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(54) Title: CEMENTED CARBIDE INSERT FOR TOUGHNESS DEMANDING SHORT HOLE DRILLING OPERATIONS

(57) Abstract: The present invention relates to a coated cutting insert with excellent toughness properties particularly useful for toughness demanding short hole drilling in low alloy and stainless steels and a method of making the same. The inserts comprise a substrate and a coating. The substrate consists of WC, 8-11 wt-% Co and 0.2-0.5 wt-% Cr with an average WC-grain size of 0.5-1.5 μm and a CW-ratio of 0.80-0.90. The coating comprises a laminar, multilayered structure of TiN+Ti_{1-x} Al_xN+TiN+Ti_{1-x} Al_xN+TiN. In polycrystalline, non-repetitive form, with x=0.4-0.β with a thickness of the individual TiN- or Ti_{1-x} Al_xN-layers of 1-30 nm varying essentially at random and with a total thickness of the multilayered coating of 1-5 μm. The layers are deposited using arc evaporation technique.

Cemented carbide insert for toughness demanding short hole drilling operations

The present invention relates to a coated cutting tool insert particularly useful for toughness demanding short hole drilling in low alloy and stainless steels. The multilayer coating greatly improves both wear resistance and resistance against plastic deformation at high feeds combined with the low speeds close to the center of the drilled hole.

Drilling in metals is divided generally in two types: long hole drilling and short hole drilling. By short hole drilling is meant generally drilling to a depth of up to 3-5 times the drill diameter.

Long hole drilling puts large demands on good chip formation, lubrication, cooling and chip transport. This is achieved through specially developed drilling systems with specially designed drilling heads fastened to a drill rod and fulfilling the above mentioned demands.

In short hole drilling, the demands are not great, enabling the use of simple helix drills formed either of solid cemented carbide or as solid tool steel or of tool steel provided with a number of cutting inserts of cemented carbide placed in such a way that they together form the necessary cutting edge. In the center of the head, a tough grade of insert is sometimes used and on the periphery a more wear resistant one. The cutting inserts are brazed or mechanically clamped.

The object of the present invention is to provide a coated cutting tool insert useful for toughness demanding short hole drilling in steel.

US 6,103,357 relates to a cutting tool comprising a body of sintered cemented carbide or cermet, ceramic or high speed steel on which at least one of the functioning parts of the surface of the body, a thin, adherent, hard and wear resistant coating is applied. The coating comprises a laminar, multilayered structure of refractory compounds in polycrystalline, non-repetitive form, MX+NX+MX+NX where the alternating layers MX and NX are metal nitrides or carbides with the metal elements M and N selected from the group consisting of Ti, Nb, Hf, V, Ta, Mo, Zr, Cr, Al and W. The sequence of individual layer thicknesses is essentially aperiodic throughout the entire multilayered structure, and layer

thicknesses are larger than 0.1 nm but smaller than 30 nm, preferably smaller than 20 nm. The total thickness of said multilayered coating is larger than 0.5 μm but smaller than 20 μm.

According to the invention there is now provided cemented carbide inserts with excellent toughness properties particularly useful for toughness demanding short hole drilling in low alloy and stainless steels consisting of WC and 8-11 wt-% Co, preferably 9.5-10.5 wt-% Co and 0.2-0.5 wt-% Cr. The WC-grains have an average grain size of 0.5-1.5 μm.

The amount of W dissolved in the binder phase is controlled by adjustment of the carbon content by small additions of carbon black or pure tungsten powder. The W-content in the binder phase can be expressed as the "CW-ratio" defined as

$$\text{CW-ratio} = M_S / (\text{wt-\% Co} * 0.0161)$$

where M_S is the measured saturation magnetization of the sintered cemented carbide body in hAm^2/kg and wt-% Co is the weight percentage of Co in the cemented carbide. The CW-ratio in inserts according to the invention shall be 0.80-0.90.

