

- [54] **CARBIDE ALLOYS SUITABLE FOR CUTTING TOOLS AND WEAR PARTS**
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 [51] Int. Cl. **C22c 27/00, C22c 29/00**
 [58] Field of Search **75/176, 134 F, 134 V, 75/175.5, 177**

References Cited

UNITED STATES PATENTS

- 3,554,737 1/1971 Foster et al. 75/176 X

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[57] **ABSTRACT**

This invention relates to refractory metal bonded carbide alloys for use as cutting tools and in other applications where high hardness and abrasion resistance are required. The desired fine-grain, lamellar microstructure is obtained preferably by casting eutectic, or near-eutectic composition alloys of a Group IVa metal (titanium, zirconium, hafnium), tungsten and carbon which may contain certain alloying and inert materials. For selected applications, the composites may be fabricated by powder-metallurgical techniques.

32 Claims, 5 Drawing Figures



FIG. 1.

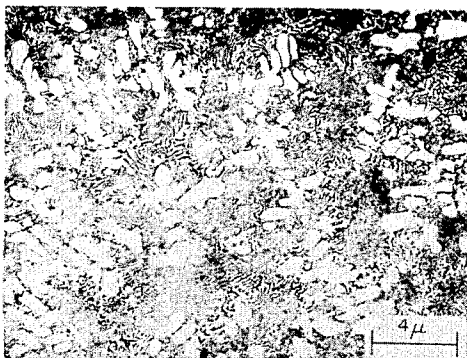


FIG. 2.

