that the overall content of tungsten carbide is always greater on a volume basis than that of the titanium carbide, the titanium carbide is only employed as a fully tungsten-carbide-saturated mixed crystal with the binder metal, and addition tungsten carbide is employed with the mixed crystal and the binder metal. When this holds true, among other things, the titanium carbide is unable to have any adverse effect on the clinging action of the binding metal and, in fact, I have determined that cobalt is the best suited binder metal for my composition. In addition, there appears to be a double strengthening type of action in the composition such that resistance to break is increased, both in the boundaries as well as in the crystal structure and to such extent that the ratio or proportioning between the two approaches unity. That is, the solid solution or crystal has substantially the same strength or resistance to break as the grain boundaries. In addition, grain growth or granulation of the crystal structure is limited during the processing of the composition and is prevented once the composition has been produced and shaped in solid form for and used as a cutting element.

After having determined that desired results could be obtained employing titanium and tungsten carbides with cobalt as a binder, I discovered that it is essential in producing the new and improved product to preliminarily prepare and to then employ a mixed crystal of the two carbides, essentially in which the titanium carbide is at least fully saturated by dissolved tungsten carbide. There is a limitation that the titanium carbide of the preliminarily formed mixed crystal or solid solution is in amount by volume that, as a maximum, is not over 57% of such crystal. Also, it is essential that the mixed crystal be used as a major ingredient of the carbide composition or product, in the sense that its volume content predominates over that of the WC and Co (the other additions of the second or final part of the procedure).

It is necessary to provide a mixed crystal that is at least a fully saturated solution of tungsten carbide in titanium carbide, as produced by comminuting or powdering, admixing, pressing and shaping, and sintering the elements or ingredients involved and at a temperature and for a period sufficient to assure the attainment of a fully saturated solid solution. This was determined to be necessary to limit the sintering time of the second operation, the temperature required for such operation, and grain growth, and to control and produce a better resultant grain structure and a desired metallographic pattern.

If the mixed crystal used is not fully saturated, it adversely affects the later added ingredients and the required structure cannot be obtained. From a processing standpoint, the heating time usually required in the second sintering operation is about 60 to 90 minutes and at a temperature of about 2725 degrees F., as compared to about 30 to 45 minutes (half the time) and at a temperature of 2700 degrees F. (25 degrees lower), when a saturated crystal is used in accordance with my invention. A relatively short sintering time and low sintering temperature is required to obtain a full densifying of the composition compact of my invention.

In this particular art where there are three components, such as WC, TiC, and Co, and with the cobalt content being held substantially constant in volume with respect to the content of the carbides, it would be expected by those skilled in the art that hardness and brittleness would increase and strength would decrease with an increasing content of titanium carbide. I have found that this is not true employing my invention, in that there is a definite critical composition area in which hardness, strength and cutting ability of carbide alloys are all greatly improved, see the cross-hatched area defined by the curve line 4' of Figure 4 of the drawings.

Those skilled in the art would expect that transverse

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rupture strength would drop as the titanium carbide content is increased. But, employing my invention, strength is actually greater in the area defined by curve 4' than in a straight tungsten carbide, cobalt grade composition and, contrary to common belief.

In producing the composition or product of my invention, I first prepare an essentially saturated or, as an optimum, a super-saturated mixed crystal of titanium and tungsten carbides. This solid crystal is crushed and ground to a powder (comminuted), then admixed and blended with comminuted tungsten carbide and cobalt. The mixed powder is then compacted (shaped) and sintered. More particularly, by way of example:

(a) take about 55% by volume of TiC and about 45% by volume of WC, with a permissible variation of up to a maximum of 57% by volume of TiC. Intimately admix the ingredients in powdered form, heat to a temperature of about 3800 degrees F. (or to a higher temperature which is the proper solution temperature where less volume TiC is used and more WC is to be dissolved) in a noncontaminating ambient atmosphere and hold for about one hour; thereafter cool to provide the mixed crystal as a saturated or super-saturated solids solution of WC in TiC. As an alternate, TiO_2 , carbon and tungsten in powdered form are used and the solution forming operation is conducted as before, but preferably in a carbon tube furnace. It appears that a higher combined carbon content is made possible by this method and that purity is better than by using TiC and WC directly;

(b) crush and grind the mixed crystal to form a powder;

(c) mix, blend and grind the mixed crystal of about 60.3% by volume with about 31.4% by volume of WC and about 8.3% by volume of cobalt;

(d) compact the mixed powder at a suitable pressure of about 10 to 15 tons per square inch;

(e) sinter at about 2700 degrees F. within a noncontaminating ambient atmosphere for about 30 to 45 minutes, or for an optimum of 30 minutes employing a hydrogen atmosphere. Vacuum sintering may also be used.