The coating comprises a laminar, multilayered structure of refractory compounds in polycrystalline, non-repetitive form, $TiN+Ti_{1-x}Al_xN+TiN+Ti_{1-x}Al_xN+TiN....$with x=0.4-0.6, preferably 0.5. In said coating the sequence of individual layer thicknesses has no repeat period but is essentially aperiodic throughout the entire multilayered structure. The individual TiN- or $Ti_{1-x}Al_xN$-layer thickness is larger than 1 nm but smaller than 30 nm, preferably smaller than 20 nm and varies essentially at random. The total thickness of the multilayered coating is >1 μm, preferably >2 μm but <5 μm, preferably <4 μm.

In one embodiment there is an additional black 0.2-1 μm, preferably 0.3-0.6 μm, thick $Ti_{1-x}Al_xN$-layer on top of the multilayer coating.

In another embodiment there is an additional bronze-coloured homogeneous $(Ti_{0.84}Al_{0.16})N$-layer with a thickness of about 0.2-0.5, preferably 0.3 μm on top of the multilayer coating.

The invention also relates to a method of making coated cemented carbide inserts with excellent toughness properties particularly useful for toughness demanding short hole drilling in low alloy and stainless steels. The cemented carbide consists of WC and 8-11 wt-% Co, preferably 9.5-10.5 wt-% Co and 0.2-0.5 wt-% Cr. The WC-grains have an average grain size of 0.5-1.5 μm. The

raw materials powders are wet milled with pressing agent, small additions of carbon black or pure tungsten powder to obtain a CW-ratio in the sintered inserts of 0.80-0.90. After the wet milling the slurry is dried to a powder, compacted and sintered. After conventional post sintering treatment a coating comprising a laminar, multilayered structure of refractory compounds in polycrystalline, non-repetitive form, $TiN+Ti_{1-x}Al_xN+TiN+Ti_{1-x}Al_xN+TiN....$ with x=0.4-0.6, preferably 0.5 is deposited by cathodic arc evaporation using two pairs of arc sources consisting of pure Ti and TiAl alloy, respectively in an N_2 gas atmosphere. In said coating the sequence of individual layer thicknesses has no repeat period but is essentially aperiodic throughout the entire multilayered structure. The individual TiN- or $Ti_{1-x}Al_xN$-layer thickness is larger than 1 nm but smaller than 30 nm, preferably smaller than 20 nm and varies essentially at random. The total thickness of the multilayered coating is >1 μm, preferably >2 μm but <5 μm, preferably <4 μm.

In one embodiment a final black 0.2-1 μm, preferably 0.3-0.6 μm, thick $Ti_{1-x}Al_xN$-layer in the multilayer coating is deposited by cathodic arc evaporation using one pair of arc sources consisting of a TiAl-alloy in an N_2 gas atmosphere.

In another embodiment a final bronze-coloured homogeneous $(Ti_{0.84}Al_{0.16})N$-layer with a thickness of about 0.2-0.5, preferably 0.3 μm is deposited on top of the multilayer coating using arc deposition from an arc source consisting of a $Ti_{0.84}Al_{0.16}$-alloy in an atmosphere of Ar=400 sccm and N_2=800 sccm.

Example 1

Aperiodic multilayers were deposited by cathodic arc evaporation on drilling inserts made of cemented carbide with composition WC + 10wt-% Co and average WC grain size of 1.0 μm and a CW-ratio of 0.86. The coating was deposited from two pairs of arc sources consisting of pure Ti and TiAl alloy, respectively. The arc evaporation was performed in an N_2 gas atmosphere. The resulting total coating thickness was 3.0 μm, and consisted of a $TiN+Ti_{0.5}Al_{0.5}N$ multilayer having a sequence of individual lamellae layers with an aperiodic, i.e., non-repetitive thickness. Cross section transmission electron microscopy investigation revealed that the individual nitride layer thicknesses ranged from 2 to 15 nm, and the total number of layers was about 400.

Half of the inserts were coated with an additional black $Ti_{0.5}Al_{0.5}N$-layer of about 0.3-0.6 μm thickness.

