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(54) **A METHOD OF PRODUCING A TOOL FOR CUTTING, DRILLING OR CRUSHING OF SOLID MATERIAL, AND SUCH A TOOL**

VERFAHREN ZUR HERSTELLUNG EINES WERKZEUGS ZUM SCHNEIDEN, BOHREN UND ZERKLEINERN VON FESTEM MATERIAL UND SOLCH EIN WERKZEUG

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(56) References cited:
**WO-A1-2012/098102 AU-A1- 2013 273 604
US-A- 4 951 762**

- **LEE W B ET AL: "Effects of Cr3C2 on the microstructure and mechanical properties of the brazed joints between WC-Co and carbon steel", INTERNATIONAL JOURNAL OF REFRACTORY METALS AND HARD MATERIALS, ELSEVIER PUBLISHERS, BARKING, GB, vol. 24, no. 3, May 2006 (2006-05), pages 215-221, XP028009730, ISSN: 0263-4368, DOI: 10.1016/J.IJRMHM.2005.04.003 [retrieved on 2006-05-01]**

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method of producing a tool for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body attached to a steel holder, wherein said method comprises the steps of providing said cemented carbide body by; providing a powder mixture, compacting said powder mixture into a compact, sintering the compact into said cemented carbide body, and attaching the compact to said steel holder.

[0002] The present invention also relates to a tool produced in accordance with the principles of the method of the present invention.

BACKGROUND OF THE INVENTION

[0003] Tools for cutting, drilling or crushing of solid material, such as rock, often comprise a cemented carbide body attached to a steel holder. The joint between the cemented carbide body and the steel holder may be a braze joint between a base surface of the cemented carbide body and the steel holder. The braze joint may be accomplished by means of a brazing process in which a solder, typically comprised by Nickel-Copper-Manganese alloy, is positioned between the base surface of the cemented carbide body and a surface of the steel holder, and in which the solder is melted and then forced to diffuse into the cemented carbide body and into the steel by means of inductive heating thereof.

As an alternative, convective heating in an oven may be applied. In order to prevent oxidation of the cemented carbide during the brazing process, the brazing process may be performed in an inert gas atmosphere, or a fluxing means may be applied onto the cemented carbide body.

[0004] During the brazing process, the cobalt in the cemented carbide body plays a vital role in the sense that is responsible for the generation of heat through the induction of an eddy current therein. A too low content of cobalt will result in a low wettability of the cemented carbide by the solder, and therefore a poor bonding between the cemented carbide and the steel. Cemented carbide bodies with low cobalt contents are therefore generally considered as unsuitable for joining by means of brazing, especially when using inductive brazing which is the most suitable brazing method to use when producing tools for cutting or drilling minerals or rock. When a low cobalt content cemented carbide body is desired, attachment by means of clamping or similar mechanical joining is considered to be the only reasonable option.

[0005] AU2013273604 A1 discloses a method of sintering a tungsten carbide body for producing a tool, wherein gradients of grain refiner (chromium or vanadium) and binder (cobalt) content are formed inwards from the surface of the compact during sintering.

[0006] Prior art, as exemplified by WO201298102A1, also mentions that cemented carbide with a mean cobalt content of up to 10 wt% actually has an outer surface that is depleted with cobalt as a result of the sintering process, making such a material unsuitable for attachment to steel by means of brazing unless said zone is cobalt enriched. WO201298102A1, as well as further prior art, such as disclosed in US4951762A, therefore suggests methods of generating a cobalt gradient in a cemented carbide body by enriching said zone with cobalt in order to make such a cemented carbide body, which has a relatively low mean content of cobalt therein, more suitable for attachment to a steel holder by means of brazing.

THE OBJECT OF THE INVENTION

[0007] It is an object of the present invention to provide a method of producing a tool for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body attached to a steel holder by a strong braze joint, the cemented carbide body has a low mean content of cobalt and/or a low cobalt content in a tip region active in cutting.

[0008] It is also an object of the invention to provide a tool for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body attached to a steel holder, which presents a strong bonded braze joint between the cemented carbide body and the steel holder despite a low mean content of cobalt in the cemented carbide body and/or a low cobalt content in a tip region active in cutting.

SUMMARY OF THE INVENTION

[0009] The object of the invention is achieved by means of a method of producing a tool for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body attached to a steel holder, wherein said method comprises the steps of

- providing said cemented carbide body by;
- providing a powder mixture,

- compacting said powder mixture into a compact comprising a hard phase mainly comprised by tungsten carbide, WC, and a binder consisting of cobalt, wherein the cobalt content of the compact is at a cobalt content level (A) and is $\leq$ about 5.5 wt%,
- providing a compound comprising a carbide or a nitride formed by carbon or nitrogen and an element that has a grain growth inhibiting effect on tungsten carbide, and providing an element that has a grain growth promoting effect on WC,
- applying said compound and said grain growth promoting element onto at least a tip region of said compact, wherein said tip region will form a tip region of the cemented carbide body aimed for engagement with material to be cut, drilled into or crushed by means of said tool, and keeping a base surface of the compact, which will form a base surface of the cemented carbide body that will be attached to said steel holder, free from said compound and grain growth promoting element,
- wherein said compound and said grain growth promoting element is of a type that will diffuse into the compact in connection to sintering of the latter and thereby will induce a generation of a cobalt content gradient in the sintered compact, with an increasing cobalt content in a direction away from a surface onto which said compound and said grain growth promoting element has been applied,
- sintering the compact provided with said compound and said grain growth promoting element into said cemented carbide body such that the cobalt content at said base surface of the cemented carbide body being cobalt content level (B) becomes $\geq$ 4.5 wt% as a result of said induced generation of a cobalt content gradient, the ratio cobalt content level (B) to cobalt content level (A) is $\geq$ 1.09, and
- attaching said base surface of the cemented carbide body to the steel holder by means of brazing.

[0010] It is thus possible to create a cemented carbide body having a low mean cobalt content and/or a low cobalt content in the tip that is active in cutting, crushing etc. at the same time the cemented carbide body has a base region having more a sufficiently high cobalt content to enable strong braze joints to steel.

[0011] According to one embodiment, the cobalt content at said base surface of the cemented carbide body being cobalt content level (B) becomes $\geq$ 5.0 wt%, or $\geq$ 5.5 wt%, or $\geq$ 6.0 wt%.

[0012] According to one embodiment, the ratio cobalt content level (B) to cobalt content level (A) is $\geq$ 1.12, or $\geq$ 1.14, or $\geq$ 1.16, or $\geq$ 1.2.

[0013] Due to the Co content gradient, tensile stresses are induced in the bottom of the cemented carbide body. If the cobalt gradient is too large, some negative effects to the braze joint strength may in some cases occur. According to one embodiment, the ratio cobalt content level (B) to cobalt content level (A) is $\leq$ 1.5, or $\leq$ 1.4.

[0014] According to one embodiment, said tip region of the cemented carbide body has a mean cobalt content, being cobalt content level (C), of $\leq$ 4.5 wt%, or $\leq$ 4.0 wt%, or $\leq$ 3.5 wt%, or $\leq$ 3.0 wt%.

[0015] The extent of the tip region into the body is suitably defined as starting at the surface and going about 2 mm down into the cemented carbide body.

[0016] According to one embodiment, the ratio cobalt content level (B) to cobalt content level (C) is $\geq$ 1.2, or $\geq$ 1.3, or $\geq$ 1.4.

[0017] According to one embodiment, the cobalt content of the cemented carbide body, being cobalt content level (A), is $\leq$ about 5.0 wt%.

[0018] According to one embodiment, the cobalt content of the cemented carbide body, being cobalt content level (A), is $\leq$ about 4.5 wt%.

[0019] According to one embodiment, said compact comprises top and lateral surfaces and said base surface, and said compound and said grain growth promoting element is applied to at least 50% of the total area of the top and lateral surfaces. The degree of coverage of the applied compound and grain growth promoting element, and the amount thereof applied, is decisive for the generation of the required cobalt gradient in the cemented carbide body.

[0020] According to one embodiment, said compact comprises top and lateral surfaces and said base surface, and said compound and said grain growth promoting element is applied to at least 70% of the total area of the top and lateral surfaces.

[0021] According to one embodiment, said compact comprises top and lateral surfaces and said base surface, and said compound and said grain growth promoting element is applied to at least 80% of the total area of the top and lateral surfaces.

[0022] According to one embodiment, said compact comprises top and lateral surfaces and said base surface, and wherein the distance between the top surface and the base surface, which is opposed to the top surface, is less than 25 mm, preferably less than 15 mm, and more preferably less than 10 mm, and wherein said compound and said grain growth promoting element are applied onto at least a part of said top surface. Thanks to a sufficiently low distance between top and base surfaces, sufficiently high cobalt content can be obtained in the base surface due to the generated cobalt gradient.

[0023] According to one embodiment, said compact comprises top and lateral surfaces and, in a zone of the lateral surface or surfaces neighbouring the base surface, the lateral surface or surfaces are excluded from the application of

said compound and said grain growth promoting element. Thereby, the generation of a cobalt-depleted zone in the transition region between lateral surfaces and base surface is avoided.

[0024] According to one embodiment said compact has a generally knob-like shape, has a generally circular bottom surface with a diameter d , and has a height h , wherein $0.5 < h/d < 2$, and said bottom surface defines said base surface.

[0025] According to another embodiment said compact has a generally plate-like shape, has width w , a height h and a thickness t , and wherein $0.2 < h/w < 2$, $t < w$, $2\text{mm} < t < 20\text{mm}$, and, said base surface is a large side of said compact, and said tip region includes at least a part of an opposite large side thereof.

[0026] According to one embodiment, in said compound, the element that has a grain growth inhibiting effect on WC is any of chromium, vanadium, tantalum or niobium, preferably chromium or vanadium, most preferably chromium. Accordingly, the grain refiner compound is suitably selected from the group of carbides, mixed carbides, carbonitrides or nitrides of vanadium, chromium, tantalum and niobium. Preferably, the grain refiner compound is a carbide or nitride of chromium or vanadium, such as Cr_3C_2 , Cr_{23}C_6 , Cr_7C_3 , Cr_2N , CrN or VC , most preferably carbides of chromium, such as Cr_3C_2 , Cr_{23}C_6 , or Cr_7C_3 .

[0027] According to one embodiment, on the surfaces on which said compound and is applied, said compound is applied onto the compact in an amount of more than 0.5 mg/cm^2 , preferably more than 2.5 mg/cm^2 , preferably more than 3.0 mg/cm^2 . According to one embodiment, said compound is applied onto the compact in an amount of not more than 10.0 mg/cm^2 , preferably not more than 7.0 mg/cm^2 , preferably not more than 6.0 mg/cm^2 . The above-mentioned limits are generally applicable for the different compounds mentioned above and particularly applicable for Cr_3C_2 . Too high levels of said compound may result in the unwanted generation of brittle phases.

[0028] According to one embodiment, said grain growth promoting element is carbon in the form of graphite. The carbon provided onto the surface of the compact may be in the form of deposited carbon from a carburizing atmosphere, amorphous carbon, which is present in e.g. soot and carbon black, or graphite. Preferably, the carbon is in the form of soot or graphite. The weight ratio of grain refiner compound, to grain growth promoter, is suitably from about 0.05 to about 50, preferably from about 0.1 to about 25, more preferably from about 0.2 to about 15, even more preferably from about 0.3 to about 12, most preferably from about 0.5 to about 8. When said compound is Cr_3C_2 and said grain-growth promoting element is C the weight ratio $\text{Cr}_3\text{C}_2/\text{C}$ may preferably be from about 1 to about 14, preferably from about 1.5 to about 6.

[0029] According to one embodiment, on the surfaces on which said grain growth promoting element is applied, said grain growth element is applied onto the compact in an amount of more than 0.2 mg/cm^2 , preferably more than 0.5 mg/cm^2 , preferably more than 1.0 mg/cm^2 . According to one embodiment, said grain growth-promoting element is applied onto the compact in an amount of not more than 3.0 mg/cm^2 , preferably not more than 2.5 mg/cm^2 . The above-mentioned limits are particularly applicable when said grain growth promoting element is carbon. Too high levels of carbon may result in an unwanted generation of a carbon shell on the sintered compact and negative effects on the sintering process.