I have found that a practical approach that works well is to produce with a permissible variation of $\pm 2\%$ of the TiC, the WC and the mixed crystal of steps (a) and (c).

If a composition of the same final or overall total content of tungsten carbide, titanium carbide and cobalt were to be produced by old methods and employing a 50 to 50% by weight mixed crystal, I would start with about 79% by volume of TiC and 21% by volume of WC and heat to 3800 degrees F. for one hour, followed by cooling, as in step (a). The mixed crystal would be crushed and ground as before, see (b). The crystal in an amount of about 42.3% by volume would then be mixed, blended and ground with about 49.4% by volume of tungsten carbide and about 8.3% by volume of cobalt. Compact as in (d). Then sinter in hydrogen or a vacuum at about 2725 degrees F. for 60 to 90 minutes, with an optimum of 60 minutes.

From the above, it will be apparent that the temperatures and period of application of temperatures required for the last step employing the old method is much greater than in my process. The basic structure and nature of the composition produced, see the micrograph of Figure 1, is entirely at variance with that of a composition produced in accordance with or having the controlled content of my inventive disclosure, see the micrograph of Figure 2.

My procedure is conducted in such a manner as to provide an area of composition wherein a superior grade of carbide product suitable for general purpose steel cutting and milling is obtained. The compositions are better grades than those outside the area by reason of

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their content alone, but as produced following the procedure of my invention, in which an essentially saturated or super-saturated mixed crystal is employed, the results are far superior. I have also determined that a proper employment of a cobalt binder is important in obtaining the results of my invention.

It appears from my work that a tantalum carbide may be substituted for titanium carbide in the mixed crystal up to about 50% by volume to also obtain a composition or product having improved properties over the prior art.

To further exemplify from the standpoint of the product produced, I have taken two representative alloys or compositions A and B (see the micrographs of Figures 2 and 3) that are located within the limitations of the area 4' of Figure 4. In this connection, Table I shows the specific composition and properties of alloy A.

TABLE I

(Alloy A)

Content for first part of procedure	Content for second part of procedure	Resultant overall content
TiC, 55% by vol....	Mixed crystal, 60.3% by vol.	TiC, 33.3% by vol.
WC, 45% by vol....	WC, 31.4% by vol.....	WC, 58.4% by vol.
	Co, 8.3% by vol.....	Co, 8.3% by vol.

In producing alloy B, the same mixed crystal content as shown in column one of Table I is employed. However, the volume content for the second step and the overall resultant content of the ingredients in the product differs. For this reason, the latter two have been tabulated in Table II.

TABLE II

(Alloy B)

Content for second part of procedure	Resultant overall content
Mixed crystal, 46.3% by vol....	TiC, 25.5% by vol.
WC, 42.9% by vol.....	WC, 63.7% by vol.
Co, 10.8% by vol.....	Co, 10.8% by vol.

Although both alloys A and B have the superior properties of my new composition, it will be noted that alloy B has less titanium carbide than A and is thus tougher and softer than A. It also has a slightly less cutting ability than A. However, both are tougher and harder than any heretofore known carbide. Table III shows the comparative properties of these two compositions. The cutting index represents surface feet per minute for a tool life of sixty minutes before regrind, based on a general purpose test, employing a depth of cut of 0.125 of an inch, with a feed of 0.020 of an inch on an AISI steel test log having a B.H.N. hardness of 285. An article entitled "Carbide Tool Evaluation" by H. O. War-nock, in the February, 1954 issue of the "Tooling and Production" magazine, discusses such a type of test.

TABLE III

	Alloy A	Alloy B
Strength (transverse rupture).....	210,000 p.s.i.....	240,000 p.s.i.
Hardness.....	92½ Rockwell A.....	91½ Rockwell A.
Cutting index.....	349 for V-60.....	300 for V-60.

Alloys produced in accordance with my invention have a hard dense structure and when employed as a cutting tool or element, show an increase in operating life to about 1,000 hours (from about 200 hours). It will also be noted that the grain size in the composition averages about 0.61 to 0.94 micron, as compared to the normal average grain size of tungsten carbide of 0.7 to 2.0 microns. Also of interest is the relationship of densities of

the three principal ingredients employed in making the composition. In this connection, TiC has a grams per cubic centimeter density of 4.25, WC of 15.7 and Co of 8.9. In arriving at my invention, weight percentages give no definite idea of the amount of material effecting an action and this is the reason why I employ a volume basis and to assure a volume balance in the composition.

Figures 1 and 2 are micrographs of two alloys having the same ultimate content or composition, namely, about 58.4% WC, 33.3% TiC, and 8.3% of Co, all by volume. The composition of Figure 1 is based on the use of an unsaturated mixed crystal of 42.3% by volume as employed with tungsten carbide of 49.4% by volume and cobalt of 8.3% by volume in the second part of the procedure (the final sintering operation).

