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(54) **Blade member of tungsten carbide based cemented carbide with hard coating.**

(57) There is disclosed a blade member of tungsten carbide based cemented carbide with a hard coating, which includes a substrate of tungsten carbide based cemented carbide and a hard coating of one or more coating layers deposited thereon. The substrate contains a binder phase of 5 to 13% by weight of cobalt, and a hard dispersed phase of no greater than 17 % by weight of hard-phase constituents, and a balance tungsten carbide. Each coating layer is formed of one substance of a carbide, a nitride and an oxide of a metal in IV_A, V_A and VI_A of the Periodic Table. The substrate is such that a parameter R, cal/(cm)(sec), defined by $(\lambda \times \sigma)/(\sigma \times E)$ and representing thermal shock resistance of the substrate takes a value of no less than 100, wherein λ, σ, α and E denote thermal conductivity, transverse rupture strength, coefficient of thermal expansion and Young's modulus of the substrate, respectively.

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to blade members of tungsten carbide (WC)-based cemented carbide having hard coatings formed by chemical vapor deposition, and particularly, those members which exhibit excellent performance when used in severe cutting operations such as milling operations accompanying thermal shock.

Prior Art

Known WC-based cemented carbide blade members, which comprise hard coatings formed on the substrates by chemical vapor deposition and including one or more layers each composed of one of carbides, nitrides and oxides of metals in groups IV_A, V_A and VI_A of the Periodic Table, solid solutions of these compounds and aluminum oxide, are utilized mainly in turning operations since they possess both the toughness inherent in the cemented carbide substrates as well as the wear resistance inherent in the hard coatings. Japanese Patent Application B2-Publication, Serial No. 58-26428, describes a cemented carbide blade member for use in processing requiring great fracture resistance. In this blade member, a cobalt enriched portion, which exhibits great toughness, is formed in the substrate so as to be adjacent to the substrate surface thereof.

However, during the milling operations, the cutting tools are subjected not only to the mechanical shock but also to the thermal shock caused by heating and/or cooling, and hence it is very difficult to avoid cracking of the hard coatings. Furthermore, in the cemented carbide blade member as disclosed in the above published Patent Application, since the surface portion of the substrate and the interior portion thereof are characteristically different, cracking caused by the thermal shock develops at the interface between the surface portion and the interior portion, resulting in fracturing.

In order to enhance the fracture resistances of these surface-coated blade members in the milling operations, Japanese Patent Application A-Publication, Serial No. 54-73392, disclosed the inclusion of free carbons in the WC-based cemented carbide substrate to prevent the propagation of the crack.

However, such a blade member has the disadvantage that it cannot bear up against cutting conditions such as milling conditions accompanying thermal shock, which are becoming extremely severe.

SUMMARY OF THE INVENTION

It is therefore the object of the present invention to provide a blade member of tungsten carbide based cemented carbide with a hard coating which exhibits excellent thermal shock resistance even when used for milling operations under very severe conditions.

According to the invention, there is provided a blade member of tungsten carbide based cemented carbide with a hard coating comprising a substrate of tungsten carbide based cemented carbide and a hard coating of at least one coating layer deposited on the substrate, the substrate consisting of a binder phase of 5 to 13% by weight of cobalt, and a hard dispersed phase of no greater than 17 % by weight of hard-phase constituents, and a balance tungsten carbide, the coating layer being formed of one substance selected from the group consisting of a carbide, a nitride and an oxide of a metal in IV_A, V_A and VI_A of the Periodic Table, the substrate being such that a parameter R, cal/(cm)(sec), defined by $(\lambda \times \sigma)/(\alpha \times E)$ and representing thermal shock resistance of the substrate takes a value of no less than 100, wherein λ, σ, α and E denote thermal conductivity, transverse rupture strength, coefficient of thermal expansion and Young's modulus of the substrate, respectively.

DETAILED DESCRIPTION OF THE INVENTION

The inventors have made an extensive study in order to obtain a blade member of tungsten carbide based cemented carbide which meets the requirements as described above. As a result, they have come to know that a parameter R, defined by $(\lambda \times \sigma)/(\alpha \times E)$ and representing thermal shock resistance of the substrate, wherein λ, σ, α and E denote thermal conductivity, transverse rupture strength, coefficient of thermal expansion and Young's modulus of the substrate, respectively, has a correlation with fracture resistance in the milling operations. More specifically, in a cemented carbide blade member without hard coating, the increase of value of the above parameter R representing the thermal shock resistance, results in the deterioration of the wear resistance, so that the tool life becomes unduly short. However, the inventors have found that when a hard coating is formed on a substrate of tungsten carbide-based cemented carbide which takes a value of R of no less than 100 cal/(cm)(sec), the resulting surface coated blade member become less susceptible to fracturing during milling operations and have high wear resistance.