[0030] The grain refiner compound and/or grain growth promoter may be provided by application in the form of a separate or combined liquid dispersion or slurry to the compact. In such a case, the liquid phase is suitably water, an alcohol or a polymer such as polyethylene glycol. The grain refiner compound and grain growth promoter may alternatively be provided by application in the form of solid substances to the compact, preferably powder. The application of the grain refiner compound and grain growth promoter onto the compact is suitably made by applying the grain refiner compound and grain growth promoter onto the compact by, dipping, spraying, painting, or application onto the compact in any other way. When the grain growth promoter is carbon, it may alternatively be provided onto the compact from a carburizing atmosphere. The carburizing atmosphere suitably comprises one or more of carbon monoxide or a C1-C4 alkane, i.e. methane, ethane, propane or butane. The carburizing is suitably conducted at a temperature of from about 1200 to about 1550°C .

[0031] According to one embodiment, the compact presents an open porosity and said compound and said grain growth promoting element is provided as powder in slurry which is applied onto the compact, and the powder particle size of said compound and said grain growth promoting element is small enough to enable said powder thereof to be introduced into pores of the compact by capillary forces generated by said pores. Open porosity may be referred to as continuous porosity, typical for a not yet fully dense material.

[0032] During sintering the grain refiner is diffused away from the surface or surfaces provided with the grain refiner compound, thereby suitably forming a zone with an in average decreasing content of grain refiner when going deeper into the body. A zone is also suitably formed during sintering with an in average increasing content of binder when going deeper into the body. The sintering temperature is suitably from about 1000°C to about 1700°C , preferably from about 1200°C to about 1600°C , most preferably from about 1300°C to about 1550°C . The sintering time is suitably from about 15 minutes to about 5 hours, preferably from about 30 minutes to about 2 hours.

[0033] According to one embodiment, said brazing is inductive brazing. Thereby, the braze joint may be accomplished by means of a brazing process in which a solder, typically comprised by Nickel-Copper-Manganese alloy, is positioned between the base surface of the cemented carbide body and a surface of the steel holder, and in which the solder is forced to diffuse into the cemented carbide body and into the steel by means of inductive heating thereof.

[0034] The object of the invention is also achieved by means of a tool for cutting, drilling or crushing of solid material, wherein

- said tool comprises a cemented carbide body attached to a steel holder by a braze joint located between a base surface of the cemented carbide body and the steel holder,
- said cemented carbide body comprises a hard phase mainly comprised by tungsten carbide, WC, and a binder consisting of cobalt, wherein the cobalt content of the cemented carbide body is at a cobalt content level (A) and is $\leq$ about 5.5 wt%, and wherein,
- the cemented carbide body presents a cobalt content gradient therein, wherein the cobalt content increases from a tip region towards said base surface to a cobalt content level (B) and is at least 4.5 wt% at said base surface, the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.09 .

[0035] According to one embodiment, the cobalt content at said base surface of the cemented carbide body being cobalt content level (B) is at least 5.0 wt%, or at least 5.5 wt%, or at least 6 wt%.

[0036] According to one embodiment, the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.12 , or ≥ 1.14 , or ≥ 1.16 , or ≥ 1.2 .

[0037] Due to the Co content gradient, tensile stresses are induced in the bottom of the cemented carbide body. If the cobalt gradient is too large, some negative effects to the braze joint strength may in some cases occur. According to one embodiment, the ratio cobalt content level (B) to cobalt content level (A) is ≤ 1.5 , or ≤ 1.4 .

[0038] According to one embodiment, said tip region of the cemented carbide body has a mean cobalt content, being cobalt content level (C), of ≤ 4.5 wt%, or ≤ 4.0 wt%, or ≤ 3.5 wt%, or ≤ 3.0 wt%.

[0039] The extent of the tip region into the body is suitably defined as starting at the surface and going about 2 mm down into the cemented carbide body.

[0040] According to one embodiment, the ratio cobalt content level (B) to cobalt content level (C) is ≥ 1.2 , or ≥ 1.3 , or ≥ 1.4 .

[0041] According to one embodiment, the cobalt content of the cemented carbide body is $\leq$ about 5.0 wt%.

[0042] According to one embodiment, the cobalt content of the cemented carbide body is $\leq$ about 4.5 wt%.

[0043] In this application the Co content gradient and the Co content at the base surface of the cemented carbide body are suitably determined by using the hardness, cobalt concentration and tungsten grain size equation (Eq. 1) by Roebuck et al, "A national measurement good practice guide" No. 20, Mechanical Tests for Hardmetals, National Physics Laboratory, 2009.

[0044] By neglecting the effect of residual stresses and the grain growth rate change caused by chromium and carbon gradients it is possible to calculate the cobalt concentration using the hardness, cobalt and WC grain size relation, equation 1, given by

$$HV5 = 888 - 9.9\%Co + [(229 + 532 \exp((6 - \%Co)/6.7))] / dWC^{0.5} \quad (\text{Eq. 1})$$

[0045] The WC grain size dWC is first calculated using equation 1 on HV5 hardness data from a reference sample with the same mean Co content. Then HV5 measurements on a sample having a Co content gradient are done by making numerous indentations on a cross sectional cut. As an example, if the cemented carbide body has a thickness of 12 mm one could program the hardness tester to make indentations at 0.3, 0.8, 1.3, 1.8, 2.3, 2.8, 3.3, 3.8, 4.3, 4.8, 5.3 and 5.8 mm distance to the edge on a cross sectional cut. The distance between the indentations can for example be set to 0.5 mm. From the results a HV5 iso lines map is provided. The HV5 hardness iso lines map can then be transformed into a Co content iso lines map by using equation 1.

[0046] The mean Co content for the whole, or part, of the cemented carbide body is suitably determined by chemical analysis.

[0047] According to one embodiment, said element that has a grain growth inhibiting effect on WC is any of chromium, vanadium, tantalum or niobium, preferably chromium or vanadium, most preferably chromium. Accordingly, the grain refiner compound is suitably selected from the group of carbides, mixed carbides, carbonitrides or nitrides of vanadium, chromium, tantalum and niobium. Preferably, the grain refiner compound is a carbide or nitride of chromium or vanadium, such as Cr_3C_2 , $Cr_{23}C_6$, Cr_7C_3 , Cr_2N , CrN or VC, most preferably carbides of chromium, such as Cr_3C_2 , $Cr_{23}C_6$, or Cr_7C_3 .

[0048] According to one embodiment, said element that has a grain growth promoting effect on WC is carbon.

[0049] The cemented carbide body can be coated with one or more layers according to known procedures in the art. For example, layers of TiN, TiCN, TiC, and/or oxides of aluminum may be provided onto the cemented carbide body. However, the base surface, aimed for attachment by means of brazing may not be provided with such coating.

[0050] According to one embodiment, the braze joint has been accomplished by means of inductive brazing. Thereby, the braze joint may be accomplished by means of a brazing process in which a solder, typically comprised by Nickel-Copper-Manganese alloy, is positioned between the base surface of the cemented carbide body and a surface of the

steel holder, and in which the solder is forced to diffuse into the cemented carbide body and into the steel by means of inductive heating thereof.

[0051] The cemented carbide body is a cemented carbide tool body. In one embodiment the cemented carbide body is a body for a mining tool, such as a rock drilling tool or a mineral cutting tool, or for an oil and gas drilling tool. In one embodiment the cemented carbide body is a coldforming tool, such as a tool for forming thread, beverage cans, bolts and nails.

[0052] According to one embodiment, said cemented carbide body comprises top and lateral surfaces and said base surface, and wherein the distance between the top surface and the base surface, which is opposed to the top surface, is less than 21.2 mm, preferably less than 12.5 mm, and more preferably less than 8.3 mm, wherein the cemented carbide body presents a cobalt content gradient therein in a direction from said top surface towards said base surface as a result of the presence of said grain growth promoting element and said grain growth inhibiting element in the region of said top surface. All measures correspond to the previously mentioned measures of a compact adjusted with regard to the fact that the dimensions of the compact are about 1.2 times larger than the corresponding measures of the sintered compact, i.e. the cemented carbide body.

[0053] For a mining tool body, the geometry of the body is typically ballistic, spherical or conical shaped, but also chisel shaped and other geometries are suitable in the present invention. According to one embodiment said compact has a generally knob-like shape (including ballistic, semi-spherical or conical shape), has a generally circular bottom surface with a diameter h , and has a height h , wherein $0.5 < h/d < 2$, and said bottom surface defines said base surface. According to another embodiment said compact has a generally plate-like shape, has width w , a height h and a thickness t , and wherein $0.2 < h/w < 2$, $t < w$, $1.7 \text{ mm} < t < 17 \text{ mm}$, and, said base surface is a large side of said compact, and said tip region includes at least a part of an opposite large side thereof. All measures correspond to the previously mentioned measures of a compact adjusted with regard to the fact that the dimensions of the compact are about 1.2 times larger than the corresponding measures of the sintered compact, i.e. the cemented carbide body.

[0054] The present invention further relates to the use of the cemented carbide tool body in rock drilling or mineral cutting operations.

[0055] Further features of the invention will be presented in the following detailed description, with reference to the annexed drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056] Embodiments of the invention will be presented more in detail with reference to the annexed drawing, on which;

Fig. 1 is a perspective view of an embodiment of a tool according to the invention,

Fig. 2 is a perspective view of a compact according to the invention before application of a coating thereon,

Fig. 3 shows the application of a coating of a grain-growth inhibiting compound and a grain growth promoting element onto an outer surface of the compact shown in fig. 2,

Fig. 4 is a side view of the coated compact,

Fig. 5 is a cross-section of a part of the tool shown in fig. 1, presenting a body formed by the compact shown in figs. 2-4 after sintering thereof and connected to a holder by means of brazing,

Fig. 6 is a perspective view of another embodiment of a compact before application of a coating thereon,

Fig. 7, shows the application of a coating of a grain-growth inhibiting compound and a grain growth promoting element onto an outer surface of the compact shown in fig. 6,

Fig. 8 shows the coated compact of fig. 7,

Fig. 9 shows a part of another embodiment of a tool provided with a body formed the compact shown in figs. 6-8 after sintering thereof and connection to a holder by means of brazing,

Fig. 10 is a perspective view of one embodiment of a coated compact,

Fig. 11 is a perspective view of another embodiment of a coated compact,

Fig. 12 is an ISO-line representation of a cross-section of a body formed by a sintered compact having a cylindrical geometry and a coating of a suspension of chromium carbide and free carbon, showing measured hardness for a cemented carbide body having a mean Co-content of 5.0 wt%,

Fig. 13 is an ISO-line representation of a cross-section of a body formed by a sintered compact having a cylindrical geometry and a coating of a suspension of chromium carbide and free carbon, showing calculated Co-content respectively for a cemented carbide body having a mean Co-content of 5.0 wt%,

Fig. 14 is an ISO-line representation of a cross-section of a body formed by a sintered compact having geometry and a coating of a suspension of chromium carbide and free carbon, as shown in figs. 3-5, showing measured hardness and calculated Co-content respectively for a cemented carbide body having a mean Co-content of 10 wt%,

Fig. 15 is an ISO-line representation of a cross-section of a cemented carbide body formed by a sintered compact having geometry and a coating of a suspension of chromium carbide and free carbon as shown in fig. 11, showing measured hardness and calculated Co-content respectively for a cemented carbide body having a mean Co-content of 6.0 wt%,

Fig. 16 is an ISO-line representation corresponding to the one shown in fig. 15, but for a cemented carbide body having an mean Co-content of 8 wt%, and

Fig. 17 is an ISO-line representation of a cross section of a body formed by a sintered compact having geometry and coating of a suspension of chromium carbide and free carbon as shown in fig. 10, showing measured hardness and calculated Co-content respectively for a cemented carbide body having a mean Co-content of 8 wt%.

DETAILED DESCRIPTION OF THE INVENTION

[0057] Fig. 1 shows an embodiment of a tool 1 according to the invention, comprising a cemented carbide body 2 and a holder 3. The cemented carbide body 1 is connected to the holder 3 by means of brazing.

[0058] The tool 1 shown in fig. 1 is an example of a so called MGT-tool designed for mining and graveling applications (MGT: Mineral and Grounds Tools). However, the invention is not limited to such tools but could be applied to all kind of tools comprising a cemented carbide body attached to a steel holder by means of brazing.

[0059] The body 2 shown in fig. 1 is produced by means of a process in which a powder mixture is compacted into a compact which is then sintered to the body 2. The process includes selection of a suitable powder mixture composition including tungsten carbide and cobalt, compaction thereof to a suitable compact geometry, and treatment of the compact in order to affect the grain size of the tungsten carbide in connection to the subsequent sintering, and to induce a cobalt gradient therein, wherein in the cobalt content increases towards a surface of the sintered body that could preferably be used as a surface which is attached to a steel holder by means of brazing. A compact produced in accordance with the teaching is shown in fig. 2 and indicated with reference number 4. A process step in which the compact 4 is provided with a coating comprising an element that has a grain growth inhibiting effect on tungsten carbide and an element that has a grain growth inhibiting effect on tungsten carbide is shown in fig. 3.

