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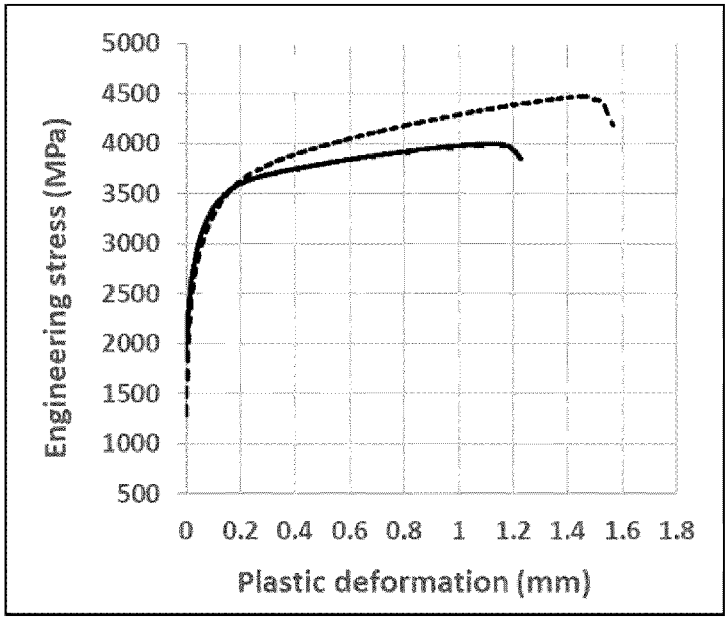


Fig 2

(57) Abstract: A rock drill insert comprising a body of cemented carbide comprising hard constituents of WC in a binder phase comprising cobalt; wherein the cemented carbide comprises 4-18 wt% Co; Cr such that the Cr/Co mass ratio in the bulk of the body is 0.04 -0.19; a balance of WC and any unavoidable impurities; wherein content of the binder phase of the cemented carbide is substantially equal throughout the rock drill insert; characterized in that: said insert has a corrected CoM/wt% Co ratio between 0.70-0.81 and the insert is substantially free of eta-phase; wherein said corrected CoM/wt% Co ratio is calculated according to: Corrected CoM/wt% Co = (magnetic-% Co + 1.13 * wt% Cr) / wt% Co where magnetic-% Co is the weight percentage of magnetic Co and wt-% Co and wt-% Cr are the weight percentage of Co and Cr in the cemented carbide, respectively.

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Rock drill insert

Field of invention

The present invention relates to a rock drill insert comprising chromium alloyed cemented carbide having a specially selected narrow and limited range of corrected CoM / wt% Co.

Background

Rock drilling is a technical area in which the inserts which are used for the purpose of drilling in the rock are subjected to high stresses, repeated impacts and severe corrosive conditions due to the inherent nature of the drilling. Different drilling techniques will generate different loads on the inserts, resulting from a combination of contact stress, impacts, shear and bending. Particularly severe stress conditions are found in applications such as those in which the rock drill inserts are mounted in a rock drill bit body of a top-hammer (TH) device, a down-the-hole (DTH) drilling device or a rotary drilling device, a raise boring device or a mechanical cutting device.

Traditionally, rock drill inserts may consist of a body made of cemented carbide that comprises hard constituents such as tungsten carbide (WC) in a binder phase such as cobalt (Co). It is desirable to increase the lifetime of the inserts. WO2018/060125 discloses that by adding chromium to the cemented carbide, the performance of the drill bits is enhanced. There is however the need to further improve the performance and lifetime of the inserts, especially in hard rock drilling applications. EP3763840 discloses a cemented carbide mining insert having a gradient microstructure and EP2011890 discloses a cemented carbide composition with a Cr/Co ratio by weight of between 0.05 – 0.15.

Therefore, the problem to be solved is how to further increase the lifetime of the drill inserts.

Definitions

By the term "bulk" is herein meant the cemented carbide of the innermost part (centre) of the rock drill insert. It is considered to be the volume of the insert excluding the outer 2mm from the surface (i.e., everything apart from the surface and sub surface).

By the term "eta-phase" herein means M_6C or $M_{12}C$ where M = (Co, W, Cr).