Fig. 3

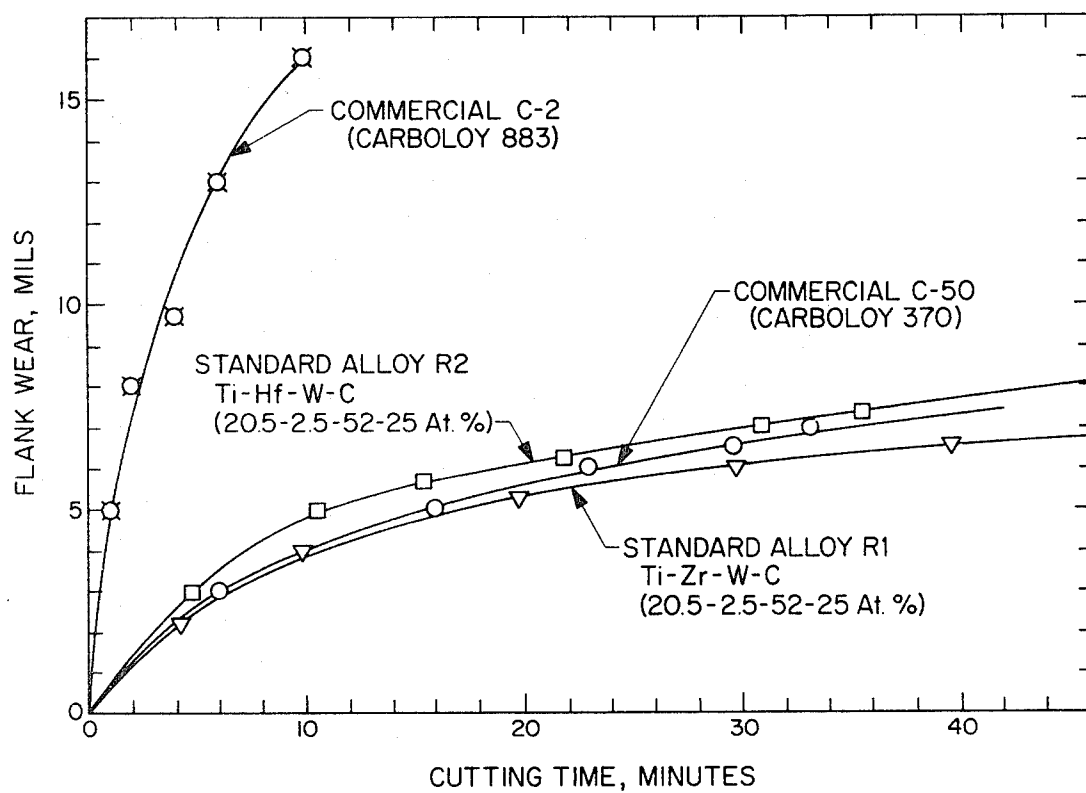


Fig. 4

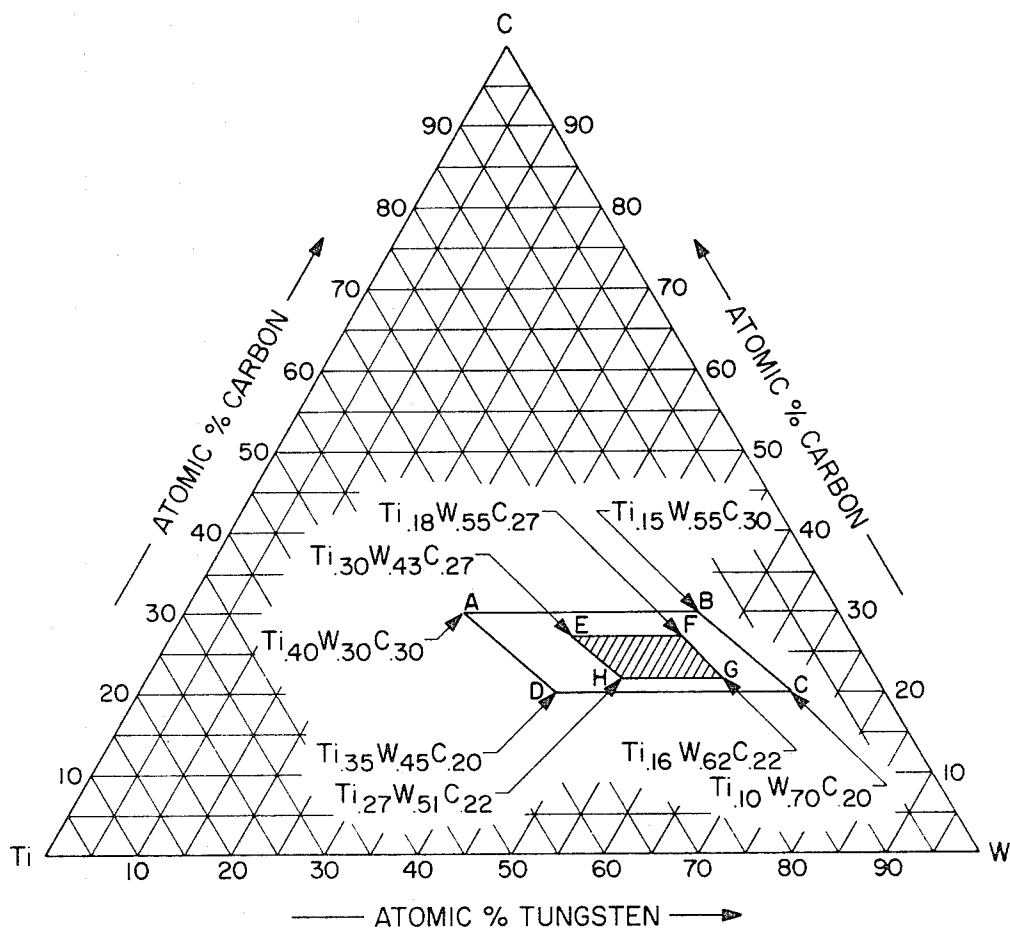
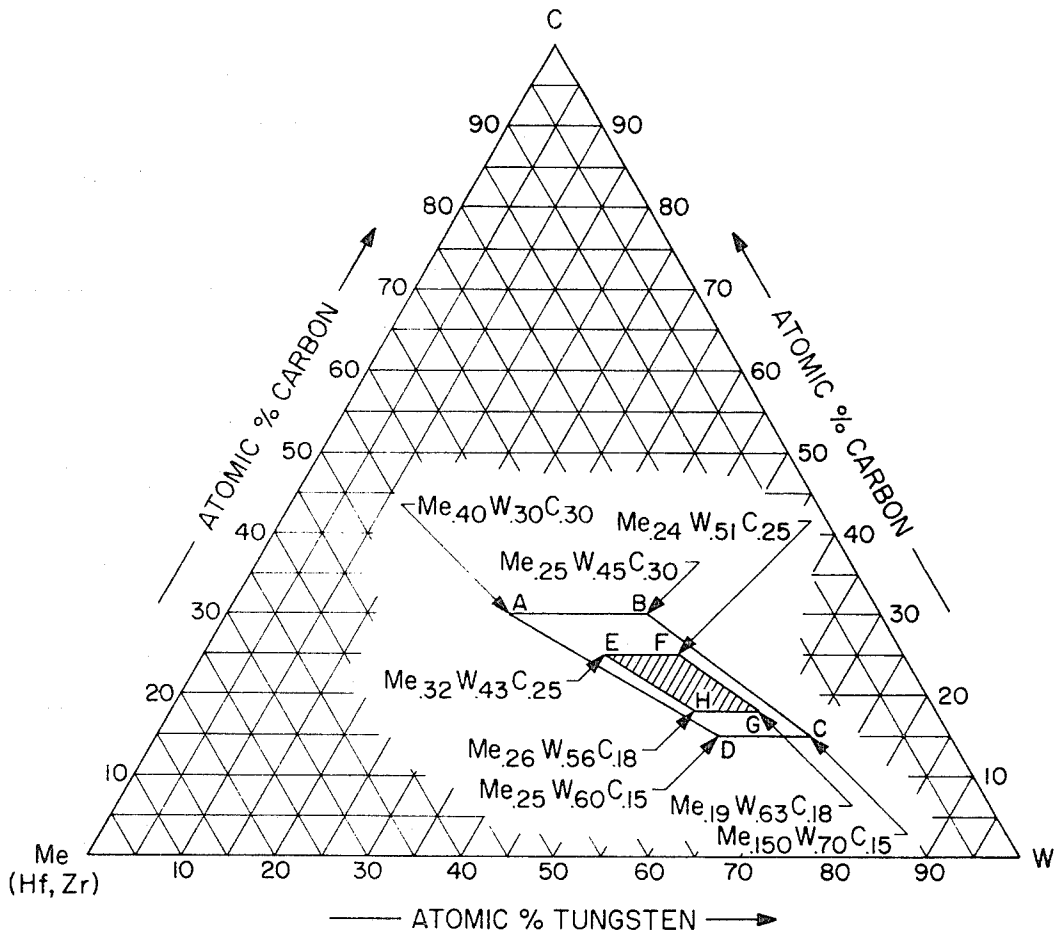


Fig. 5



CARBIDE ALLOYS SUITABLE FOR CUTTING TOOLS AND WEAR PARTS

This application is a division of application Ser. No. 802,625, filed Feb. 26, 1969, now U.S. Pat. No. 3,690,962, Issued Sept. 12, 1972.