[0060] The invention thus includes a method of producing a tool 1 for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body 2 attached to a steel holder 3, wherein said method comprises the steps of providing said cemented carbide body 2 by; providing a powder mixture, compacting said powder mixture into a compact 4 comprising a hard phase mainly comprised by tungsten carbide, WC, and a binder consisting of cobalt, wherein the cobalt content of the compact 4 is equal to or lower than about 5.5 wt%, providing a compound comprising a carbide or a nitride formed by carbon or nitrogen and an element that has a grain growth inhibiting effect on tungsten carbide, and providing an element that has a grain growth promoting effect on WC, and applying said compound and said grain growth promoting element onto at least a tip region 5 of said compact 4, wherein said tip region 5 will form a tip region 6 of the cemented carbide body 2 aimed for engagement with material to be cut, drilled into, turned or crushed by means of said tool 1, and keeping a base surface 7 of the compact 4, which will form a base surface 8 of the cemented carbide body 2 that will be attached to said steel holder 3, free from said compound and grain growth promoting element, wherein said compound and said grain growth promoting element is of a type that will diffuse into the compact 4 in connection to sintering of the latter and thereby will induce a generation of a cobalt content gradient in the sintered compact, with an increasing cobalt content in a direction away from a surface onto which said compound and said grain growth promoting element has been applied. The compact 4 provided with said compound and said grain growth promoting element is then sintered into said cemented carbide body 2 such that the cobalt content at said base surface 8 becomes equal to or higher than 4.5 wt% as a result of said induced generation of a cobalt content gradient, the ratio cobalt content level at the base surface 8 to cobalt content of the compact becomes ≥ 1.09 , and said base surface 8 of the cemented carbide

body 2 is attached to the steel holder 3 by means of brazing. Normally, brazing would not be conceived for a body having such a low mean content of cobalt, but due to a surprisingly strong effect of said compound and said grain growth promoting element, the cobalt content at the base surface 8 of the body 2 is surprisingly high and therefore enables brazing as a means of attaching the body to the steel holder 3. With this technique of controlling the cobalt content of the base surface of the body, bodies with a very low mean content of cobalt can be attached to a steel holder by means of brazing. Depending on the design of the compact and how much of said compound and grain growth promoting element that is adopted by the compact, the mean cobalt content may be below 5 wt% or even below 4.5 wt%.

[0061] The compact 4, as presented in figs. 2-4, as well as the body 2 formed therefrom, is cylindrical with a conical tip. It may be generally defined as knob-shaped. The generally circular base surface 7 of the compact 4, and thus the base surface 8 of the body 2, is formed by a bottom surface thereof located opposite to the tip region 5, 6 of the compact 4 and body 2 respectively. The base surface 7 of the compact 4 and the base surface 8 of the body 2 are generally flat, but could have some other geometry if necessitated by the design of the steel holder 3 or because of other design-related or function-related reasons.

In order to apply said compound and said grain growth promoting element, slurry 9 comprising said compound, said grain growth promoting element and a solvent, suitably water, an alcohol or a polymer such as polyethylene glycol, is provided in a can 10, and the compact 4 is dipped into the slurry 9, as shown in fig. 3. The compact 4 has an open porosity, and the particles of said compound and said grain growth promoting element in the slurry 9 are of such size that particles of said compound and said grain growth promoting element will be introduced into pores of the compact 4 by capillary forces generated by said pores. Other principles of application of said compound are possible, and have been mentioned in the foregoing summary of the invention.

[0062] In the exemplifying embodiment, said compound consists of particles of Cr_3C_2 and said grain growth promoting element consists of carbon in the form of soot. As previously mentioned, other alternatives are feasible within the scope of the invention.

[0063] In order to achieve sufficient cobalt gradient, and as a result thereof a sufficiently high cobalt content at the base surface 8 of the body 2 to enable attachment of the latter to a steel holder 3 by means of brazing, the amount of said compound and said grain growth promoting element adopted by the compact 4 should be above a predetermined level in relation to the mass of the compact 4. However, a primary reason for introducing said compound and said grain growth promoting element in the compact may be to control the grain size of the tungsten carbide during the subsequent sintering of the compact 4 in order to obtain a body presenting a tip surface having higher hardness due to lower binder content (and slightly larger tungsten carbide grains) and a more ductile region below said surface having higher binder content. Thus, this may be determining for the amount of added compound and grain growth promoting element and the displacing effect thereof on cobalt. Accordingly, in order to promote sufficiently high cobalt content at the base surface 8 of the body 2, the shape of the compact 4, in particular the height is designed with regard thereto. The height h of the compact 4 should be less than 25 mm, preferably less than 20 mm, preferably less than 15 mm, and more preferably less than 10 mm. A too high cylindrical compact will result in insufficiently high cobalt content at the base surface thereof. Referring to fig. 4, for a cylindrical compact having a height h and a generally circular base surface with a diameter d , $0.5 < h/d < 2$. In other words, the mass of compact into which cobalt is displaced from the region in which said compound and grain growth promoting element is added should be delimited such that a significant cobalt gradient is achieved and remarkably increased cobalt content is obtained at said base surface. The porosity of the compact may be in the region of 50%, whereby the measures of the non-sintered compact 4 are about 1.2 times the measures of the sintered compact, i.e. the cemented carbide body 2.

[0064] In order to further promote the generation of high cobalt content at the base surface, said compound and grain growth promoting element may also be applied onto lateral surfaces 11 of the compact 4. However, if applied all the way to the edge 12 or transition region between lateral surfaces 11 and base surface 7, said compound and grain growth promoting element may have a negative effect on the cobalt content of the base surface 7 in the region of said edge 12 or transition region. Therefore, it is preferred that, in a zone 11' of the lateral surface or surfaces 11 neighbouring the base surface 7, the lateral surface or surfaces 11 are excluded from the application of said compound and said grain growth promoting element. Figs. 2-4 show the presence of such a zone.

[0065] When said compact comprises top and lateral surfaces 11 and said base surface 7, said compound and said grain growth promoting element should be applied to at least 50%, preferably at least 70%, and most preferably to at least 80% of the total area of the top and lateral surfaces. In the case of a knob-like body like the one shown in fig. 2, the tip region 5 defines a rounded or conical top surface 5.

[0066] Fig. 6 shows an alternative embodiment of a compact 13, wherein said compact 13 has a generally plate-like shape, has a width w , a height h and a thickness t , and wherein $0.2 < h/w < 2$, $t < w$, $2\text{ mm} < t < 20\text{ mm}$, and, said base surface 14 is a large side of said compact, and said tip region 16 includes at least a part of an opposite large side 15 thereof.

[0067] Fig. 7 shows an alternative approach of where to apply said compound and grain growth element onto the compact 13. The tip region 16 of the compact 13, which will form a tip region of the cemented carbide body aimed for engagement with material to be cut, drilled into, turned or crushed by means of said tool, is provided with said compound

and grain growth promoting element. Application is achieved by means of dipping of the compact 13 into a can filled with slurry corresponding to the can 10 and slurry 9 shown in fig. 3. Depending on the dipping angle α of the compact into the slurry, wherein α is the angle between the large side of the compact opposite to said base surface, the application may be more or less concentrated to the tip region 16. Fig. 10 shows an example in which α is approximately 45°, and only an edge region defining said tip region 16 is provided with said compound and grain growth promoting element. Fig. 11 shows an alternative embodiment in which the whole large side 15 opposite said base surface 14 has been provided with said compound and grain growth promoting element by using a dipping angle α of approximately 0°. Parts of the lateral sides 17, from the large side 15 and a distance x towards the base surface 14 of the compact 13 has been provided with said compound and grain growth promoting element. The compact 13 has lateral surfaces 18 neighbouring the base surface 14. A zone 18' of the lateral surface or surfaces neighbouring the base surface 14, is excluded from the application of said compound and said grain growth promoting element. In this context it should be emphasized that other application principles than dipping into slurry are of course conceivable for the application of said compound and grain growth promoting element. However, dipping into slurry has been found a relatively reliable and relatively uncomplicated way of application and is therefor, for the moment being, suggested as preferred application method.

[0068] Fig. 9 shows a body 19 formed by means of sintering of a compact 13 provided with said compound and grain growth promoting element in accordance with the principles disclosed in figs. 7 and 8. A base surface 20, corresponding to the base surface 14 of the compact 13, is attached to a steel holder 21 by means of brazing. Also an end region of the body 19 opposite to the end at which the tip region is located may be attached to steel holder 21 by means of brazing. The body 19 and the steel holder 21 together define a tool 22. The tip region of the body is indicated with 23.

[0069] As previously discussed regarding the cylindrical compact and body presented in figs. 1-5, the design of the compact will have an impact on the possibility of obtaining sufficiently high cobalt content at the base surface 20 of the body 19. The mass of compact into which cobalt is displaced should be delimited. Accordingly, for a compact with the design presented in fig. 6, $2\text{ mm} < t < 20\text{ mm}$. The lower the mean cobalt content in the compact, the more important it becomes that the thickness thereof is relatively low in order to reduce the mass of compact into which cobalt displaced from regions in which said compound and grain growth promoting element are applied is low, such that a high level of cobalt (equal to or higher than 6 wt%) is obtained at the base surface 20. Therefore, t is less than 20 mm, preferably less than 15 mm, and more preferably less than 10 mm, wherein said compound and said grain growth promoting element are applied onto at least a part of said top surface (here large side 15), preferably on the whole top surface. The porosity of the compact may be in the region of 50%, whereby the measures of the non-sintered compact are about 1.2 times the measures of the sintered compact, i.e. the cemented carbide body.

EXAMPLES

[0070] In the following, examples that prove the unexpectedly strong effect of the application of a compound according to the invention and a grain growth promoting element according to the invention on the cobalt gradient in a sintered compact comprising tungsten carbide and cobalt are presented. Though the mean cobalt content in some of the test samples are higher than the mean cobalt content according to the claimed invention, these examples give a very clear vision of what cobalt content levels that could be expected at a base surface for sintered compacts with a mean cobalt content as suggested by the invention. Accordingly, the following examples should be regarded as supporting the general inventive concept of providing a sufficiently high cobalt content at the base surface of a sintered compact, including for different shapes of the cemented carbide body, such that the latter may be attached to a steel holder by means of brazing, preferably inductive brazing.

Powder

[0071] The powder used in the test samples was granulated by spray drying, had a mixture of tungsten carbide, cobalt binder and polymer binder having a carbon balance in such way that no eta phase is found after sintering without green body surface treatment with grain growth promoters and grain growth inhibitors and in the same time having a carbon balance that is compensated for the carbon absorbed from the treatment.

Sintering

[0072] The sintering was done under normal production sintering conditions for hardmetals.

Hardness measurement

[0073] Hardness measurement was done using a programmable hardness tester, KB30S by KB Prüftechnik GmbH. Untreated samples were used as references.

Estimation of the cobalt concentration

[0074] An estimation of the cobalt concentration was done using the known equation by Roebuck et al^[1] that relates hardness with weight% Co and tungsten carbide grain size, d_{WC} . The untreated reference samples were used to evaluate the tungsten carbide grain size by using the known %Co and measured hardness. Finally, the weight% Co was back calculated from the measured hardness values of the treated samples.

$$HV5 = 888 - 9.9\%Co + [(229 + 532 \exp((6 - \%Co)/6.7))] / d_{WC}^{0.5} \text{ (Equation 1).}$$

[0075] One important approximation with this method is using a constant tungsten carbide grain size. The carbide grain size is affected by the treatment in a zone below the treated surface to about 2-3 mm below the treated surface. However, the calculation of %Co is used to see the amount of cobalt far away from the surface that was treated. Another approximation was to neglect the residual stresses both from sample preparation and variation in thermal expansion. Each reference sample used for establishing d_{WC} was measured ten times on HV5. Results are presented in table 1.

Table 1

Grade	HV5 (std-dev.)	d_{WC} (μm) Eq. 1
5% Co	1502 (12)	1.6
10%Co	1088 (7)	3.0
6%Co	1383 (6)	1.9
8%Co	1199 (15)	2.6

Example 1 (cylindrical sample)

[0076] Green bodies, compacts, were powder pressed to 50% porosity into 12 mm diameter cylindrical bodies (pellets) having a total height of 12 mm.