Summary of the Invention

It is an objective of the present invention to improve the lifetime of the cemented carbide inserts, this objective is achieved by providing a rock drill insert comprising a body of cemented carbide comprising hard constituents of tungsten carbide (WC) in a binder phase comprising cobalt; wherein the cemented carbide comprises 4-18 wt % Co; Cr such that the Cr/Co mass ratio in the bulk of the body is 0.04 - 0.19; a balance of WC and any unavoidable impurities; wherein content of the binder phase of the cemented carbide is substantially equal throughout the rock drill insert; said insert has a corrected CoM / wt% Co ratio between 0.70 – 0.81 and the insert is substantially free of eta-phase; wherein said corrected CoM / wt% Co ratio is calculated according to Equation 1:

Corrected CoM / wt% Co = (magnetic-% Co + 1.13 * wt% Cr) / wt% Co *Equation 1*

where magnetic-% Co is the weight percentage of magnetic Co and wt-% Co and wt-% Cr are the weight percentage of Co and Cr in the cemented carbide, respectively.

Advantageously, it has surprisingly been found that when an insert having this special range of corrected CoM / wt% Co is subjected to static / low strain rate contact stress, which could be through a mechanical post-sintering treatment process such as high energy tumbling and / or through the actual drilling process, the material's strain hardening capacity will be enhanced. The material will also exhibit enhanced ultimate compressive strength (UCS), leading to the reduction of the risk of premature insert breakages in the rock drilling application. This is surprising as the person skilled in the art would typically

think to use cemented carbide having a higher CoM / wt% Co in order to avoid embrittlement. Additionally, it has been found that if the corrected CoM / wt% Co is in this range the wear properties of the insert are improved which also contributes to increasing the lifetime of the inserts when used in the field.

In one embodiment the cobalt content is between 8 – 18 wt%. Advantageously, this range facilitates obtaining high fracture toughness in the material, thus making it suitable especially for toughness-focused rock drilling applications such as rotary drill bits, raise boring pilot bits, and raise boring cutters. A further advantage in this cobalt range when in combination with the claimed Cr/Co mass ratio and corrected CoM / wt% Co ratio is that the material's plasticity in compression will be enhanced. The term plasticity is herein used to designate the material's capability to undergo a higher degree of plastic strain before the onset of failure. Typically, in material design, increasing its ultimate strength results in a decrease in plasticity and vice versa. In the present invention, in this cobalt range the material's strain hardening capacity, USC and plasticity in compression are all enhanced simultaneously, which leads to the reduction of risk of premature insert breakages in the rock drilling application. Furthermore, the enhanced plasticity and strain hardening in compression allow for an optimally enhanced level of induced residual stresses in the material, which further increases the resistance of the insert to premature breakage and thus extends the insert lifetime.

In another embodiment the cobalt content is between 4 – 8 wt%. Advantageously, this range makes it possible to reach particularly high wear resistance, typically required in applications such as top hammer and down the hole drilling.

In one embodiment the corrected CoM / wt% Co is between 0.73 – 0.79. Advantageously, this range results in the most optimal enhancement of the material's strain hardening capacity in compression and its plasticity when in combination with the cobalt content being between 8 – 18 wt%.

In one embodiment the difference between an average hardness at 0.3 mm below the surface of the rock drill insert and an average hardness in the bulk of the rock drill insert is

at least 30 HV3 wherein hardness is measured according to EN ISO 6507-1:2005 (E). The hardness difference results from mechanically induced compressive residual stresses and strain hardening of the binder phase. Advantageously, this leads to an increased strength and apparent toughness of the rock drill insert, reducing the risk of early damage and failure of the insert and consequently increasing the insert lifetime.

In one embodiment, the difference between the hardness at any point 0.3 mm below the surface of the rock drill insert and the hardness at 1 mm below the surface of the rock drill insert is at least 20 HV3 wherein hardness is measured according to EN ISO 6507-1:2005 (E). The hardness difference reflects the induced compressive residual stresses and strain hardening of the binder phase, leading to enhanced apparent toughness and strength of the insert, consequently increasing its lifetime during drilling.

In one embodiment the WC grain size mean value of the cemented carbide is above 0.7 µm but less than 18 µm as measured according to Jeffries method defined in the description hereinbelow. Advantageously, these grain sizes provide the optimal balance between wear resistance and toughness for rock tool applications.

In one embodiment the mean WC grain size value of the cemented carbide is above or equal to 1.0 µm but less than 10 µm. Advantageously, these grain sizes provide the optimal balance between wear resistance and toughness for rock tool applications.

In one embodiment the mass ratio Cr/Co in the cemented carbide is between 0.05 - 0.17, preferably between 0.065 – 0.16, even more preferably between 0.075 – 0.15. Advantageously, this provides optimum wear resistance and capacity for strain hardening.