The other half of the inserts was coated with an additional homogeneous $(Ti_{0.84}Al_{0.16})N$-layer with a thickness of about 0.3 μm. This layer was deposited using arc evaporation from an arc source consisting of a $Ti_{0.84}Al_{0.16}$-alloy in an atmosphere of Ar=400 sccm and N_2=800 sccm. In this way a stable bronze colour, on all inserts and also from batch to batch, was obtained.

Example 2

Bronze coloured inserts from example 1 were tested and compared with inserts from Sandvik commercial grade 1020 with respect to toughness in a short hole drilling operation. The tested inserts were mechanically clamped on the center of the drill head. In the periphery, inserts according to Swedish Patent Application No SE 0500235-7 were used. Tool life criteria: crater wear, plastic deformation, flank wear, or chipping >0.25 mm.

Material: Low alloy steel SS2541-03, 285 HB.
Emulsion: Blasocut BC25, 7%.
Operation: Through hole, 48 mm.
Cutting speed: 260 m/min
Feed: 0.10 mm/r
Drill: Diameter 23 mm, 3XD
Insert style: CoroDrill 880, US0802C-GM

Results. A surprisingly significant difference in tool life, regarding crater wear resistance, was seen. The inserts according to the invention showed a much improved crater wear resistance compared to the inserts reference. Drilled length at tool life:

Inserts invention >40 meters
Inserts reference tool failure after 30 meters

Example 3

Black inserts from Example 1 were tested and compared with inserts from Sandvik commercial grade 1020 with respect to toughness in a short hole drilling operation. The tested inserts were mechanically clamped on the periphery of the drill head. In the center, bronze coloured inserts from Example 1 were used. Tool

life criteria: crater wear, plastic deformation, flank wear, or chipping >0.25 mm.

Material: Low alloy steel SS2541-03, 270-285 HB.
Emulsion: Blasocut BC25, 7%.
Operation: Through hole, 50 mm.
Cutting speed: 200 m/min
Feed: 0.15 mm/r
Drill: Diameter 24 mm, 3XD
Insert style: CoroDrill 880, US0807P-GM

Results. Drilled length at tool life:
Inserts invention >20 meters
Inserts reference 13.3 meters

Example 4

Bronze coloured inserts from Example 1 were tested and compared with inserts from Sandvik commercial grade 1020 with respect to toughness in a short hole drilling operation. The tested inserts were mechanically clamped on the center of the drill head. In the periphery, black inserts from Example 1 were used. Tool life criteria: crater wear, plastic deformation, flank wear, or chipping >0.25 mm.

Material: Low alloy steel SS2541-03, 300 HB.
Emulsion: Syntilo XPS, 6.5%, 10 bar.
Operation: Through hole, 40 mm.
Cutting speed: 150 m/min
Feed: 0.20 mm/r
Drill: Diameter 24 mm, 3XD
Insert style: CoroDrill 880, US0802C-GM

Results: At high feeds combined with the low speeds near the center of the hole the inserts invention showed a much improved wear resistance and resistance against plastic deformation compared to the inserts reference. Drilled length at tool life:
Inserts invention 13.5 meters
Inserts reference 2.3 meters

Claims

1. Cutting insert with excellent toughness properties particularly useful for toughness demanding short hole drilling in low alloy and stainless steels comprising a substrate and a coating c h a r a c t e r i s e d in that

- the substrate consists of WC, 8-11 wt-% Co, preferably 9.5-10.5 wt-% Co and 0.2-0.5 wt-% Cr with an average WC-grain size of 0.5-1.5 μm and a CW-ratio of 0.80-0.90 and

- the coating comprises a laminar, multilayered structure of $TiN+Ti_{1-x}Al_xN+TiN+Ti_{1-x}Al_xN+TiN$....in polycrystalline, non-repetitive form, with x=0.4-0.6, preferably 0.5 with a thickness of the individual TiN- or $Ti_{1-x}Al_xN$-layers of 1-30 nm, preferably 1-20 nm varying essentially at random, and with a total thickness of the multilayered coating of 1-5 μm, preferably 2-4 μm.