[0077] The treatment was done by coating the body from the top all the way down to 2/3 (about 8 mm) below the top with a suspension holding chromium carbide and free carbon. This corresponds to about a projected surface area $\pi 2rh + \pi r^2 = \pi \cdot 2 \cdot 8 + \pi \cdot 6 \cdot 6 = 415 \text{ mm}^2$ (treated part of the body approximated with a cylinder with radius r and height h). Note that effective surface area (the true surface area due to roughness of the surface) is not considered.

[0078] The sintered samples were cut along their cylindrical center line and then ground and polished before the HV5 measurement.

[0079] A few bodies were chemically analyzed on chromium and cobalt. Prior analyzing, the bodies were cut in a top piece defined by a cut at 2.3 mm below the top and a bottom piece defined by a cut at 1.5 mm above the bottom. The analyzing methods are Co % XRF:H12 and Cr % XRF:HM12. Results are presented in table 2.

Table 2 (5.0 % Co-grade)

Position	Co %	Cr %
Top	4.17	0.33
Bottom	5.71	<0.10

[0080] From the chemical results it is indeed seen a higher Co concentration in the bottom.

[0081] The HV5 data and the estimation of the cobalt concentration are reproduced in figures 12 and 13. The results agree well with chemical analysis above. It is therefore appropriate to use the hardness, cobalt concentration and tungsten grain size equation by Roebuck et al. The difference is partly affected by that the chemical analysis gives an average cobalt content of the whole piece analysed while the hardness method by Roebuck et al. gives cobalt content maps over the whole body.

The amount of C and Cr_3C_2 is roughly 5 mg and 30 mg respectively and hence the specific treatment would be 0.012 mg/mm² and 0.072 mg/mm² C and Cr_3C_2 respectively.

Figure 13 shows that the cobalt concentration difference between the zone closest to the treated surface and zone most distant from the treated surface is about 1.8 wt%.

Example 2 (cylindrical sample with cone) - background example

[0082] Green bodies, compacts, were powder pressed to 50% porosity into 19 mm diameter cylindrical bodies with a conical tip having a total height of 25 mm.

[0083] The treatment was done by coating the body from the tip all the way down to 20mm below the tip with a suspension holding chromium carbide and free carbon. This corresponds to about a projected surface area $\pi r(S+2h) = \pi \cdot 9.5 \cdot (14.2 + 2 \cdot 9.4) = 985 \text{ mm}^2$ (treated part of the body approximated with a cone with radius r and side S and a cylinder with radius r and height h). Note that effective surface area is not considered.

[0084] A few bodies were chemically analyzed on chromium and cobalt. Prior analyzing, the bodies were cut in a top piece defined by a cut at 6.5 mm below the tip and a bottom piece defined by a cut at 3 mm above the bottom. The analyzing methods are Co % XRF:H12 and Cr % XRF:HM12. Results are presented in table 3.

Table 3 (10% Co-grade)

Position	Co %	Cr %
Top	9,27	0,14
Bottom	10,90	0,06

[0085] From the chemical results it is indeed seen a higher Co concentration in the bottom. The sintered samples were cut along their cylindrical center line and then ground and polished before the HV5 measurement. The HV5 data and the estimation of the cobalt concentration are reproduced in figure 14. The results agree well with chemical analysis above. It is therefore appropriate to use the hardness, cobalt concentration and tungsten grain size equation by Roebuck et al. The difference is partly affected by that the chemical analysis gives an average cobalt content of the whole piece analyzed while the hardness method by Roebuck et al. gives cobalt content maps over the whole body.

[0086] The amount of C and Cr_3C_2 is roughly 12 mg and 60 mg respectively and hence the specific treatment would be 0.012 mg/mm² and 0.061 mg/mm² C and Cr_3C_2 respectively.

[0087] Figure 14 shows that the cobalt concentration difference between the zone closest to the treated surface and zone most distant from the treated surface is about 2.2 wt%.

Examples 3-5 (rectangular samples) - background examples

[0088] Green bodies, compacts, were powder pressed to 50% porosity into 15x15x6 mm rectangular samples. The green bodies were dipped according to the drawing showed by figure 7. Sintering was done with standard production sintering furnaces. The samples were cut after sintering followed by grinding, polishing and HV5 measurement.

Example 3 (6%Co)

[0089] Treatment was done on the projective surface area about $1 \cdot 15 \cdot 4 + 15 \cdot 15 = 285 \text{ mm}^2$. The added amount of C and Cr_3C_2 is 2.8 mg and 14.0 mg respectively and hence the specific treatment is 0.010 mg/mm² and 0.049 mg/mm² respectively.

[0090] The planar treated or dipped sample of the 6% Co grade shows that the HV5 is highest at the treated side and lowest at the opposite side, see figure 15. The calculation of the Co distribution shows that the difference in cobalt concentration between treated surface and opposite surface is about 1.8%.

Example 4 (8%Co)

[0091] Treatment was done on the projective surface area about $1 \cdot 15 \cdot 4 + 15 \cdot 15 = 285 \text{ mm}^2$. The amount of C and Cr_3C_2 is 3.0 mg and 15.1 mg respectively and hence the specific treatment is 0.011 mg/mm² and 0.053 mg/mm² respectively.

[0092] The planar treated or dipped sample of the 8% Co grade shows that the HV5 is highest at the treated side and lowest at the opposite side, see figure 16. The calculation of the Co distribution shows that the difference in cobalt concentration between treated surface and opposite surface is about 2.2%.

Example 5 (8%Co)

[0093] Treatment was done on the projective surface area about $15 \cdot 1.3 \cdot (1/\cos 60^\circ + 1/\sin 60^\circ) + 1.3^2/\sin 120^\circ = 63 \text{ mm}^2$. The amount of C and Cr_3C_2 is 0.6 mg and 3.2 mg respectively and hence the specific treatment is 0.010 mg/mm² and 0.051 mg/mm² respectively.

[0094] The edge treated or dipped sample of the 8% Co grade shows that the HV5 is highest at the treated edge and lowest at the opposite side, see figure 17. The calculation of the Co distribution shows that the difference in cobalt concentration between treated surface and opposite surface is about 2.3%.

Summary of iso-lines maps from examples 1-5:

[0095] Table 4 shows a summary of the found differences in cobalt concentration (iso-lines maps) between zones closest and most far away from the treated surface.

Table 4

	5.0%Co (ex. 1)	10.0%Co (ex. 2)	6.0%Co (ex. 3)	8.0%Co (ex. 4)	8.0%Co (ex. 5)
Averaged %Co difference	1.7	2.2	1.8	2.2	2.3

[0096] The results agree well with chemical analysis for samples of Example 1 (table 2) and Example 2 (table 3). It is therefore appropriate to use the hardness, cobalt concentration and tungsten grain size equation by Roebuck et al. for determining cobalt content.

Example 6 (brazing of 5% sample onto steel)

[0097] Samples of Example 1 were brazed onto steel plates 20 mm in diameter and 5 mm in thickness made of EN 42CrMo4. Before brazing the steel plates were shot blasted with steel grains. Afterwards the plates were cleaned in an ultrasound cleaner in an ethanol solvent. The cemented carbide samples were grit blasted with SiC grit and also afterwards cleaned in an ultrasound cleaner in an ethanol solvent.

The used braze material was also cleaned in an ultrasound cleaner in an ethanol solvent.

[0098] Braze material used: High Temp 548 (55% Cu, 6% Ni, 35% Zn, 4% Mn) with solidus temp. 880°C and liquidus temp. 920°C.

Flux used: Superior 609

Assembling procedure: Cover braze shim with flux. Put shim on steel and cemented carbide-disc on top. Cover with flux.

[0099] Inductive brazing under ambient conditions was used. The brazing unit consisted of two 20kW generators, but just one was used due to the reason that just one coil (single coil) was necessary to heat the assembly. The frequency was adjusted to between 70 and 450kHz according to resonance frequency which guarantees fast heating. The assembly was heated up to 950°C (temperature measured by two pyrometers). After around 15 s the braze melted. After about 10 s the assembly was let to cool down in air to room temperature.

[0100] The braze joint was satisfactory strong.

References

[0101] Ref [1]. A national measurement good practice guide, No 20, Mechanical tests for hardmetals, B Roebuck, M Gee, E G Bennet and R Morell, National Physical Laboratory. 1999.

Claims

1. A method of producing a tool (1, 22) for cutting, drilling or crushing of solid material, said tool comprising a cemented carbide body (2, 19) attached to a steel holder (3, 21), wherein said method comprises the steps of

- providing said cemented carbide body (2, 19) by;
- providing a powder mixture,
- compacting said powder mixture into a compact (4, 13) comprising a hard phase mainly comprised by tungsten carbide, WC, and a binder consisting of cobalt, wherein the cobalt content of the compact (4, 13) is at a cobalt content level (A) and is ≤ 5.5 wt%,
- providing a compound comprising a carbide or a nitride formed by carbon or nitrogen and an element that has a grain growth inhibiting effect on tungsten carbide, and providing an element that has a grain growth promoting effect on WC,
- applying said compound and said grain growth promoting element onto at least a tip region (5, 16) of said

compact (4, 13), wherein said tip region (5, 16) will form a tip region (6, 23) of the cemented carbide body (2, 19) aimed for engagement with material to be cut, drilled into or crushed by means of said tool (1, 22), and keeping a base surface (7, 14) of the compact (4, 13), which will form a base surface (8, 20) of the cemented carbide body that will be attached to said steel holder (3, 21), free from said compound and grain growth promoting element,

- wherein said compound and said grain growth promoting element is of a type that will diffuse into the compact (4, 13) in connection to sintering of the latter and thereby will induce a generation of a cobalt content gradient in the sintered compact (2, 19), with an increasing cobalt content in a direction away from a surface onto which said compound and said grain growth promoting element has been applied,

- sintering the compact (4, 13) provided with said compound and said grain growth promoting element into said cemented carbide body (2, 19) such that the cobalt content at said base surface (8, 20) being cobalt content level (B) becomes ≥ 4.5 wt% as a result of said induced generation of a cobalt content gradient, the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.09 , and

- attaching said base surface (8, 20) of the cemented carbide body (2, 19) to the steel holder (1, 22) by means of brazing.

2. A method according to claim 1, wherein the cobalt content at said base surface (8, 20) being cobalt content level (B) becomes ≥ 5.0 wt%.

3. A method according to any one of claims 1-2, wherein the cobalt content at said base surface (8, 20) being cobalt content level (B) becomes ≥ 6.0 wt%.

4. A method according to any one of claims 1-3, wherein the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.14 .

5. A method according to any one of claims 1-4, wherein said tip region (6, 23) of cemented carbide body (2, 19) has a mean cobalt content, being cobalt content level (C), of ≤ 4.5 wt%.

6. A method according to any one of claims 1-5, wherein the ratio cobalt content level (B) to cobalt content level (C) is ≥ 1.2 .

7. A method according to any one of claims 1-6, wherein the cobalt content of the cemented carbide body, being cobalt content level (A), is ≤ 5.0 wt%.

8. A method according to any one of claims 1-7, wherein, in said compound, the element that has a grain growth inhibiting effect on WC is any of chromium, vanadium, tantalum or niobium and said grain growth promoting element is carbon in the form of graphite.

9. A tool (1, 22) for cutting, drilling or crushing of solid material, wherein

- said tool (1, 22) comprises a cemented carbide body (2, 19) attached to a steel holder (3, 21) by a braze joint located between a base surface (8, 20) of the cemented carbide body (2, 19) and the steel holder (3, 21),

- said cemented carbide body (2, 19) comprises a hard phase mainly comprised by tungsten carbide, WC, and a binder consisting of cobalt, wherein the cobalt content of the cemented carbide body (2, 19) is at a cobalt content level (A) and is equal to or lower than 5.5 wt%, and wherein,

- the cemented carbide body (2, 19) presents a cobalt content gradient therein wherein the cobalt content increases from a tip region (6, 23) towards said base surface (8, 20) to a cobalt content level (B) and is at least 4.5 wt% at said base surface (8, 20), the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.09 .

10. A tool (1, 22) according to claim 9, wherein the cobalt content level (B) is at least 5.0 wt% at said base surface (8, 20) of the cemented carbide body (2, 19).

11. A tool (1, 22) according to any one of claims 9-10, wherein the cobalt content level (B) is at least 6 wt% at said base surface (8, 20) of the cemented carbide body (2, 19).

12. A tool (1, 22) according to any one of claims 9-11, wherein the ratio cobalt content level (B) to cobalt content level (A) is ≥ 1.14 .