In another embodiment the mass ratio Cr/Co in the cemented carbide is between 0.05 – 0.12. Advantageously, this provides the optimum balance between plasticity, capacity for strain hardening, wear resistance, and fracture toughness.

In one embodiment the cemented carbide has a bulk hardness of not higher than 1750 HV20. Advantageously, this means that the insert is not so brittle that it is prone to failure.

According to another aspect of the present application there is a rock drill bit body comprising one or more mounted rock drill inserts as described hereinbefore or hereinafter.

Brief description of the drawings

Figure 1 is a schematic representation of the geometry of a rock drill insert used in the wear tests.

Figure 2 shows the deformation curves in uniaxial compression for samples A and B.

Figure 3 shows the deformation curves in uniaxial compression for samples C and D.

Figure 4 shows the deformation curves in uniaxial compression for samples E and F.

Detailed description

Figure 1 shows a rock drill insert 2 comprising a body of cemented carbide comprising hard constituents of WC in a binder phase comprising cobalt; wherein the cemented carbide comprises 4-18 wt % Co; Cr such that the Cr/Co mass ratio in the bulk of the body is 0.04 -0.19; a balance of WC and any unavoidable impurities; wherein content of the binder phase of the cemented carbide is substantially equal throughout the rock drill insert; wherein said insert has a corrected CoM / wt% Co ratio between 0.70 – 0.81 and the insert is substantially free of eta phase; wherein said corrected CoM / wt% Co ratio is calculated according to equation 1.

$$\text{Corrected CoM / wt\% Co} = (\text{magnetic-\% Co} + 1.13 * \text{wt\% Cr}) / \text{wt\% Co} \qquad \textit{Equation.1}$$

Where magnetic-% Co is the weight percentage of magnetic Co and wt-% Co and wt-% Cr are the weight percentage of Co and Cr in the cemented carbide, respectively.

This specific range of corrected CoM / wt% Co is achieved by careful control of the carbon content. The corrected CoM / wt% Co of a sintered sample is measured and calculated by using commercially available Foerster Koerzimat CS 1.096 equipment. The sample is weighed and then put into the magnetic coil as described in the Koerzimat CS 1.096 V3.09 manual. The magnetic moment is measured and from that the weight-specific saturation magnetization, σs, is calculated from the ratio of magnetic moment to weight of the sample. Then the proportion of magnetic material in % (known as magnetic-% Co) is calculated by dividing σs with the material constant for Co, which is 2010 10^{-7} Tm^3/kg. For chromium containing materials a correction factor of 1.13 * wt% Cr is used (the 1.13 factor is derived from the ratio of the atomic weights of cobalt and chromium), as in Equation. 1:

Corrected CoM / wt% Co = (magnetic-% Co + 1.13 * wt% Cr) / wt% Co *Equation.1*

where magnetic-% Co is the weight percentage of magnetic Co and wt-% Co and wt-% Cr are the weight percentage of Co and Cr in the cemented carbide, respectively.

The desired corrected CoM / wt% Co is achieved taking a sample of the powder blend slurry from the mill, which is then dried, pressed, and sintered so that the corrected CoM / wt% Co can be measured and calculated. Using methods known by the person skilled in the art an amount of carbon (soot) or very fine tungsten metal powder to be added in order to achieve the desired corrected CoM / wt% Co can be calculated. This is essentially a means to control the carbon balance, however it is necessary to use methods as described hereinabove for the definition of the desired properties rather than measuring and controlling an absolute carbon content as the absolute carbon content is influenced by other factors such as binder content, Cr-content and sintering conditions. The rock drill insert 2 of the present invention is produced by means of a process in which a ready to press powder comprising the elements of the cemented carbide is produced by milling, spray drying and then compacted into a compact which is then sintered. A grinding step to obtain the precise dimension of the drill insert is generally made. A drill insert of the present invention generally has a cylindrical base part and a rounded top which may be

hemispherical, conical, or asymmetric. It should be understood that the rock drill insert could have alternative geometries to that shown in figure 1. Typically, the curved surface of the cylindrical base part is ground to obtain the precise diameter wanted, while the surfaces of the top part and the circular base part are kept in their as sintered state. The drill insert is then subjected to mechanical post-treatment which introduces high levels of compressive stresses in the insert, such as high energy tumbling.

The binder phase content of the cemented carbide is substantially equal throughout the rock drill insert, i.e., no substantial gradient of Co content is present when going from the surface of the rock drill insert to its interior. Preferably, there is also no substantial gradient in the chromium content present when going from the surface of the rock drill insert to its interior.