On the other hand, in the second part employed in producing the composition of Figure 2, a fully saturated mixed crystal constitutes about 60.3% by volume, the tungsten carbide 31.4% by volume, and the cobalt 8.3% by volume.

This mixed crystal employed in the second part in producing the composition of Figure 1 is not saturated. Thus, during sintering, there is a tendency for the titanium carbide to continue towards saturation and this tendency is strong enough to cause excessive grain growth which is further enhanced by the longer sintering time and higher temperature that is required.

The composition of Figure 2 is characterized by its volume balanced relationship, finer grain structure, increased hardness and surprisingly, by its increased strength and toughness, all in combination. The micrograph shows a matrix of TiC-WC solid solution (essentially fully saturated) and uniformly dispersed finer than usual WC grains. In this connection, a slight excess of WC is employed to assure full saturation of the mixed crystal, as produced in accordance with the first part of my procedure. Normally in sintering, as occurs in connection with the second part of the procedure used in providing the composition of Figure 1, there is an absorption of WC into the structure while in the composition of Figure 2, there is an equilibrium of structure as to the mixed crystal, itself, and between the mixed crystal and the additional tungsten carbide and the cobalt.

A uniform, finer and homogeneous structure with more interrupted or jagged break lines defining a more tortuous path is also shown in the structure of Figure 2. There is no evidence of unreacted titanium carbide, as such, and the cobalt content is primarily in grain boundaries, is spread more thinly and is not in the solution of the crystal. There is a larger solution area (the snow area of Figure 2) of matrix and with more widely dispersed tungsten carbide grains and essentially, of a finer structure. It is a precipitation-interrupted structure and is basically different and improved in its characteristics from prior art compositions and from one employing an unsaturated mixed crystal or one having an unsaturated final composition (see Figure 1) and even when, as in the case of Figure 1, the same total ingredient content exists in both compositions.

The product of my invention represents a new concept in carbide metallurgy, since it gives increased hardness with increased strength to thus provide a greater wear resistance combined with increased shock resistance, as in milling applications. When used as a cutting tool, it provides an increased amount of metal removed in mass production operations to materially reduce unit costs through its uniform performance. In tests against ten competitive grades, it has proved superior in all cases, showing from 20 to 55% less wear at 5 cuts and 23% less wear at 20 cuts. Six of the ten grades were worn beyond repair before the test was completed.

Such tests were conducted under severe breakdown conditions on a 10 inch milling machine, using a 6 inch R.H. cutter with one tooth of 1 inch square having a $\frac{1}{32}$ of an inch corner radius. The material used for the work

piece was a S.A.E. 1020, normalized, forged steel bar that was climb milled at 1375 s.f.p.m. with 4% inch feed per minute, resulting in about .0053 of an inch chip load. The depth of the cut was .050 of an inch and the overhang of the work was 3 inches.

Summarized briefly, I have produced a sintered or hard metal cemented carbide composition that has a precipitation-interrupted micro-structure consisting of fine-grain precipitated tungsten carbide grains or particles, some retained coarser medium-grain tungsten carbide grains or particles and all, as uniformly and widely dispersed in a matrix of a saturated tungsten carbide-titanium carbide solid solution. The composition is bound together between its grains or crystals with a thin layer of an evenly distributed cobalt binder; it has a volume-balanced composition and essentially, of the ingredients making up its crystal structure.

My invention is made possible by the production of a volume-balanced composition whose total content falls within the area enclosed by the line 4' of Figure 4 of the drawings. It utilizes a saturated or super-saturated mixed crystal in which the titanium carbide is in an amount of not over 57% by volume of such crystal; it has a new and improved combination of strength, hardness and cutting index properties; and, it has a new and improved microstructure and strength relationship between its carbide crystals and its cobalt binder. This application is a division of application S.N. 485,876, filed February 3, 1955.

What I claim is:

1. A sintered carbide alloy hard metal characterized by its superior combination of transverse rupture strength, hardness and cutting index and by its improved micro-structure and which contains tungsten carbide and titanium carbide in solid solution, and tungsten carbide and cobalt dispersed with the solid solution as auxiliary ingredients, all employed in finely comminuted particle form, characterized in that the titanium carbide is employed in a supersaturated condition with and in volume predominance over the tungsten carbide of the solid solution, that the solid solution is employed in volume predominance over the auxiliary ingredients, and that the total tungsten carbide volume content is in predominance over the other individual ingredients of the metal; further characterized in that the solid solution contains about 55% titanium carbide and about 45% tungsten carbide, by volume $\pm 2\%$ of each, and the total content of the ingredients of the metal being within a range by volume of about 54.5 to 63.7% tungsten carbide, about 25.5 to 36.0% titanium carbide and about 6.3 to 12.0% cobalt.