13. A tool (1,22) according to any one of claims 9-12, wherein said tip region (6, 23) of cemented carbide body (2, 19) has a mean cobalt content, being cobalt content level (C), of ≤ 4.5 wt%.

14. A tool (1,22) according to claim 13, wherein the ratio cobalt content level (B) to cobalt content level (C) is ≥ 1.2 .

15. A tool (1,22) according to any one of claims 9-14, wherein the cobalt content of the cemented carbide body, being cobalt content level (A), is ≤ 5.0 wt%.

16. A tool (1, 22) according to any one of claims 9-15, wherein

- at least in the tip region (6, 23) thereof, the cemented carbide body (2, 19) presents an outer surface zone having an elevated WC mean grain size as a result of an elevated content of an element that has a grain growth promoting effect on WC, and a second zone below said outer surface zone, wherein, in said second zone, the WC mean grain size is smaller than in said outer surface zone as a result of an elevated content therein of an element that has a grain growth inhibiting effect on WC, and wherein
- the cemented carbide body (2, 19) presents the cobalt content gradient therein as a result of the presence of said grain growth promoting element and said grain growth inhibiting element therein.

Patentansprüche

1. Verfahren zum Herstellen eines Werkzeuges (1, 22) zum Schneiden, Bohren oder Brechen von festem Material, wobei das Werkzeug einen Körper (2, 19) aus Sintercarbid aufweist, welcher an einem Stahlhalter (3, 21) angebracht ist, wobei das Verfahren die Schritte aufweist:

- Bereitstellen des Sintercarbidkörpers (2, 19) durch
- Bereitstellen einer Pulvermischung,
- Zusammenpressen der Pulvermischung zu einem Kompaktkörper (4, 13), der eine harte Phase aufweist, welche hauptsächlich Wolframcarbid, WC, und ein Bindemittel aufweist, welches aus Kobalt besteht, wobei der Kobaltgehalt des Kompaktkörpers (4, 13) ein Kobaltgehaltsniveau (A) hat, welches $\leq 5,5$ Gew.-% ist,
- Bereitstellen einer Verbindungssubstanz, welche aus einem Carbid oder Nitrid durch Kohlenstoff oder Stickstoff und ein Element gebildet wird, welches einen Kornwachstum verhindernden Effekt auf Wolframcarbid hat, und Bereitstellen eines Elementes, welches einen Kornwachstum fördernden Effekt auf WC hat,
- Aufbringen der Verbindungssubstanz und des Kornwachstum förderlichen Elementes auf zumindest einen Spitzenbereich (5, 16) des Kompaktkörpers (4, 13), wobei der Spitzenbereich (5, 16) einen Spitzenbereich (6, 23) des Sintercarbidkörpers (2, 19) bildet, welcher für den Eingriff mit dem mit Hilfe des Werkzeuges (1, 22) zu schneidenden, zu bohrenden oder zu brechenden Material vorgesehen ist, und Freihalten einer Grundfläche (7, 14) des Kompaktkörpers (4, 13), welche eine Grundfläche (8, 20) des Sintercarbidkörpers bildet, der an dem Stahlhalter (3, 21) angebracht wird, von der Verbindungssubstanz und dem Kornwachstum fördernden Element,
- wobei die Verbindungssubstanz und das Kornwachstum fördernde Element von einer Art ist, die in Verbindung mit dem Sintern des Kompaktkörpers in letzteren eindiffundiert und dadurch die Erzeugung eines Kobaltgehaltsgradienten in dem gesinterten Kompaktkörper (2, 19) induziert, mit einem zunehmenden Kobaltgehalt in einer Richtung weg von einer Oberfläche auf welcher die Verbindungssubstanz und das Kornwachstum fördernde Element aufgebracht worden ist,
- Sintern des Kompaktkörpers (4, 13), welcher mit der Verbindungssubstanz und dem Kornwachstum fördernden Element versehen ist, zu einem Sintercarbidkörper (2, 19), sodass der Kobaltgehalt an der Grundfläche (8, 20) ein Kobaltgehaltsniveau (B) annimmt, welches $\geq 4,5$ Gew.-% wird als Folge der induzierten Erzeugung eines Kobaltgehaltsgradienten, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobaltgehaltsniveau (A) $\geq 1,09$ ist, und
- Anbringen der Grundfläche (8, 20) des Sintercarbidkörpers (2, 19) an dem Stahlhalter (1, 22) durch Hartlöten.

2. Verfahren nach Anspruch 1, wobei der Kobaltgehalt an der Grundfläche (8, 20), der auf dem Kobaltgehaltsniveau (B) liegt, $\geq 5,0$ Gew.-% wird.

3. Verfahren nach einem der Ansprüche 1 bis 6, wobei der Kobaltgehalt an der Grundfläche (8, 20), welcher das Kobaltgehaltsniveau (B) ist, $\geq 6,0$ Gew.-% wird.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobalt-

gehaltsniveau (A) $\geq 1,14$ ist.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei der Spitzenbereich (6, 23) des Sintercarbidskörpers (2, 19) einen mittleren Kobaltgehalt hat, der ein Kobaltgehaltsniveau (C) $\leq 4,5$ Gew.-% ist.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobaltgehaltsniveau (C) $\geq 1,2$ ist.

7. Verfahren nach einem der Ansprüche 1 bis 6, wobei der Kobaltgehalt des Sintercarbidskörpers, welcher das Kobaltgehaltsniveau (A) hat ≤ 5 Gew.-% ist.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei in der Verbindungssubstanz das Element, welches einen Kornwachstum verhindernden Effekt auf WC hat, eines der Elemente Chrom, Vanadium, Tantal oder Niob ist, und dass das Kornwachstum fördernde Element Kohlenstoff in der Form von Graphit ist.

9. Werkzeug (1, 22) zum Schneiden, Bohren oder Brechen von festem Material, wobei

- das Werkzeug (1, 22) einen Sintercarbidskörper (2, 19) aufweist, der an einem Stahlhalter (3, 21) durch eine Hartlotverbindung angebracht ist, die zwischen einer Basisfläche (8, 20) des Sintercarbidskörpers (2, 19) und dem Stahlhalter (3, 21) liegt,

- wobei der Sintercarbidskörper (2, 19) eine harte Phase aufweist, die hauptsächlich Wolframcarbid, WC, und ein Bindemittel aufweist, welches aus Kobalt besteht, wobei der Kobaltgehalt des Sintercarbidskörpers (2, 19) ein Kobaltgehaltsniveau (A) hat, welches gleich 5,5 Gew.-% oder geringer ist, und wobei

- der Sintercarbidskörper (2, 19) einen Kobaltgehaltsgradienten aufweist, wobei der Kobaltgehalt von einem Spitzenbereich (6, 23) in Richtung der Basisfläche (8, 20) auf ein Kobaltgehaltsniveau (B) ansteigt, welches zumindest 4,5 Gew.-% an der Basisfläche (8, 20) beträgt, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobaltgehaltsniveau (A) $\geq 1,09$ ist.

10. Werkzeug (1, 22) nach Anspruch 9, wobei das Kobaltgehaltsniveau (B) an der Basisfläche (8, 20) des Sintercarbidskörpers (2, 19) zumindest 5 Gew.-% beträgt.

11. Werkzeug (1, 22) nach einem der Ansprüche 9 bis 10, wobei das Kobaltgehaltsniveau (6) an der Basisfläche (8, 20) des Sintercarbidskörpers (2, 19) zumindest 6 Gew.-% beträgt.

12. Werkzeug nach einem der Ansprüche 9 bis 11, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobaltgehaltsniveau (A) $\geq 1,14$ ist.

13. Werkzeug (1, 22) nach einem der Ansprüche 9 bis 12, wobei der Spitzenbereich (6, 23) des Sintercarbidskörpers (2, 19) einen mittleren Kobaltgehalt hat, der sich auf einem Kobaltgehaltsniveau (C) $\geq 4,5$ Gew.-% befindet.

14. Werkzeug (1, 22) nach Anspruch 13, wobei das Verhältnis des Kobaltgehaltsniveaus (B) zu dem Kobaltgehaltsniveau (C) $\geq 1,2$ ist.

15. Werkzeug (1, 21) nach einem der Ansprüche 9 bis 14, wobei der Kobaltgehalt des Sintercarbidskörpers, welcher das Kobaltgehaltsniveau (A) hat, $\leq 5,0$ Gew.-% beträgt.

16. Werkzeug (1, 22) nach einem der Ansprüche 9 bis 15, wobei

- zumindest in dem Spitzenbereich (6, 23) desselben Sintercarbidskörpers (2, 19) einen äußeren Oberflächenbereich eine erhöhte mittlere Korngröße von WC hat als Folge eines erhöhten Gehaltes eines Elementes, welches einen Kornwachstum fördernden Effekt auf WC hat, sowie eine zweite Zone unterhalb der äußeren Oberflächenzone, wobei in der zweiten Zone die mittlere Korngröße von WC kleiner als in der äußeren Oberflächenzone ist als Folge eines erhöhten Gehaltes eines Elementes darin, welches einen Kornwachstum verhindernden Effekt auf WC hat, und wobei

- der Sintercarbidskörper (2, 19) den Kobaltgehaltsgradienten als Folge der Anwesenheit des Kornwachstum fördernden Elementes und des Kornwachstum verhindernden Elementes darin aufweist.

Revendications

1. Procédé de production d'un outil (1, 22) destiné à couper, percer ou broyer un matériau solide, ledit outil comprenant un corps en carbure cémenté (2, 19) fixé à un support en acier (3, 21), où ledit procédé comprend les étapes consistant à

- fournir ledit corps en carbure cémenté (2, 19) :

- en fournissant un mélange de poudre,

- en compactant ledit mélange de poudre en une pièce compacte (4, 13) comprenant une phase dure principalement composée de carbure de tungstène, WC, et un liant composé de cobalt, où la teneur en cobalt de la pièce compacte (4, 13) est à un niveau de teneur en cobalt (A) et est $\leq 5,5$ % en poids,

- en fournissant un composé comprenant un carbure ou un nitrure formé par du carbone ou de l'azote et par un élément qui a un effet d'inhibition de croissance de grain sur le carbure de tungstène, et en fournissant un élément qui a un effet de facilitation de croissance de grain sur le WC,

- en appliquant ledit composé et ledit élément de facilitation de croissance de grain sur au moins une région de pointe (5, 16) de ladite pièce compacte (4, 13), où ladite région de pointe (5, 16) formera une région de pointe (6, 23) du corps en carbure cémenté (2, 19) destinée à s'engager dans le matériau à découper, à percer ou à broyer au moyen dudit outil (1, 22), et en conservant une surface de base (7, 14) de la pièce compacte (4, 13), laquelle formera une surface de base (8, 20) du corps en carbure cémenté qui sera fixée audit support en acier (3, 21), exempté dudit composé et dudit élément de facilitation de croissance de grain,

- où ledit composé et ledit élément de facilitation de croissance de grain sont de type à se diffuser dans la pièce compacte (4, 13) conjointement au frittage de cette dernière et à induire de ce fait une formation d'un gradient de teneur en cobalt dans la pièce compacte frittée (2, 19), la teneur en cobalt augmentant à mesure que l'on s'écarte d'une surface sur laquelle ledit composé et ledit élément de facilitation de croissance de grain ont été appliqués,

- en frittant la pièce compacte (4, 13) dotée dudit composé et dudit élément de facilitation de croissance de grain pour former ledit corps en carbure cémenté (2, 19) de telle sorte que la teneur en cobalt au niveau de ladite surface de base (8, 20) correspondant à un niveau de teneur en cobalt (B) devient $\geq 4,5$ % en poids en conséquence de ladite formation induite d'un gradient de teneur en cobalt, le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (A) est $\geq 1,09$, et

- fixer ladite surface de base (8, 20) du corps en carbure cémenté (2, 19) au support en acier (1, 22) par brasage.

2. Procédé selon la revendication 1, où la teneur en cobalt au niveau de ladite surface de base (8, 20) correspondant à un niveau de teneur en cobalt (B) devient $\geq 5,0$ % en poids.

3. Procédé selon l'une quelconque des revendications 1 et 2, où la teneur en cobalt au niveau de ladite surface de base (8, 20) correspondant à un niveau de teneur en cobalt (B) devient $\geq 6,0$ % en poids.

4. Procédé selon l'une quelconque des revendications 1 à 3, où le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (A) est $\geq 1,14$.

5. Procédé selon l'une quelconque des revendications 1 à 4, où ladite région de pointe (6, 23) du corps en carbure cémenté (2, 19) présente une teneur en cobalt moyenne, correspondant à un niveau de teneur en cobalt (C), de $\leq 4,5$ % en poids.