In one embodiment the cobalt content is preferably between 5 – 16 wt%.

In another embodiment the cobalt content is between 8 – 18 wt%, preferably between 10 – 16 wt%.

In another embodiment the cobalt content is between 4 – 10 wt%, preferably between 4 – 8 wt%.

In one embodiment the corrected CoM / wt% Co is between 0.70 – 0.81, preferably between 0.72 – 0.80, more preferably between 0.73 – 0.79.

In one embodiment the difference between an average hardness at 0.3 mm below the surface of the rock drill insert and an average hardness in the bulk of the rock drill insert is at least 30 HV3, preferably at least 35 HV3, more preferably at least 40 HV3, even more preferably at least 40 HV3, even more preferably at least 50 HV3, even more preferably at least 60 HV3, wherein hardness is measured according to EN ISO 6507-1:2005 (E).

In one embodiment, the difference between the hardness at any point 0.3 mm below the surface of the rock drill insert and the hardness at 1 mm below the surface of the rock drill

insert is at least 20 HV3, preferably at least 35 HV3, more preferably at least 40 HV3, more preferably at least 45 HV3 wherein hardness is measured according to EN ISO 6507-1:2005 (E).

The HV3 measurements were carried out in the following way, using the KB30S programmable hardness tester by KB Prüftechnik GmbH:

- Sectioning of insert sample along its longitudinal axis.
- Grinding and polishing of sectioned surface using progressively finer grit and polishing suspensions.
- Scanning the edge of the sample.
- Programming the hardness tester to make series of indentations at defined distances to the edge.
- Programming the distances between the individual indentations at each distance from edge to 0.3 mm or more.
- Indentation with 3 kg load at all programmed coordinates.
- Computer moves stage to each coordinate with indentation and runs auto adjust light and auto focus, followed by automatic measurement of the size of each indentation.
- User inspects all photos of the indentations for possible focus errors and other effects which may lead to an invalid result and manually re-evaluates the selected invalid ones in each series (if any are present).

The average hardness at a certain depth from the surface is defined as the average of at least 50 measured hardness values at that depth evenly distributed around the insert.

In one embodiment the mean value of the cemented carbide grain size is above 0.7 µm but less than 18 µm as measured according to Jeffries method defined in the description. The WC grain size is chosen to suit the desired end properties of the cemented carbide in terms of, for example, toughness, strength, wear resistance and thermal conductivity. According to one embodiment the WC mean grain size is above 0.7 µm, or above 0.9, or above 1 µm, or above 1.25 µm, or above 1.5 µm, or above 1.75 µm, or above 2.0 µm. If the WC grain size is too large, the material becomes difficult to sinter. Therefore, it is

preferred that the WC mean grain size is less than 18 µm, or less than 15 µm, or less than 10 µm, or less than 6 µm.

The micrographs for WC grain size evaluation were obtained using a scanning electron microscope (SEM) in backscatter electron (BSE) contrast. Prior to the imaging, the material samples were polished using standard procedures and etched with Murakami solution to generate contrast at grain boundaries. The mean WC grain size was then evaluated using the Jeffries method described below, from at least two different micrographs for each material. An average value was then calculated from the mean grain size values obtained from the individual micrographs (for each material respectively). The procedure for the mean grain size evaluation using a modified Jeffries method was the following:

A rectangular frame of suitable size is selected within the SEM micrograph so as to contain a minimum of 300 WC grains. The grains inside the frame and those intersected by the frame are manually counted, and the mean grain size is obtained from equations (2-4):

$$M = \frac{L_{scale\ mm} \times 10^{-3}}{L_{scale\ micro} \times 10^{-6}} \qquad \textit{Equation 2}$$

$$vol\%WC = 100 \times \left(-1.308823529 \times \frac{\left(\frac{wt\%Co}{100} - 1\right)}{\left(\frac{wt\%Co}{100} + 1.308823529\right)} \right)$$

Equation 3

$$d = \frac{1500}{M} \times \sqrt{\frac{L_1 \times L_2 \times vol\%\ WC}{\left(n_1 + \frac{n_2}{2}\right) \times 100}} \qquad \textit{Equation 4}$$

Where:

d = mean WC grain size (µm)

L_1, L_2 = length of sides of the frame (mm)

M = magnification

$L_{scale\ mm}$ = measured length of scale bar on micrograph in mm

$L_{scale\ micro}$ = actual length of scale bar with respect to magnification (µm)

n_1=no. of grains fully within the frame

n_2=no. of grains intersected by frame boundary

wt % Co = known cobalt content in weight %.