DISCUSSION OF THE PRIOR ART

Modern carbide tooling materials consist of a mechanically pulverized, hard carbide phase dispersed in a matrix (binder) of an iron group metal, usually cobalt or nickel. The binder phase contributes toughness to the composite and also serves as an aid in sintering the carbide particles. The loss of strength of iron metal-based binder phases at relatively low temperatures can cause thermal wear to become the dominant wear mechanism at high cutting speeds. The low melting temperatures of these binder phases also preclude their use as abrasion-resistant composites at temperatures above 800° C to 1,000° C.

Binderless, cast carbides such as $W_2C + WC$ eutectics played a role in the initial development of carbide-based tools and die materials, but became obsolete with the advent of the tougher, cobalt-bonded carbides fab-

the invention, grains of primary carbide are dispersed throughout the lamellar microstructure. The interspersed primary carbide grains significantly improve the cutting action of the composite when employed as a machining tool.

The carbide alloys of the invention are made possible by the existence of a pseudobinary eutectic (see Table I) in the systems of Ti-W-C, Zr-W-C, and Hf-W-C. The solidification of the eutectic liquid provides a refractory metal phase and a monocarbide phase that are in solid state two-phase equilibria. The co-existence of the metal phase and the monocarbide phase in the solid state microstructure is necessary to the concept of the metal-bonded carbide tool of the invention. The occurrence of eutectic or near-eutectic-composition reactions provides the means by which the desired microstructure, which possesses an extremely fine-grain, lamellar mixture of metal and monocarbide phases, can be obtained by melting and casting.

Table I shows the exact eutectic compositions and the compositions of the coexisting component phases of each of the three respective eutectics in the Ti-W-C, Zr-W-C, and the Hf-W-C systems.

TABLE I.—DATA FOR THE PSEUDOBINARY EUTECTIC EQUILIBRIA IN THE SYSTEMS OF Ti-W-C, Zr-W-C, AND Hf-W-C

Alloy system	Eutectic temperature (°C.)	Compositions (In atomic percent)		
		Eutectic liquid	Metal—solid solution (approximate)	Monocarbide—solid solution (approximate)
Ti-W-C	2700	Ti(21)-W(57)-C(22)*	Ti(8)-W(92)-C(<0.5)	Ti(28)-W(33)-C(39)
Zr-W-C	2850	Zr(25)-W(55)-C(20)*	Zr(3)-W(97)-C(<0.5)	Zr(44)-W(16)-C(40)
Hf-W-C	2980	Hf(21)-W(61)-C(18)*	Hf(4)-W(96)-C(<1)	Hf(40)-W(20)-C(40)

* Carbon concentrations ± 1 atomic percent, metal concentrations ± 2 atomic percent.

ricated by powder-metallurgical techniques.

Despite the attractive features of the casting process, including its adaptability to low cost manufacturing methods and need for only moderate capitalization, castable tooling materials of equivalent performance to the iron group metal bonded carbides were not developed.

DESCRIPTION OF THE INVENTION

The carbide composite materials of this invention have excellent thermal and mechanical shock resistance compared to the conventional cobalt-bonded carbide tool. This is achieved through the formation of a fine-grain, lamellar microstructure having a hard monocarbide phase and a tough refractory metal phase.

The carbide composite of this invention, in a preferred embodiment, comprises a base alloy system of a Group IVa metal (Ti, Zr or Hf), tungsten and carbon having a fine-grain, lamellar microstructure which is derived from a pseudobinary eutectic or near-eutectic composition. The lamellar microstructure possesses a monocarbide cutting phase and metal phase with the latter phase being rich in tungsten and contributing toughness to the composite. The monocarbide phase contains significant amounts of both the tungsten and the Group IVa metal. In a preferred embodiment (hypereutectic composition) of the carbide composite of

Alloy compositions from the Ti-W-C systems, even when they are located somewhat away from the eutectic composition, will still solidify almost isothermally and thus produce acceptable microstructures closely resembling those of the true eutectics. Hence, there is in this alloy system, considerable latitude in varying the properties of the composites by changing the overall composition of the alloys without losing castability or changing the basic morphology of the cast structure derived from the pseudobinary eutectic or near-eutectic reaction.

There is considerably less freedom in varying the compositions of the Zr-W-C and Hf-W-C alloy systems, and in both of the latter systems it has been found that solidification occurs over a relatively wide temperature range when the compositions are located more than approximately 10 atomic percent to the zirconium or hafnium side away from the pseudobinary eutectic. Hence, the microstructure of the latter two systems, if provided with too much zirconium or hafnium, will have a coarser grain structure and the composites will be less suitable for cutting tool applications.

Other advantages of the invention will be apparent from the following detailed descriptions and drawings in which:

FIG. 1 is a photomicrograph of a typical Group IVa metal (in this instance titanium)-tungsten-carbon composition system which contains (Ti(21)-W(57)-C(22))

in atomic percents) taken at a magnification of 1000X;

FIG. 2 is a photomicrograph at a magnification of 500X of another Group IVa metal-tungsten-carbon system of somewhat different composition namely (Ti(23)-W(52)-C(25) atomic percent) wherein there are grains of primary carbide dispersed throughout the lamellar microstructure;

FIG. 3 is a graph presenting typical comparative wear curves obtained in turning Type 347 stainless steel with the cast alloy tools prepared according to the invention and with top grade C-2 and C-50 type commercial carbide tools.