The present invention is based on the above findings, and provides a blade member of tungsten carbide based cemented carbide with a hard coating which comprises a substrate of tungsten carbide-based cemented carbide and a hard coating of one or more coating layers deposited thereon. Each coating layer is formed of one substance selected from the group consisting of a carbide, a nitride and an oxide of a metal in IV_A, V_A and VI_A of the Periodic Table. Furthermore, the present invention is characterized by the substrate in which the parameter R, cal/(cm)(sec), defined by $(\lambda \times \sigma)/(\alpha \times E)$ and representing thermal shock resistance of the substrate takes a value of no less than 100, where λ = thermal conductivity, cal/(cm)(sec)(°C); σ = transverse rupture strength, kg/mm^2; α = coefficient of thermal expansion, /°C; and E = Young's modulus, kg/mm^2.

In the foregoing, if the parameter, R, is less than 100 cal/(cm)(sec), thermal cracking develops in the substrate, such that the blade member is susceptible to fracturing.

In addition, it is preferable that the thickness of the hard coating ranges from 2 to 7μm. If the thickness is below 2μm, the wear resistance is deteriorated. On the other hand, if the thickness exceeds 7μm, the blade member is susceptible to fracturing.

It is also preferable that the interior portion of the cemented carbide substrate has Rockwell "A" hardness, HRA, ranging from 88.0 to 91.0. If the hardness HRA is less than 88.0, the wear resistance of the blade member is deteriorated. On the other hand, if the hardness HRA exceeds 91.0, the resulting blade member becomes inferior in fracture resistance.

Furthermore, it is preferable that the cemented carbide substrate has cobalt content of 5 to 13 % by weight. If the cobalt content is less than 5 % by weight, the toughness is reduced. On the other hand, if the cobalt content exceeds 13 % by weight, the blade member may be subjected to chipping, due to the adhesion of workpiece. Moreover, it is more preferable that the hard phase of the constituents other than balance WC, e.g., TiC, TaC and so on, is present in an amount no greater than 17 % by weight. If the total content of such hard phase constituents exceeds 17 % by weight, a lot of cracking develops due to thermal shock, such that the chipping resistance of the cutting edge is deteriorated.

As described above, the blade member of tungsten carbide based cemented carbide with a hard coating in accordance with the present invention exhibits excellent thermal shock resistance even when used for milling operations under the severe conditions accompanying thermal shock.

The present invention will now be described in detail with reference to the following example.

Example

Starting powders of WC, TiC, TaC, VC and Co were prepared, each of which had an average particle size of 0.5 to 6μm. These powders were blended in blend compositions depicted in Table 1 and were subjected to wet mixing in a ball mill for 72 hours. After being dried, the mixtures were pressed into green compacts under a pressure of 1 ton/cm^2, and the green compacts were sintered in a vacuum to produce WC-based cemented carbides a to e. Subsequently, as to each of the cemented carbides a to e thus obtained, the hardness HRA, the thermal conductivity λ (cal/(cm)(sec)(°C)), the transverse rupture strength σ (kg/mm^2), the coefficient of thermal expansion α (/°C) and the Young's modulus E (kg/mm^2) were measured, and the parameter R (cal/(cm)(sec)) representing the thermal shock resistance was calculated based on the measured values. The results are also shown in Table 1.

Subsequently, cutting inserts having ISO standards of SEEN1203AFTN1 were prepared using the above WC-based cemented carbides a to e, and hard coatings as shown in Table 2 were formed on the surfaces thereof by means of chemical vapor deposition to provide surface coated blade members 1 to 8 of the invention and comparative surface coated blade members 9 to 12.

In the foregoing, the conditions for the chemical vapor deposition were as follows:

(1) Conditions for chemical vapor deposition of TiC layer:

Temperature:	1,030°C
Pressure:	100 Torr
Composition of reaction gas:	4 vol.% $TiCl_4$ - 5 vol.% CH_4 -91 vol.% H_2

(2) Conditions for chemical vapor deposition of TiN layer:

Temperature:	980°C
Pressure:	100 Torr
Composition of reaction gas:	4 vol.% $TiCl_4$ - 8 vol.% N_2 -88 vol.% H_2

(3) Conditions for chemical vapor deposition of TiCN layer:

Temperature:	1,000°C
Pressure:	100 Torr
Composition of reaction gas:	4 vol.% $TiCl_4$ - 3 vol.% CH_4 -4 vol.% N_2 - 89 vol.% H_2

(4) Conditions for chemical vapor deposition of Al_2O_3 layer:

Temperature:	1,000°C
Pressure:	100 Torr
Composition of reaction gas:	3 vol.% $AlCl_4$ - 5 vol.% CO_2 -92 vol.% H_2

As to each of the surface coated blade members 1 to 8 of the invention and the comparative blade members 9 to 12, a milling test was conducted under the following conditions:

Workpiece:	steel (JIS.SCM440; Hardness H_B: 140)
Cutting speed:	250 m/minute
Feed rate:	0.2 mm/cutting edge
Depth of cut:	2.5 mm
Cutting time:	30 minutes

In this test, the flank wear widths were measured, and the results are shown in Table 2 together with the observation as to how the cutting edges are damaged.