6. Procédé selon l'une quelconque des revendications 1 à 5, où le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (C) est $\geq 1,2$.

7. Procédé selon l'une quelconque des revendications 1 à 6, où la teneur en cobalt du corps en carbure cémenté, correspondant à un niveau de teneur en cobalt (A), est $\leq 5,0$ % en poids.

8. Procédé selon l'une quelconque des revendications 1 à 7, où, dans ledit composé, l'élément qui a un effet d'inhibition de croissance de grain sur le WC est un élément quelconque parmi le chrome, le vanadium, le tantale, et le niobium et ledit élément de facilitation de croissance de grain est du carbone sous forme de graphite.

9. Outil (1, 22) destiné à couper, percer ou broyer un matériau solide, où

- ledit outil (1, 22) comprend un corps en carbure cémenté (2, 19) fixé à un support en acier (3, 21) par une

brasure située entre une surface de base (8, 20) du corps en carbure cémenté (2, 19) et le support en acier (3, 21),
- ledit corps en carbure cémenté (2, 19) comprend une phase dure principalement composée de carbure de tungstène, WC, et un liant composé de cobalt, où la teneur en cobalt du corps en carbure cémenté (2, 19) est à un niveau de teneur en cobalt (A) et est inférieure ou égale à 5,5 % en poids, et où

- ledit corps en carbure cémenté (2, 19) présente un gradient de teneur en cobalt en son sein, où la teneur en cobalt augmente depuis une région de pointe (6, 23) en direction de ladite surface de base (8, 20) jusqu'à un niveau de teneur en cobalt (B) et est d'au moins 4,5 % en poids au niveau de ladite surface de base (8, 20), le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (A) est $\geq 1,09$.

10. Outil (1, 22) selon la revendication 9, dans lequel le niveau de teneur en cobalt (B) est d'au moins 5,0 % en poids au niveau de ladite surface de base (8, 20) du corps en carbure cémenté (2, 19).

11. Outil (1, 22) selon l'une quelconque des revendications 9 et 10, dans lequel le niveau de teneur en cobalt (B) est d'au moins 6 % en poids au niveau de ladite surface de base (8, 20) du corps en carbure cémenté (2, 19).

12. Outil (1, 22) selon l'une quelconque des revendications 9 à 11, dans lequel le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (A) est $\geq 1,14$.

13. Outil (1, 22) selon l'une quelconque des revendications 9 à 12, dans lequel ladite région de pointe (6, 23) du corps en carbure cémenté (2, 19) présente une teneur en cobalt moyenne, correspondant à un niveau de teneur en cobalt (C), de $\leq 4,5$ % en poids.

14. Outil (1, 22) selon la revendication 13, dans lequel le rapport du niveau de teneur en cobalt (B) sur le niveau de teneur en cobalt (C) est $\geq 1,2$.

15. Outil (1, 22) selon l'une quelconque des revendications 9 à 14, dans lequel la teneur en cobalt du corps en carbure cémenté, correspondant à un niveau de teneur en cobalt (A), est $\leq 5,0$ % en poids.

16. Outil (1, 22) selon l'une quelconque des revendications 9 à 15, dans lequel

- au moins dans la région de pointe (6, 23) de celui-ci, le corps en carbure cémenté (2, 19) présente une zone de surface extérieure ayant une taille moyenne de grain de WC importante en conséquence d'une teneur élevée d'un élément qui a un effet de facilitation de croissance de grain sur le WC, et une deuxième zone sous ladite zone de surface extérieure, où, dans ladite deuxième zone, la taille moyenne de grain de WC est inférieure à celle dans ladite zone de surface extérieure en conséquence d'une teneur élevée en son sein d'un élément qui a une effet d'inhibition de croissance de grain sur le WC, et où

- le corps en carbure cémenté (2, 19) présente le gradient de teneur en cobalt en son sein en conséquence de la présence en son sein dudit élément de facilitation de croissance de grain et dudit élément d'inhibition de croissance de grain.

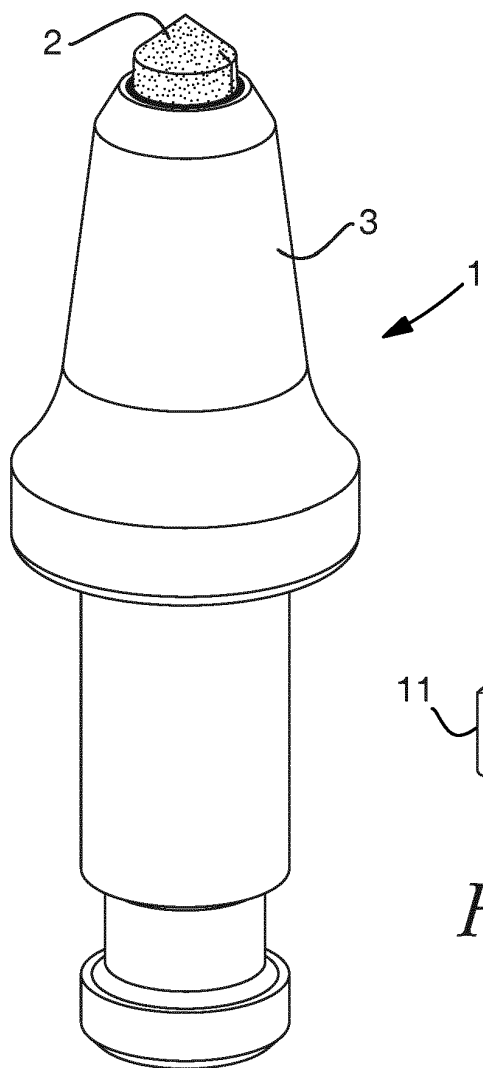


Fig 1

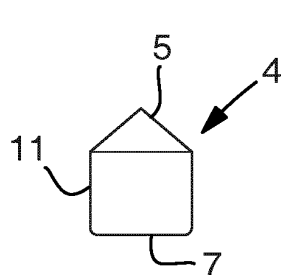


Fig 2

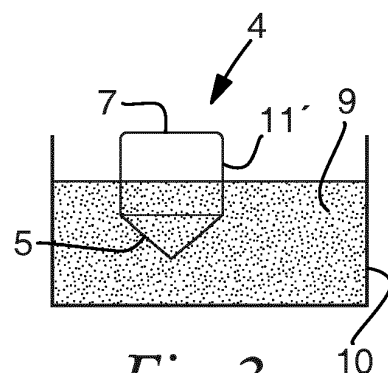


Fig 3

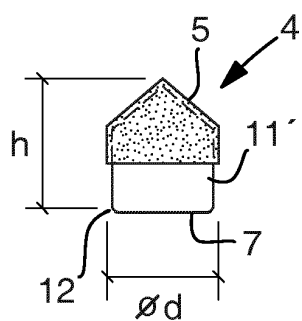


Fig 4

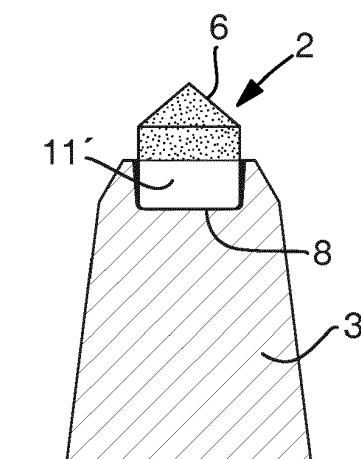
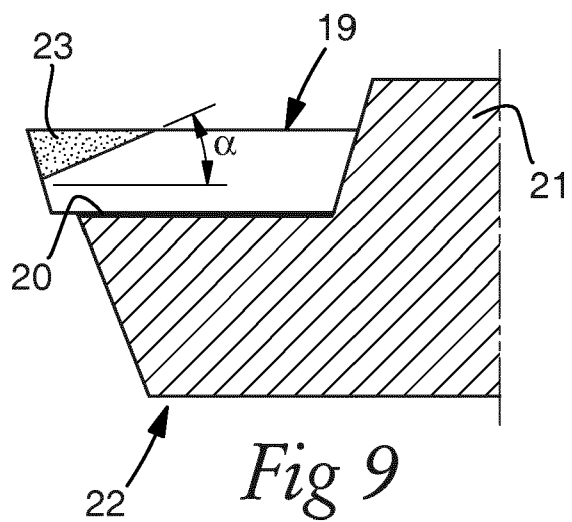
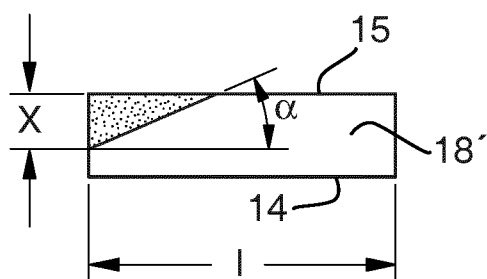
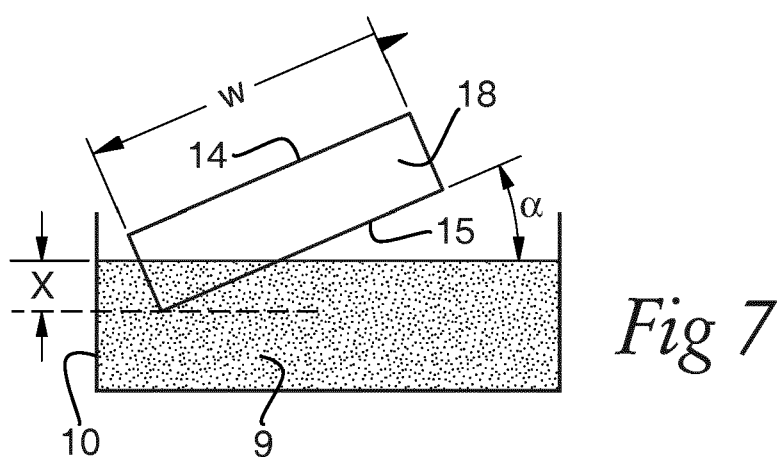
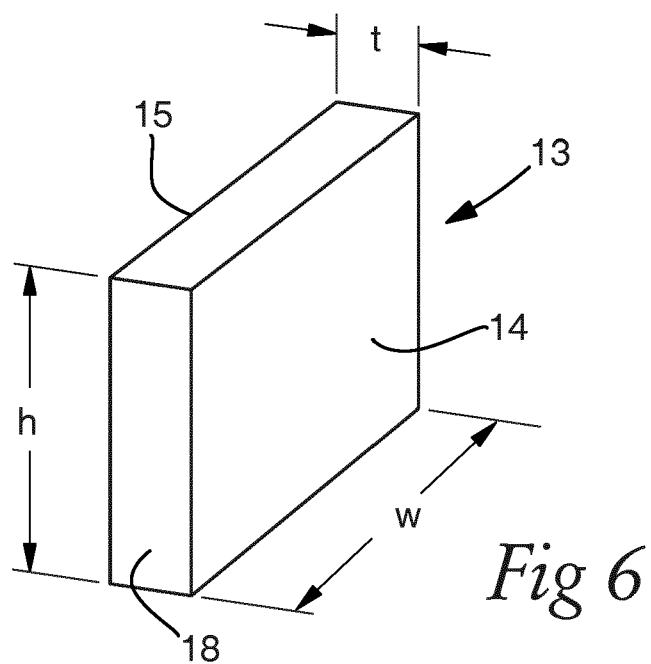
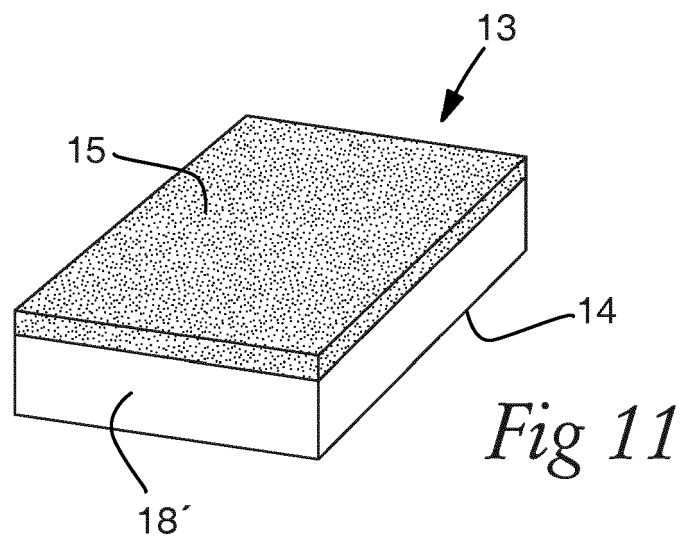
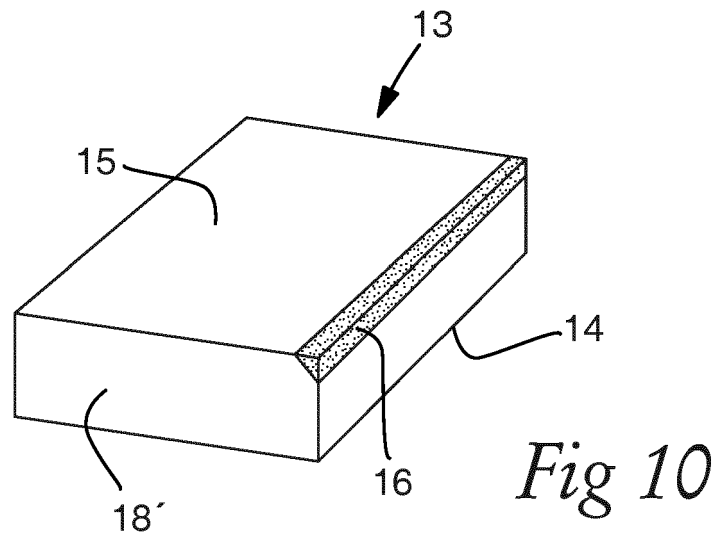