2. A hard metal alloy as defined in claim 1, further characterized in that tantalum carbide is substituted for titanium carbide in the solid solution up to about 50% by volume of the titanium carbide, and the total volume content of the tantalum and titanium carbides is maintained within the volume range of about 25.5 to 36.0% for the titanium carbide of claim 1.

3. A hard metal alloy as defined in claim 1, further characterized in that it contains about 44.3 to 62.3% by volume of the solid solution, and contains about 29.4 to 44.9% by volume of tungsten carbide and about 8.3 to 10.8% by volume of cobalt as the auxiliary ingredients.

4. A hard metal alloy as defined in claim 1, further characterized in that it contains about 60.3% by volume of the solid solution, and contains about 31.4% by volume of tungsten carbide and about 8.3% by volume of cobalt as the auxiliary ingredients.

5. A hard metal alloy as defined in claim 1, further characterized in that it contains about 46.3% by volume of the solid solution, and contains about 42.9% by volume of tungsten carbide and about 10.8% by volume of cobalt as the auxiliary ingredients.

6. A cemented carbide alloy hard metal that is compacted and sintered and is made up of tungsten carbide and titanium carbide in solid solution and of tungsten

carbide and cobalt dispersed as auxiliary ingredients with the solid solution, all employed in a finely comminuted particle form, characterized in that the titanium carbide is employed in a supersaturated condition with and in volume predominance over the tungsten carbide of the solid solution when sintered with the auxiliary ingredients, that the solid solution is in volume predominance over the auxiliary ingredients, and that the total volume content of tungsten carbide is in volume predominance over the other individual ingredients of the metal; and further characterized in that the solid solution contains about 55% titanium carbide and about 45% tungsten carbide, by volume $\pm 2\%$ of each, and the total content of the ingredients of the metal consists of about 54.5 to 63.7% tungsten carbide, about 25.5 to 36.0% titanium carbide, and about 6.3 to 12.0% cobalt.

7. An alloy hard metal as defined in claim 6, further characterized by its high combination of transverse rupture strength of greater than 200,000 p.s.i., a minimum Rockwell A hardness of 91, and a minimum cutting index of 300 on a V-60 general purpose test.

8. An alloy hard metal as defined in claim 6, further characterized in that its microstructure is bound together by a thin layer of substantially evenly distributed cobalt binder between tungsten carbide grains and of lesser amount than precipitated tungsten carbide and the solid solution.

9. A cemented carbide alloy metal containing a solid solution made up of tungsten carbide and titanium carbide and of tungsten carbide and cobalt as auxiliary ingredients therewith, all employed in a finely comminuted particle form, characterized in that the titanium carbide is employed in a supersaturated condition with and in volume predominance over the tungsten carbide of the solid solution, that the solid solution is in volume predominance over the auxiliary ingredients, and that the total volume content of tungsten carbide is in volume predominance over the other individual ingredients in the metal; further characterized in that the solid solution employed contains about 55% titanium carbide and about 45% tungsten carbide, by volume $\pm 2\%$ of each, and the total content of the individual ingredients of the metal consists of about 54.5 to 63.7% tungsten carbide, about 25.5 to 36.0% titanium carbide, and about 6.3 to 12.0% cobalt; and further characterized in that the metal

has a precipitation-interrupted micro-structure consisting of fine-grain precipitated tungsten carbide grains, some retained coarser medium-grain tungsten carbide grains, as uniformly and widely dispersed in a matrix of a saturated titanium-tungsten carbide solid solution, and as bound together between its grains with a thin layer of a substantially evenly distributed cobalt binder.

10. A cemented carbide alloy hard metal that is compacted and sintered and is made up of tungsten carbide and titanium carbide in solid solution and of tungsten carbide and cobalt dispersed as auxiliary ingredients with the solid solution, all employed in a finely comminuted particle form, characterized in that the titanium carbide is employed in a supersaturated condition with and in volume predominance over the tungsten carbide of the solid solution when sintered with the auxiliary ingredients, that the solid solution is in volume predominance over the auxiliary ingredients, and that the total volume content of tungsten carbide is in volume predominance over the other individual ingredients of the metal; further characterized in that the solid solution contains about 55% titanium carbide and about 45% tungsten carbide, by volume $\pm 2\%$ of each, the solid solution is within a range by volume of about 44.3 to 62.3% with respect to the auxiliary ingredients, the content of the tungsten carbide as an auxiliary ingredient is within a volume range of about 29.4 to 44.9% with respect thereto, and the total content of the individual ingredients of the metal by volume is within a range of about 58.4 to 63.7% tungsten carbide, about 25.5 to 33.3% titanium carbide, and about 8.3 to 10.8% cobalt.

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