FIG. 4 is a compositional ternary diagram showing desired composition areas for Ti-W-C base alloys of the invention; and

FIG. 5 is a compositional ternary diagram showing desired composition areas for Zr-W-C and Hf-W-C base alloys of the invention.

The carbide composites of the invention are preferably prepared by melting and casting to produce the fine-grain, lamellar microstructure of monocarbide phase and refractory metal phase formed through solidification of an eutectic or near-eutectic-composition liquid. A typical fine-grain, lamellar microstructure of the invention is illustrated in FIG. 1 where the metal is dark and the carbide light. The photomicrograph of that figure, while showing a titanium-tungsten-carbon system, is typical of the lamellar microstructure of all three base alloy systems i.e., Ti-W-C, Hf-W-C, and Zr-W-C of the invention.

For carbide cutting tool applications it has been found desirable to have grains of primary carbide dispersed throughout the lamellar microstructure as seen in FIG. 2. The photomicrographs of the hafnium and zirconium systems show similar microstructures to those of FIGS. 1 and 2. The presence of the grains of primary carbide in the lamellar structure significantly improve the use of the carbide composite for machine tool cutting purposes.

The ternary diagrams of FIGS. 4 and 5 depict base alloy compositions suitable for producing the carbide composites of the invention. Referring to FIG. 4, which is concerned with titanium-tungsten-carbon base alloys, it is seen that the preferred compositions fall within the inner hatched area E, F, G, H. The larger area A, B, C, D includes compositions of generally less suitable composites, but which are acceptable for some applications. Similarly, the inner hatched area of E, F, G, H of FIG. 5 depicts the more desirable compositions of either the hafnium or zirconium systems. The larger enclosed area A, B, C, D includes composites generally less suitable, but still of a useful nature. The lamellar microstructures of the preferred areas E, F, G, H of FIGS. 4 and 5 include grains of primary carbide dispersed throughout the microstructure. These primary carbide grains enhance the cutting characteristics of the composites when used in machine tools. However, too much of the primary carbide grains promotes chipping of the machine tool. Compositions falling within the general areas A, B, C, D graphically above the preferred areas E, F, G, H will have some tendency to chip. Such is tolerable for some machine tool applications and not objectionable at all for other applications where high hardness and abrasive resistance are required. Below the preferred areas E, F, G, H of FIGS. 4 and 5 but within the area A, B, C, D there is a tendency for primary metal grains to form within the la-

mellar microstructure. Primary metal lessens the value of the carbide composite when used as cutting tools. To the right of the preferred areas E, F, G, H of both FIGS. 4 and 5 and within the general areas A, B, C, D there is a tendency for subcarbide grains to form within the lamellar microstructure. Subcarbides are less hard than monocarbides and, therefore, less suitable for machining applications. The inner hatched areas E, F, G, H of FIGS. 4 and 5 contain the primary carbide grains in desired amounts for most machine tool purposes.

Melting and casting, plasma-arc spraying, as well as powder-metallurgical methods have been employed in preparing metal and monocarbide composites based on the alloy systems Ti-W-C, Zr-W-C, and Hf-W-C of the invention. Melting followed by casting into chilled molds has produced composites with the best mechanical properties and performance for cutting tool purposes. Experience indicates that skull melting, a technique using either a nonconsumable (tungsten) or a consumable electrode, is the most efficient and reliable method for obtaining the melts needed for casting. Melting of the charges in resistively or inductively heated graphite containers has been proven feasible for Ti-W-C base alloys, although care has to be exercised to avoid excessive carbon pick-up upon prolonged exposure of the alloys to hypereutectic temperatures. Continuous melting of presintered compacts in the field of an eddy-current concentrator, or resistance heating and melting of alloy charges in an arrangement where the container is formed by a solidified portion of the alloy to be melted, appear to be promising techniques.

Centrifugal casting of the melt is preferable to casting techniques employing stationary molds, because the former casting techniques minimize the problems associated with the formation of shrinkage pipes and, as the result of the high casting speeds, allows complex parts to be cast to shape.

Other uses of the alloys of the invention are many including hard facings for plows, bulldozer blades, bearings, and for penetrator cores for armor-piercing projectiles. Application of hard facings to various shaped objects by plasma melting and spraying of the powdered alloys of the invention, has been proven feasible. The plasma-arc spraying technique further holds promise for preparing extremely rapid chilled, and thus very-fine-grained, alloying powders, which then can be consolidated into shapes by powder-metallurgical techniques.

It is important in whatever manner of fabrication which is employed that the eutectic or near-eutectic liquid phase be rapidly cooled in order to assure the formation of the fine-grained, lamellar microstructure of the invention.

Dense bodies can also be prepared from powdered material by hot pressing, and also by cold pressing followed by sintering, preferably with the addition of sintering aids. The powders may comprise the desired carbides and metals mixed in the desired quantities. Preferably the powders should be pre-alloyed, said alloys being prepared by comminution of melted and rapidly cooled alloys of the desired carbides and metals. The iron group metals or their alloys, as well as manganese and copper-containing alloys, may be used as sintering aids. Among these, nickel or nickel-iron alloys seem to afford the best properties in terms of toughness and

shock-resistance, but as cutting tools, the sintered materials are inferior to the cast alloys.