Fig 5





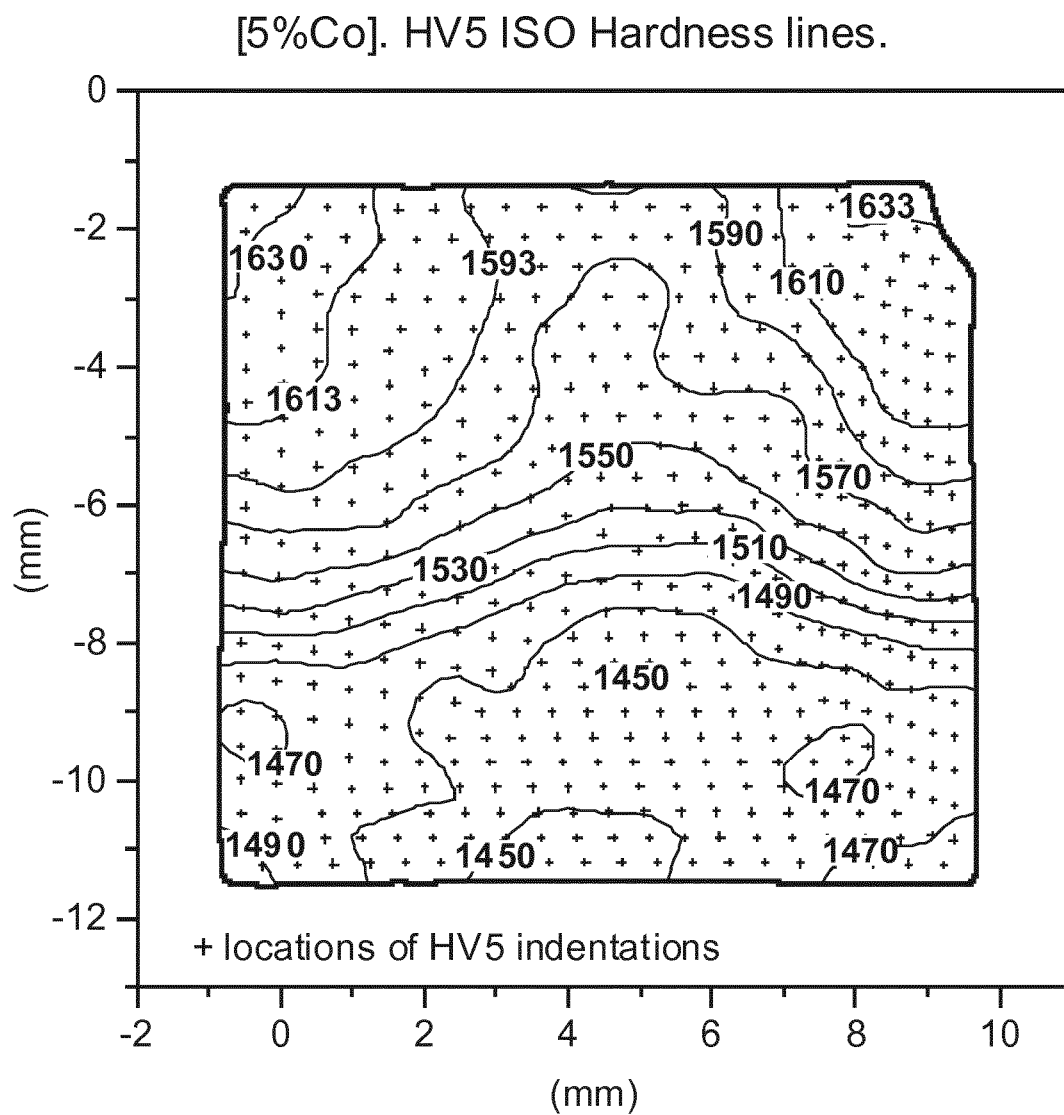
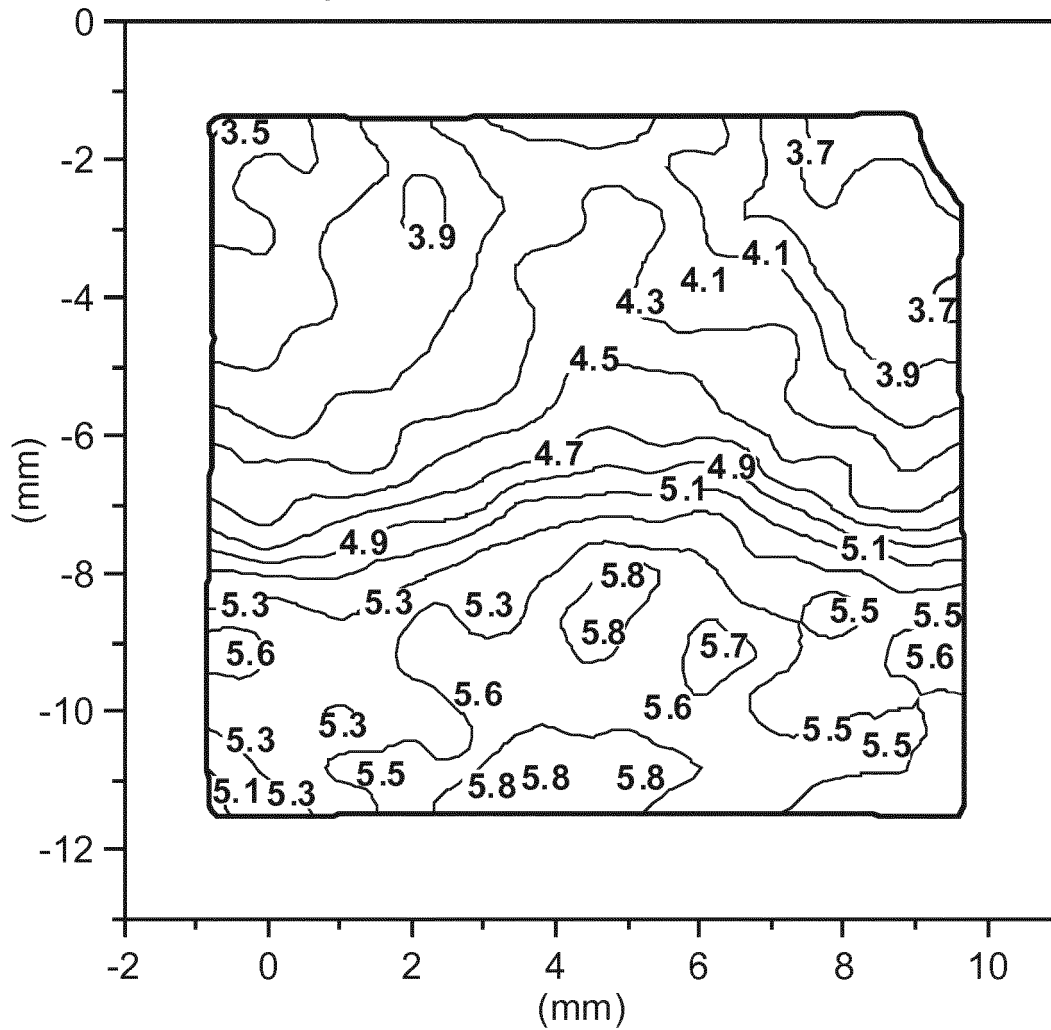


Fig 12

[5% Co]. Calculated %Co ISO lines.

Green body treated from top and 8mm down.



* %Co estimated using Roebuck et al.