Equation 3 is used to estimate the WC fraction based on the known Co content in the material. Equation 4 then yields the mean WC grain size from the ratio of the total WC area in the frame to the number of grains contained in it. Equation 4 also contains a correction factor compensating for the fact that in a random 2D section, not all grains will be sectioned through their maximum diameter.

In one embodiment the mass ratio Cr/Co in the cemented carbide is between 0.05 - 0.17, more preferably between 0.065 – 0.16, even more preferably between 0.075 - 0.15.

In another embodiment the mass ratio Cr/Co in the cemented carbide is between 0.05 – 0.12, preferably between 0.05 – 0.10.

According to yet another embodiment, the M_7C_3 phase is present in the cemented carbide, where M designates a combination of Cr, Co and W, i.e. $(Cr,Co,W)_7C_3$. The Co solubility can reach as high as 38 at. % of the metallic content in the M_7C_3 carbide. The balance of Cr:Co:W is influenced by the overall carbon content in the cemented carbide.

In another embodiment the cemented carbide insert has a bulk hardness of not higher than 1750 HV20, preferably not higher than 1700 HV20, more preferably not higher than 1650 HV20. The cemented carbide of the rock drill insert has suitably a hardness of the bulk of at least 800 HV20, or at least 900 HV20, or at least 950 HV20 or at least 1000 HV20. Hardness is measured according to EN ISO 6507-1:2005 (E).

In another embodiment the cemented carbide insert comprises < 1 area % eta-phase, preferably < 0.8 area % eta-phase. The quantity of eta-phase is measured by binary image

analysis using optical microscopy, measuring 10 random areas and calculating an average area %.

In another embodiment the cemented carbide insert is substantially free of eta-phase. Substantially free of eta-phase herein means < 0.5 area % eta-phase. The quantity of eta-phase is measured by binary image analysis using optical microscopy, measuring 10 random areas and calculating an average area %.

In one embodiment the corrected Com / wt% Co is substantially equal throughout the volume of the cemented carbide insert.

In one embodiment, the cobalt content is substantially equal throughout the volume of the cemented carbide insert. For example, this could be measured using EDS.

In one embodiment, the chromium content is substantially equal throughout the volume of the cemented carbide insert. For example, this could be measured using EDS.

In one embodiment the sintering temperature used is between 1350 – 1550°C, preferable 1400-1530°C

According to one embodiment, rock drill inserts 2 according to the invention are mounted in a rock drill bit body of a top-hammer (TH) device or a down-the-hole (DTH) drilling device or a rotary drilling device or a raise boring pilot bit device or a raise boring cutter device or a push boring (blind boring) device or a mechanical cutting device or a horizontal directional drilling (HDD) device. The rotary drilling device may be an oil and gas rotary cutter device.

Example 1 - Samples

The samples shown in table 1 were prepared by milling WC having a dm_FSSS=1.2-18.0 µm with Co and Cr_3C_2 with 2% polyethylene glycol (PG8000) in milling liquid containing 92% alcohol in a ball mill. To adjust the corrected CoM / wt% Co ratio to the target value,

a small amount of the slurry was taken from the mill, dried and pressed to a green body that was sintered in a Sinter HIP furnace for 60 minutes at 1410°C and with a 55 bar Ar pressure during the last 20 minutes. The corrected CoM / wt% Co ratio was measured and calculated as described hereinabove. If the corrected CoM / wt% Co ratio was too low, carbon (soot) was added to the mill and if it was too high, very fine tungsten metal powder was added. The amount of the soot or tungsten to be added was calculated specifically for each material based on how large the deviation from the corrected CoM / wt% Co target value was. The ball mill was then run for a short time to homogenize the slurry. The slurry was then spray dried in a N_2 atmosphere. Inserts were produced by uniaxially pressing the powder to form green bodies and then sintering the green bodies in the same way as above. The properties of the inserts were measured using the methods as described hereinabove.