Alloying of the Group IVa Metal (Ti, Zr, and Hf)-W-C Base Alloys of the Invention

The ternary alloys from all three base systems of the invention can be extensively modified by alloying additions of other metals. Alloying results, in some instances, in considerable improvement of cutting performance. The studies of the effect of alloyed compositions upon performance of the materials as cutting tools in turning 347 stainless steel are summarized as follows:

1. Ti-W-C base tools had the best cutting performance in terms of tool life. The optimum composition in this base system lies at, or near, the composition Ti-W-C (23-52-25 atomic percent) which is slightly hypereutectic. Hypoeutectic alloys located to the tungsten side of the pseudobinary eutectic have slightly higher wear rates than the optimum composition, but also have somewhat higher edge-stability and cracking resistance; alloys located to the titanium side of the eutectic have good wear characteristics, but tend toward chip-welding at high cutting speeds; alloys with more than 28 atomic percent carbon are prone to edge-chipping; alloys with less than 22 atomic percent carbon are hypoeutectic, contain primary metal-phase, and are subject to high wear.

2. Tungsten may be partially replaced by molybdenum (for instance, up to 20 atomic percent of the base alloy system) without impairing performance. Small quantities of chromium (up to 10 atomic percent of the base alloy system) also may be substituted for tungsten, but larger quantities result in embrittlement of the composites.

3. The Group IVa metals (Ti, Hf, and Zr) may be interchanged for each other in any ratio in their respective base alloy systems. Low level alloying (1 to 5 atomic percent) of the Ti-W-C system with Zr or Hf increases the tool life in comparison with unsubstituted base alloys, still higher concentrations of Hf or Zr result in a gradual drop-off of cutting performance to the levels observed for ternary Zr-W-C or Hf-W-C alloys. Generally speaking, the Hf or Zr will not be substituted in an amount in excess of 20 atomic percent of the Ti in the base alloy Ti-W-C system. More typically, the alloying Group IVa metal or metals Hf and Zr will comprise not more than 5 atomic percent of the base alloy Ti-W-C system.

4. Substitution of Group Va metals, such as vanadium for tungsten in quantities up to 10 atomic percent of the base alloy system decreases the cracking sensitivity, but somewhat impairs performance and edge strength. Edge-chipping tendency is increased by additions of more than 5 atomic percent of such Group Va metals as niobium or tantalum, although cratering and chip-welding characteristics appear improved. Overall, the addition of Group Va metals in quantities of more than 5 atomic percent (preferably, not more than 2 atomic percent) is not recommended.

5. No significant change in cutting performance was observed upon substituting up to 10 atomic percent rhenium for tungsten. Substitution of rhenium up to 20 atomic percent for tungsten appears acceptable.

6. Low level additions of iron group metals (Co, Ni, Fe), of manganese and copper, and of rare earth metals in quantities less than 3 atomic percent of the carbide

composite of the invention were found to be essentially inert.

7. Eutectic, or slightly hypereutectic, Zr-W-C and Hf-W-C based alloys are tougher than Ti-W-C based alloys, but were found to have higher wear-rates in cutting tool applications.

The base alloy systems of the invention including the added amount of cutting tool performance improving alloying metals will typically comprise at least 90 atomic percent of the carbide composite. Generally speaking, the atomic percent age of inerts is held to less than 3 to 5 atomic percent of the carbide composite.

The refractory metal phase of the lamellar microstructure of the invention will typically have a melting point around 2,700°C which is a decided improvement over the 1,400°C melting temperature of the conventional cobalt cutting tool.

The rate of cooling of the alloy of the invention during its fabrication determines grain size. Desirably, cooling is accomplished at a rate of at least 20°C per second to obtain a generally fine grain. Cooling at a slower rate gives a product with a coarser grain. Preferably, cooling is performed at a rate of more than 30°C per second.

Preliminary test results indicate transverse rupture strength levels for the cast Ti-W-C eutectic structure in the range of from 220,000 psi and extending to above 350,000 psi, depending upon fabrication conditions.

The majority of tests has been carried out in studying the performance of the alloys as cutting tools in straight turning of cylindrical test bars on a LeBlonde machineability lathe. For these tests, the carbide alloys were either machined into inserts suitable for clamping in standard tool holders, or more or less irregular shaped bits were brazed onto steel tool holders and then ground on a K.O. Lee diamond grinder to the desired geometry. The test material consisted of annealed 347 stainless steel in the form of 3 inch diameter × 18 inch long cylindrical bars. The surface was removed to a depth of 0.050 inch prior to testing the experimental alloys. In the standard test, the steel was cut at 400 surface feet per minute (sfm), using a depth of cut of 50 mils and a feed of 10 mils per revolution. The tool geometry for the standard test was as follows: back rake, 0°; side rake, 5°; side relief, 5°; end relief, 5°; side clearance end angle, 25°.

A number of representative commercial cutting tools were evaluated under machineability test conditions described above. In addition to the examples below, a selected list of additional tests is contained in Table II, *Infra*.

FIG. 3 graphically depicts the comparative wear curves obtained in the turning of Type 347 stainless steel with the cast alloy tools prepared according to the invention and with top grade C-2 and C-50 type commercial carbides. It will be seen that the cast alloyed tools of the invention have equivalent wear resistance to the top grade wear resistant C-50 tools. In addition, it has been shown that the tools of the invention have equivalent toughness to that of the C-2 tools. Therefore, the cast tools of the invention combine the best qualities of the tough C-2 tools and the wear resistant C-50 tools.