$$HV5 = 888 - 9.9\%Co + [(229 + 532 \exp((6 - \%Co)/6.7)) / d_{WC}^{0.5}]$$

$$d_{WC} = 1.6 \mu m$$

Fig 13

10% Co medium WC grain size

Green body treated from the tip and 20mm down

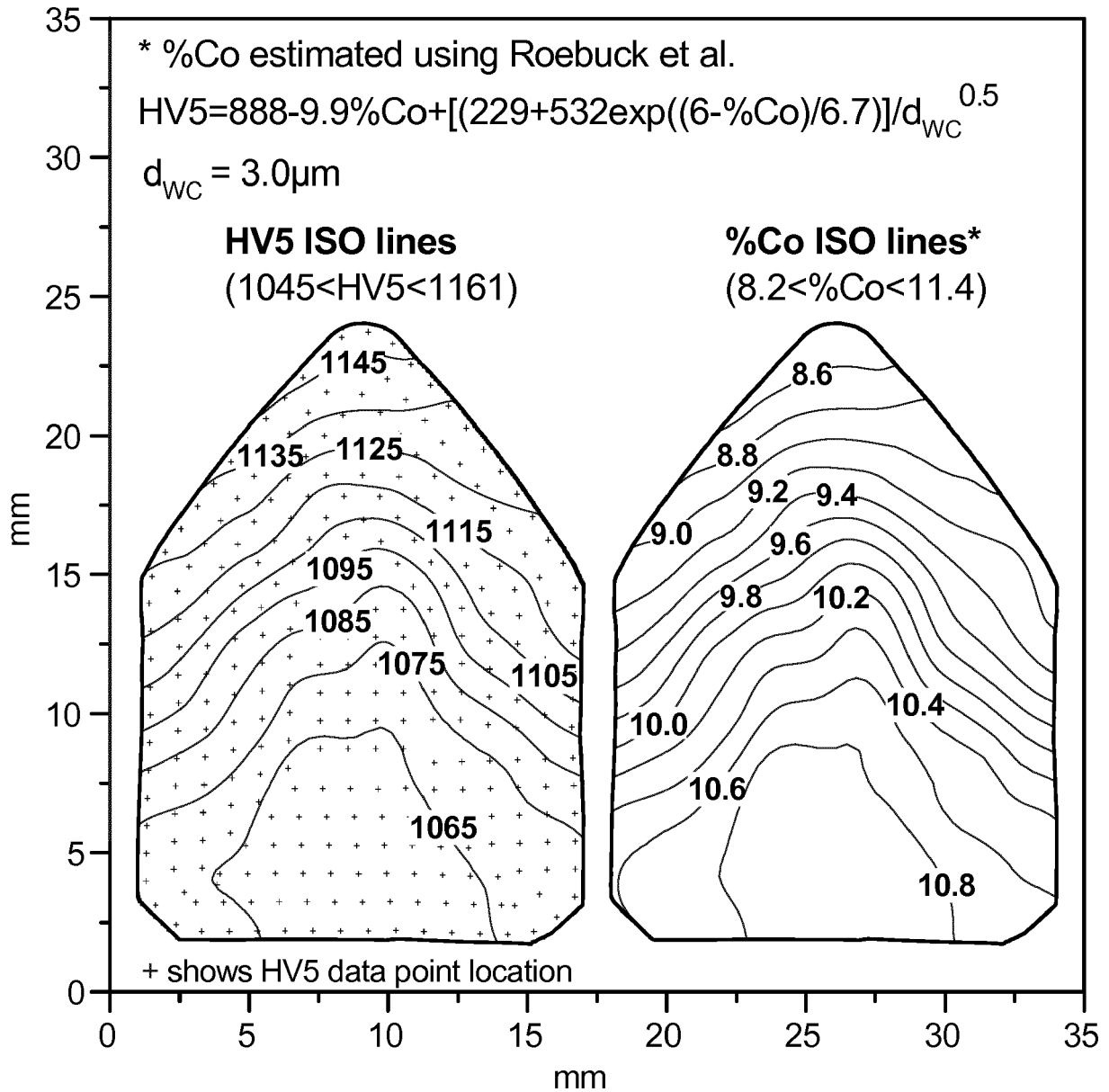


Fig 14

6% Co medium WC grain size

Green body treated on the upper surface

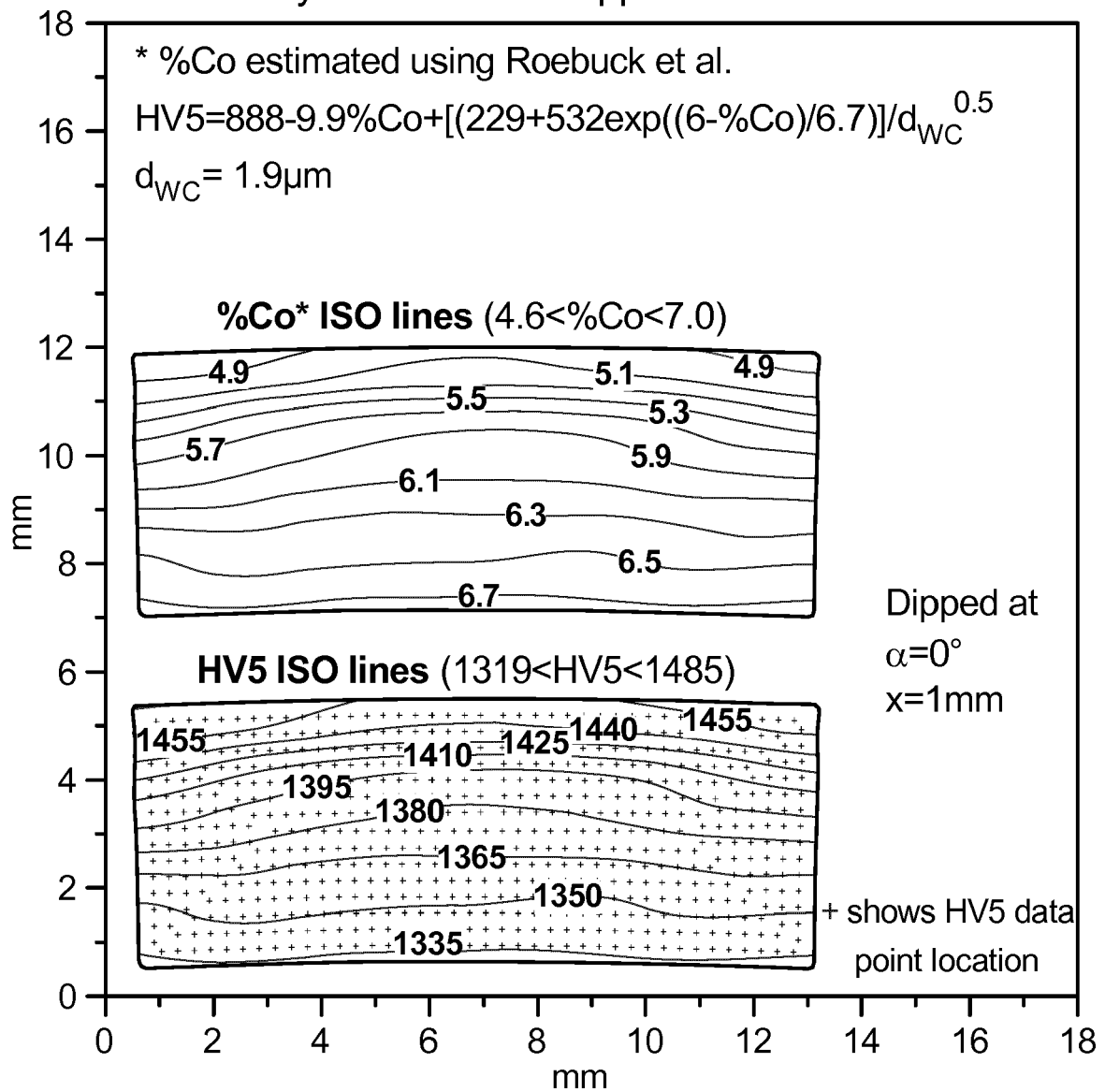


Fig 15

8% Co medium WC grain size
Green body treated on the upper surface

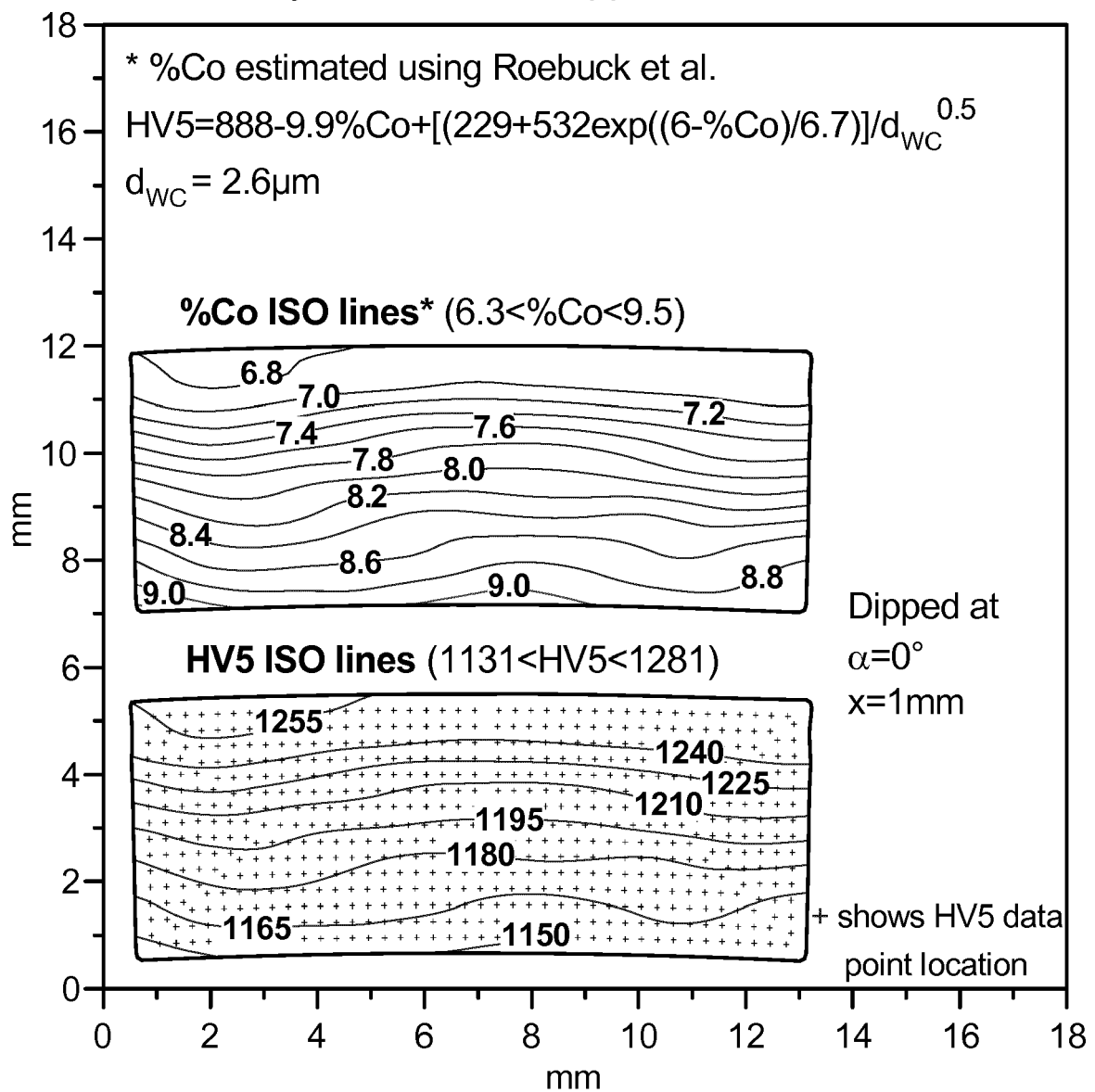


Fig 16

8% Co medium WC grain size

Green body treated on the lower left hand corner

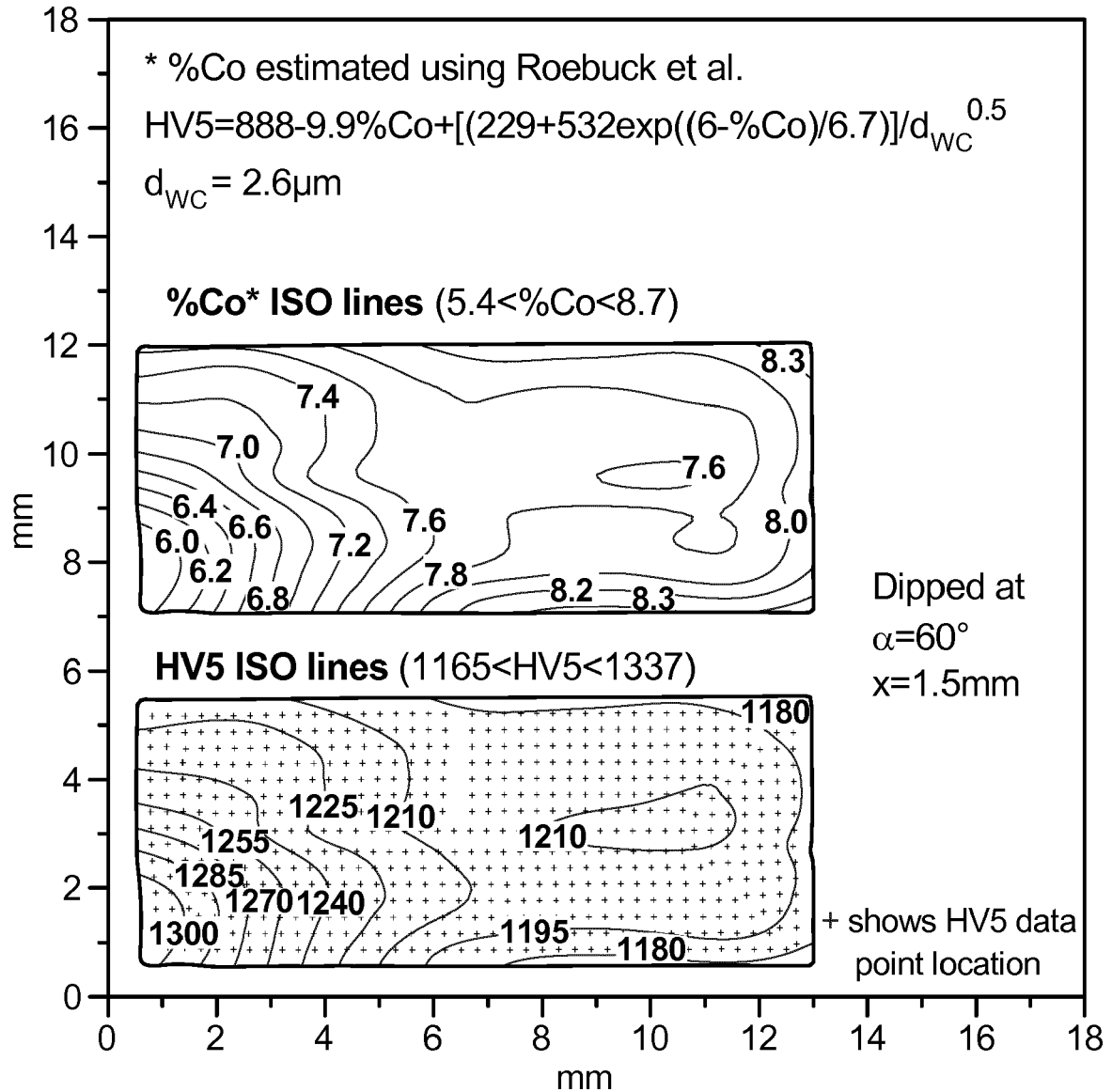


Fig 17

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- AU 2013273604 A1 [0005]
- WO 201298102 A1 [0006]
- US 4951762 A [0006]

Non-patent literature cited in the description

- A national measurement good practice guide. **ROE-BUCK et al.** Mechanical Tests for Hardmetals. National Physics Laboratory, 2009 [0043]
- A national measurement good practice guide. **B ROEBUCK ; M GEE ; E G BENNET ; R MORELL.** Mechanical tests for hardmetals. National Physical Laboratory, 1999 [0101]