As will be seen from the results shown in Table 2, almost all of the comparative surface-coated blade members were fractured, but the surface-coated blade members 1 to 8 of the invention exhibit excellent fracture resistance and wear resistance.

Table 1

		Composition (wt%)	HRA	λ (cal/cm·s·℃)	σ (kg/mm²)	α (×10⁻⁶/℃)	E (kg/mm²)	R (cal/cm·s)
Cemented carbides	a	WC-12%Co-5%TiC-10%TaC	88.5	0.14	220	5.5	54000	104
	b	WC-9%Co-2%TaC	89.0	0.17	240	5.2	59000	133
	c	WC-11%Co	90.0	0.16	390	5.5	57000	199
	d	WC-5.7%Co	91.0	0.19	220	4.6	64000	142
	e	WC-9%Co-19%TiC-17%TaC	91.5	0.07	160	6.5	48000	35※
	f	WC-9%Co-8%TiC-10%TaC	91.3	0.09	270	5.5	53000	83※
	g	WC-15%Co	87.0	0.15	310	6.1	53000	144※
	h	WC-4.5%Co-3%TiC	92.5	0.19	150	4.5	61000	104※

※ not falling within the range of this invention

Table 2

Kind of blade member		Cemented carbide used	Constituents and thickness of coating layers (μm)	Cutting test Flank wear width (mm)
Blade members of the invention	1	a	TiC(1)-TiN(1)	0.31
	2	c	TiC(1)-TiN(1)	0.35
	3	b	TiC(1)-TiN(1)-TiC(1)-TiN(1)	0.22
	4	b	TiC(1)-TiN(1)-TiC(1)-Al_2O_3(0.5)-TiN(0.5)	0.21
	5	a	TiN(2)	0.33
	6	c	TiC(1)-TiCN(2)-TiN(1)	0.27
	7	d	TiCN(4)-TiC(2)-TiN(1)	0.20
Comparative blade members	9	f	TiC(1)-TiN(1)	flank wear of 0.61mm wide developed in 14 minutes
	10	e	TiC(1)-TiN(1)-TiC(1)-TiN(1)	fractured in 3 minutes
	11	e	TiC(1)-TiCN(2)-TiN(1)	fractured in 2 minutes
	12	f	TiC(8)-Al_2O_3(2)-TiN(1)	fractured in 1 minute
	13	g	TiC(1)-TiN(1)-TiC(1)-TiN(1)	flank wear of 0.70mm wide developed in 7 minutes
	14	h	TiC(2)-TiCN(2)-TiC(2)-Al_2O_3(1)-TiN(1)	fractured within 1 minute

Claims

1. A blade member of tungsten carbide based cemented carbide with a hard coating, comprising a substrate of tungsten carbide based cemented carbide and a hard coating deposited on said substrate

and composed of at least one coating layer, characterized in that said substrate consists of a binder phase of 5 to 13% by weight of cobalt, and a hard dispersed phase of no greater than 17 % by weight of hard-phase constituents, and a balance tungsten carbide, that said coating layer is formed of one substance selected from the group consisting of a carbide, a nitride and an oxide of a metal in IV_A, V_A and VI_A of the Periodic Table, and that said substrate is such that a parameter R, cal/(cm)(sec), defined by $(\lambda \times \sigma)/(\alpha \times E)$ and representing thermal shock resistance of said substrate takes a value of no less than 100, wherein λ, σ, α and E denote thermal conductivity, transverse rupture strength, coefficient of thermal expansion and Young's modulus of said substrate, respectively.

2. A blade member of tungsten carbide based cemented carbide with a hard coating as recited in claim 1, wherein said substrate has an interior portion having a hardness ranging from 88.0 to 91.0.

3. A blade member of tungsten carbide based cemented carbide with a hard coating as recited in claim 1, wherein said coating layer is formed of one substance selected from the group consisting of a titanium carbide, a titanium nitride and a titanium carbo-nitride.

4. A blade member of tungsten carbide based cemented carbide with a hard coating as recited in claim 1, wherein said hard coating has the strongest X-ray diffraction peak indexed by index of plane (2, 2, 0) for titanium carbo-nitride layer.