EXAMPLE I

A button of an alloy Ti-W-C (19-58-23 atomic percent) was prepared by arc melting in a non-consumable

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EXAMPLE I

A button of an alloy Ti—W—C (19-58-23 atomic percent) was prepared by arc melting in a non-consumable electrode arc furnace under helium at $\frac{1}{2}$ atmosphere pressure; the melt was allowed to solidify on the water-cooled copper hearth. Metallographic examination of the alloy showed very small amounts of primary monocarbide grains in an eutectic lamellar matrix. The average lamellae width of the eutectic structure was about one micron. The hardness was $R_A = 86$. The tool was brazed onto a mild steel tool holder, ground to the standard tool geometry, and tested in turning 347 stainless steel with the standard conditions outlined above. The tool life, based on a flank wear of 0.016 inch was 45 minutes; the tool showed local wear (crater) of 0.028 inch at the end of the cutting flank.

EXAMPLE II

An alloy Ti—Zr—W—C (20.5-2.5-52-25 atomic percent) (standard alloy R1 in FIG. 3) was prepared in the same way as the sample described under Example I. The composite had a hardness of $R_A = 87$, and the metallographic examination showed small amounts of primary monocarbide in an eutectic matrix (substantially identical to the microstructure shown in photomicrograph of FIG. 2). The average lamellae width of the eutectic was about 0.4 microns. The heterogenous matrix of the photomicrograph of FIG. 2 is an eutectic of

metal plus carbide, and the white or light islands are primary carbide. A uniform wear rate of 0.07 mils per minute was derived from a 40-minute turning test of 347 stainless steel with aforesaid standard conditions, yielding an extrapolated tool life of 190 minutes (0.016 inch flank wear). Cratering of the tool after 40 minutes cutting time was negligible.

EXAMPLE III

An arc cast alloy Hf—W—C (27-51-22 atomic percent) containing a small amount of primary carbide grains in addition to the eutectic lamellar microstructure was prepared. Tool life in the standard test on 347 stainless steel was 15 minutes, with the tool showing negligible cratering or edge wear at the end of the test.

EXAMPLE IV

The alloy cited under Example II and another arc cast alloy Ti—Hf—W—C (20.5-2.5-52-25 atomic percent) were tested for edge stability by gradually increasing the feeds while maintaining a surface speed of 400 feet/min. and a cutting depth of 0.050 inch. Both tools performed reliably at feeds up to 0.05 inch per revolution. At still higher feeds, the tool edges showed signs of chipping.

EXAMPLE V

The behavior of the cast carbide tooling materials at high depth of cut were established in another test run using the same alloys as listed under Example IV with a cutting speed of 400 sfm (surface feet per minute). A constant cutting depth of $\frac{1}{4}$ inch was maintained in the experiments, while the feed was gradually increased, starting at 0.005 inch per revolution. No breakdown occurred at feeds up to 0.030 inch/rev., after which the experiment had to be stopped for lack of lathe power.

EXAMPLE VI

An arc cast alloy Ti—W—C (19-58-23 atomic percent) was comminuted to a grain size below 50 microns and thoroughly mixed with 3 weight percent nickel powder. The mixture was cold-compacted at 4 tons/square inch in steel dies and then sintered for 1 hour at 1,500°C under vacuum. The metallographic examination showed a dense structure consisting of rounded monocarbide grains embedded in a metallic matrix. Tool life in the standard turning test on 347 stainless steel was 14 minutes. The tool had a higher crater wear than the cast alloy of the same composition.

EXAMPLE VII

A composite tool was fabricated by facing one edge of an M-2 tool steel insert with a 0.080 inch wide $\times$ 0.20 inch long $\times$ 0.050 inch thick platelet of the cast standard alloy R1, Ti—Zr—W—C (20.5-2.5-52-25 atomic percent). The carbide tip was attached to the steel insert by brazing. The performance of this composite tool under the standard test condition on 347 stainless steel was found to be the same as the solid carbide inserts; however, as a result of the lower thermal conductivity of the tool steel base compared to the cast carbide alloys, higher tip temperatures, and, as a consequence, higher wear rates were observed on the composite insert as the total load on the tool was increased by either increasing the depth of cut or the feed.

higher wear rates were observed on the composite insert as the total load on the tool was increased by either increasing the depth of cut or the feed.

What is claimed is:

1. A cutting tool comprising a carbide-metal composite derived from a base alloy composition of (a) a Group IVa metal selected from the group consisting of titanium, zirconium and hafnium, (b) tungsten and (c) carbon, with the composition of the base alloy Ti-W-C, selected from within the boxed-in area ABCD of FIG.

4 when the Group IVa metal is titanium and with the composition of the base alloys Hf-W-C, and Zr-W-C selected from within the area ABCD of FIG. 5 when the Group IVa metal is zirconium or hafnium, said composite having a fine-grained, lamellar microstructure derived from a pseudobinary or near-pseudobinary eutectic composition, said lamellar microstructure having a monocarbide phase and a metal phase with the metal phase being rich in tungsten and contributing toughness to the composite and said monocarbide phase containing significant amounts of both the tungsten and the Group IVa metal, said carbide composite being shaped to have a cutting edge and being free of an extraneously added binder metal.

2. A cutting tool in accordance with claim 1 wherein the base alloy composition of the composite is selected from within the boxed-in area EFGH of FIG. 4.