2. Cutting insert according to claim 1 c h a r a c t e r i s e d in that there is an additional black 0.2-1 μm, preferably 0.3-0.6 μm, thick $Ti_{1-x}Al_xN$-layer atop the multilayer coating.

3. Cutting insert according to claim 1 c h a r a c t e r i s e d in that there is an additional bronze-coloured homogeneous $(Ti_{0.84}Al_{0.16})N$-layer with a thickness of about 0.2-0.5, preferably 0.3 μm atop of the multilayer coating.

4. Method of making a cutting insert comprising a cemented carbide substrate and a coating c h a r a c t e r i s e d in the substrate consisting of WC, 8-11 wt-% Co, preferably 9.5-10.5 wt-% Co and 0.2-0.5 wt-% Cr with an average WC-grain size of 0.5-1.5 μm and a CW-ratio of 0.80-0.90 is coated with a coating comprising a laminar, multilayered structure of $TiN+Ti_{1-x}Al_xN+TiN+Ti_{1-x}Al_xN+TiN$....in polycrystalline, non-repetitive form, with x=0.4-0.6, preferably 0.5 with a thickness of the individual TiN- or $Ti_{1-x}Al_xN$-layers of 1-30 nm, preferably 1-20 nm varying essentially at random, and with a total thickness of the multilayered coating of 1-5 μm, preferably 2-4 μm by cathodic arc evaporation using two pairs of arc sources consisting of pure Ti and TiAl alloy, respectively in an N_2 gas atmosphere.

5. Method according to claim 4 c h a r a c t e r i s e d in depositing a final black 0.2-1 μm, preferably 0.3-0.6 μm, thick $Ti_{1-x}Al_xN$-layer by cathodic arc evaporation using one pair of arc sources consisting of TiAl alloy in an N_2 gas atmosphere.

6. Method according to claim 4 c h a r a c t e r i s e d in depositing a final bronze-coloured homogeneous $(Ti_{0.84}Al_{0.16})N$-layer with a thickness of about 0.2-0.5, preferably 0.3 µm atop of the multilayer coating using arc evaporation from an arc source consisting of a $Ti_{0.84}Al_{0.16}$-alloy in an atmosphere of Ar=400 sccm and N_2=800 sccm.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
MF 12085 WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/SE2006/000117	26 January 2006	31 January 2005
Applicant		
Sandvik Intellectual Property AB et al		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

   b. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II)

3. ☐ **Unity of invention is lacking** (see Box No. III)

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. -

   ☐ as suggested by the applicant.

   ☐ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000117

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C23C, B23B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20030175536 A1 (RONALD M. PENICH ET AL), 18 Sept 2003 (18.09.2003), figures 1-5, abstract, paragraphs (0001), (0015)-(0069) --	1-6
A	US 6103357 A (TORBJÖRN SELINDER ET AL), 15 August 2000 (15.08.2000), column 2, line 30 - column 4, line 37, figure 1, abstract --	1-6
A	EP 1038989 A2 (SANDVIK AKTIEBOLAG), 27 Sept 2000 (27.09.2000), claims 1-5, abstract --	1-6

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 April 2006	05 -05- 2006
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Ingrid Grundfelt/Els Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000117

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6627049 B2 (ANDERS JONSSON ET AL), 30 Sept 2003 (30.09.2003), column 1, line 10 - line 15; column 2, line 44 - column 3, line 64, figure 1, claim 4, abstract --	1-6
A	US 6071560 A (HANS BRAENDLE ET AL), 6 June 2000 (06.06.2000), column 2, line 7 - column 6, line 54; column 9, line 16 - column 10, line 44, abstract -- --------	1-6

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International patent classification (IPC)

C23C 30/00 (2006.01)
C23C 14/06 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT
Information on patent family members

04/03/2006

International application No.
PCT/SE2006/000117

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				TR	200000711	T	00/00/0000