3. A cutting tool in accordance with claim 1 wherein the base alloy composition of the composite is selected from within the boxed-in area EFGH of FIG. 5.

4. A cutting tool in accordance with claim 1 wherein there are grains of primary carbide dispersed throughout the lamellar microstructure of the composite.

5. A cutting tool in accordance with claim 1 wherein the tungsten is replaced in part by a member selected from the group consisting of rhenium, molybdenum and combinations thereof; said member comprising to 20 atomic percent of the base alloy composition.

6. A cutting tool in accordance with claim 1 wherein an alloying material consisting of at least one other metal selected from the Group IVa metals consisting of zirconium, titanium and hafnium is substituted in part in the base alloy compositions; said alloying material comprising up to about 20 atomic percent of the base alloy composition.

7. A cutting tool in accordance with claim 6 wherein the alloying material comprises up to about 5 atomic percent of each base alloy composition.

8. A cutting tool in accordance with claim 1 wherein an alloying material selected from the group consisting of vanadium, niobium, and tantalum or a combination thereof is substituted in the metal content in the base alloy compositions, said alloying material comprising up to 5 atomic percent of each base alloy composition.

9. A cutting tool in accordance with claim 1 wherein the Group IVa metal-tungsten-carbon base alloy composition including any alloying substituents added thereto comprises at least 90 atomic percent of the carbide composite, the remainder being inert ingredients.

10. A cutting tool in accordance with claim 9 wherein an alloying material consisting of at least one other metal selected from the Group IVa metals consisting of zirconium, titanium and hafnium is substituted in part in the base alloy compositions; said alloying material comprising up to about 20 atomic percent of the base alloy composition.

11. A cutting tool comprising a carbide-metal composite of a composition of from 10 to 40 atomic percent titanium, from 0 to 5 atomic percent of zirconium,

hafnium or mixtures thereof, from 30 to 70 atomic percent tungsten, and from 20 to 30 atomic percent carbon, wherein the sum of the atomic percentages of the titanium and the zirconium, or hafnium, or mixture of zirconium and hafnium is from 10 to 40 atomic percent, and wherein the sum of the titanium, zirconium, hafnium, tungsten, and carbon is 100 atomic percent; said composite having a fine-grained, lamellar microstructure derived from a pseudobinary or near-pseudobinary eutectic composition said lamellar microstructure having a monocarbide phase and a metal phase with the metal phase being rich in tungsten and contributing toughness to the composite and said monocarbide phase containing significant amounts of both the tungsten and the Group IVa metals, said carbide composite being shaped to have a cutting edge and being free of an extraneously added binder metal.

12. A cutting tool as in claim 11, wherein the composition of the composite consists essentially of titanium, zirconium, tungsten, and carbon wherein the zirconium is present in the amounts of about 1 to 5 atomic percent.

13. A cutting tool blank comprising a cast carbide composite having a base alloy composition of titanium, tungsten and carbon, said composite having a lamellar microstructure characterized by a monocarbide phase and a tungsten-rich metal phase, said composite being derived from solidification of a pseudobinary eutectic or near-pseudobinary eutectic liquid, said base alloy composition being selected from within the boxed-in area ABCD of the ternary diagram, FIG. 4, said blank being capable of being provided with a cutting edge.

14. A cutting tool blank in accordance with claim 13 wherein an alloying material selected from the group consisting of zirconium, hafnium or a combination thereof is substituted in part for the titanium, said alloying material comprising up to about 5 atomic percent of the base alloy system.

15. A cutting tool blank comprising a cast carbide composite having a base alloy composition of zirconium, tungsten and carbon, said composite having a lamellar microstructure characterized by a monocarbide phase and a tungsten-rich metal phase said composite being derived from solidification of a pseudobinary eutectic of near-pseudobinary eutectic liquid, said base alloy composition being selected from within the boxed-in area ABCD of the ternary diagram FIG. 5, said blank being capable of being provided with a cutting edge.

16. A cutting tool blank in accordance with claim 15 wherein an alloying material selected from the group consisting of titanium, hafnium or a combination thereof is substituted in part for the zirconium, said alloying material comprising up to about 5 atomic percent of the base alloy system.

17. A cutting tool blank comprising a cast carbide composite having a base alloy composition of hafnium, tungsten and carbon, said composite having a lamellar microstructure characterized by a monocarbide phase and a tungsten-rich metal phase said composite being derived from solidification of a pseudobinary eutectic or near-pseudobinary eutectic liquid, said base alloy composition being selected from within the boxed-in area ABCD of the ternary diagram FIG. 5, said blank being capable of being provided with a cutting edge.

18. A cutting tool blank in accordance with claim 17 wherein an alloying material selected from the group consisting of titanium and zirconium or a combination thereof is substituted in part for the hafnium, said alloy-

ing material comprising up to about 5 atomic percent of the base alloy system.

19. A cutting tool blank comprising a carbide-metal composite whose composition comprises from 10 to 40 atomic percent titanium, from 0 to 5 atomic percent of either zirconium, hafnium or mixtures thereof, from 30 to 70 atomic percent tungsten, and from 20 to 30 atomic percent carbon, whereby the sum of the atomic percentages of titanium + zirconium or hafnium, or mixtures of zirconium and hafnium is from 10 to 40 atomic percent, and whereby the sum of the titanium, zirconium, hafnium, tungsten, and carbon is 100 atomic percent; said composite having a lamellar microstructure characterized by a monocarbide phase and a tungsten-rich metal phase; said composite being derived from solidification of a pseudobinary eutectic or near-pseudobinary eutectic liquid; said blank being capable of being provided with a cutting edge.

20. A cutting tool blank as in claim 19 wherein the composition of the composite consists essentially of titanium, zirconium, tungsten, and carbon wherein the zirconium is present in the amount of about 1 to 5 atomic percent.

21. A cutting tool comprising a carbide-metal composite of the compositional formula $[Ti_xZr_yHf_z]W_aC_k$ wherein the subscripts x , y , z , a , and k are given in atomic percent and whereby:

$$0 \leq x \leq 40$$

$$0 \leq y \leq 40$$

$$0 \leq z \leq 40$$

$$30 \leq a \leq 70$$

$20 \leq k \leq 30$ when the fraction $x/(x+y+z)$ is equal to or greater than 0.5

$15 \leq k \leq 30$ when the fraction $x/(x+y+z)$ is less than 0.5

$10 \leq (x+y+z) \leq 40$ when the fraction $x/(x+y+z)$ is equal to or greater than 0.5

$15 \leq (x+y+z) \leq 40$ when the fraction $x/(x+y+z)$ is less than 0.5;

the total of the atomic percentages x , y , z , a , k therefore adding up to 100 At. percent, said carbide composite having a cutting edge.

22. The process of making a cast cutting tool blank comprising: (1) preparing a melt of a composition of a pseudobinary eutectic or near pseudobinary eutectic base alloy of a Ti-W-C, Zr-W-C, or Hf-W-C composition, which composition is selected from within the boxed-in area ABCD, FIG. 4 when the base alloy is Ti-W-C, and selected from within the boxed-in area ABCD, FIG. 5 when the base alloy is Zr-W-C or Hf-W-C; (2) casting said melt into a mold, (3) solidifying and cooling said melt at a rate of at least 20°C per second to form a solid composite having a fine grained, lamellar, pseudobinary or near pseudobinary eutectic microstructure with grains of either primary carbide or primary refractory metal dispersed throughout said lamellar microstructure, said microstructure being melt-composition dependent.

23. The process of preparing a cutting tool which comprises shaping and forming a cutting edge on the blank prepared according to claim 22.

24. The process of making a cast cutting tool blank in accordance with claim 22 including the step of dispersing grains of primary carbide throughout the lamellar microstructure of the composite.

25. The process of making a cast cutting tool blank in accordance with claim 22 wherein the tungsten is replaced in part by a member selected from the group

consisting of rhenium, molybdenum, and mixtures thereof; said member comprising up to 20 atomic percent of the base alloy composition.

26. The process of making a cast cutting tool blank in accordance with claim 22 wherein an alloying material consisting of at least one other metal selected from the Group IVa metals consisting of titanium, zirconium and hafnium is substituted in part in the base alloy compositions; said alloying material comprising up to about 5 atomic percent of the base alloy composition.

27. The process of making a cast cutting tool blank in accordance with claim 26 wherein a second alloying material selected from the group consisting of vanadium, niobium, and tantalum, or combination thereof is substituted in part for the metal content of base alloy composition, said second alloying material comprising up to 5 atomic percent of the base alloy composition, and wherein the compositions including any alloying substituents added thereto comprise at least 90 atomic percent of the carbide composite, the remainder being inert ingredients.

28. The process of claim 22 wherein the composition being melted is a Ti-W-C composition selected from within the boxed in area ABCD of FIG. 4.

29. The process of claim 22 wherein the composition being melted is a Zr-W-C composition selected from within the boxed in area ABCD of FIG. 5.

30. The process of claim 22 wherein the composition being melted is a Hf-W-C composition selected from within the boxed in area ABCD of FIG. 5.

31. The process of making a cast cutting tool comprising: (1) Melting a composition of a pseudobinary eutectic or near pseudobinary eutectic base alloy of a $Ti_xZr_yHf_zW_aC_k$ composition wherein the subscripts x , y , z , a , and k are given in atomic percent and wherein:

$$0 \leq x \leq 40$$

$$0 \leq y \leq 40$$

$$0 \leq z \leq 40$$

$$30 \leq a \leq 70$$

$20 \leq k \leq 30$ when the fraction $x/(x+y+z)$ is equal to or greater than 0.5

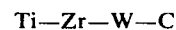
$15 \leq k \leq 30$ when the fraction $x/(x+y+z)$ is less than 0.5

$10 \leq (x+y+z) \leq 40$ when the fraction $x/(x+y+z)$ is equal to or greater than 0.5

$15 \leq (x+y+z) \leq 40$ when the fraction $x/(x+y+z)$ is less than 0.5;

the total of the atomic percentages x , y , z , a , k therefore adding up to 100 At. percent, (2) casting the melted composition into a mold, (3) solidifying and cooling said melted composition at a rate of at least 20°C per second to form a solid composite having a fine grained, lamellar, pseudobinary or near pseudobinary eutectic microstructure, said microstructure being melt-composition dependent, (4) dispersing grains of either primary carbide or primary refractory metal throughout said lamellar microstructure, during solidification and cooling, (5) shaping and forming a cutting edge on the solidified composite.

32. A cutting tool as in claim 11, wherein the composition of the composite is of the elemental formula



wherein Ti is present at about 20.5 atomic percent

Zr is present at about 2.5 atomic percent

W is present at about 52 atomic percent

C is present at about 25 atomic percent

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