Sample	Co content (wt%)	Cr content (wt%)	Cr / Co mass ratio	HV20 in bulk	Average grain size (µm)	Corrected CoM / wt% Co
A (comparison)	11.0	1.10	0.10	1099	4.92	0.88
B (invention)	11.0	1.10	0.10	1092	4.31	0.78
C (comparison)	13.5	1.35	0.10	1095	3.74	0.87
D (invention)	13.5	1.35	0.10	1059	3.76	0.74
E (comparison)	6.0	0.60	0.10	1449	2.10	0.91
F (invention)	6.0	0.60	0.10	1499	2.00	0.79
G (comparison)	7.0	1.05	0.15	1502	1.30	0.99
H (invention)	7.0	1.05	0.15	1570	1.60	0.79

Table 1: Sample summary

Example 2 – Uniaxial compression test / plastic deformation

Samples A-F were strained at room temperature in uniaxial compression until fracture using an Instron 5989 test frame, at a constant rate of crosshead displacement equal to 0.6 mm / min, while recording load-displacement curves. The test fixture, the hardness and parallelism of the counter surfaces, as well as the sample geometry were in accordance with the ISO 4506:2017 E standard "Hardmetals – Compression test". A compliance curve obtained by loading the test fixture without a sample, accounting for elastic deformation of the test rig and load string, was subtracted from the load-displacement curve measured on the samples directly during each measurement. Engineering stress was calculated from the load values by dividing the load with the initial minimum cross-sectional area, obtained from the minimum diameter measured on each individual test sample prior to testing. Elastic deformation of the samples was subtracted from the stress – displacement curves during test data post-processing using linear regression, in order to isolate only the plastic deformation of the materials. This isolation of the plastic deformation from the stress – displacement curves was carried out as follows:

- Linear regression was applied to the part of the data set corresponding to the initial section of the stress – displacement curve which was visually estimated to be linear.
- The displacement range of this partial data set used for the linear regression was then varied so as to maximize the R^2 value of the fit.
- The first derivative of the resulting regression equation (slope of the fitted line) was used to calculate the plastic deformation from the total measured displacement using the relationship in equation 5 below:

$$e_{plast} = e - \sigma/a \qquad \textit{Equation 5}$$

where "e_{plast}" designates plastic deformation, "e" the measured displacement after the subtraction of the compliance curve, "σ" the engineering stress, and "a" the coefficient corresponding to the slope of the line fitted by linear regression to the elastic part of the stress – displacement curve, as described above.

Figure 2 compares the deformation curves in uniaxial compression for samples A and B, i.e. the samples having 11 wt% Co. Sample A (comparative sample) is illustrated with a solid line and sample B (inventive sample) is illustrated from a dashed line.

Figure 3 compares the deformation curves in uniaxial compression for samples C and D, i.e., the samples having 13.5 wt% Co. Sample C (comparative sample) is illustrated with a solid line and sample D (inventive sample) is illustrated from a dashed line.

Figure 4 compares the deformation curves in uniaxial compression for samples E and F, i.e., the samples having 6 wt% Co. Sample E (comparative sample) is illustrated with a solid line and sample F (inventive sample) is illustrated from a dashed line.

The deformation curves in figures 2 - 4 were plotted from 0.001 mm of plastic deformation.

The inventive samples B and D show a more pronounced strain hardening, i.e., a steeper deformation curve, throughout most of the deformation until failure; higher ultimate compressive strength (UCS) and substantially greater plasticity (plastic deformation to failure) as compared to the comparative sample A and C. Figure 3 shows that this effect is present also when the samples have equal mean tungsten carbide grain size, in addition to having equal binder phase content.

The inventive sample F shows higher ultimate compressive strength (UCS) and more pronounced strain hardening as compared to the comparative sample E. Figure 4 shows that this effect is present also when the samples have equal mean tungsten carbide grain size, in addition to having equal binder phase content. This, together with the properties of samples B – D, demonstrates that the inventive effects are present over a broad range of cobalt contents and grain sizes.

Example 3 – Abrasion wear test

Rock drill bit inserts with a 10 mm outer diameter and a hemispherical top geometry were produced out of all eight materials (A,B,C,D, E, F, G, H) and in their as ground state subjected to wear testing using a rotating granite log counter surface with continual water flow aimed at the insert / rock contact. During the test, the insert / rock contact was maintained by applying a constant force of 10 kgf (98 N). Since the inserts were ground only on their cylindrical section, the part of the insert in contact with the rock surface was in all cases in the as sintered state. While the granite log was rotating, the insert was moved along it with a constant feed rate of 0.9 mm /s, resulting in a total sliding distance between 432 and 446 m. All inserts were carefully weighed prior to and after the testing. Volume wear per unit of sliding distance was then calculated for each material from measured mass loss and density. Three inserts were tested for each of the eight materials (A, B, C, D, E, F, G and H) and average values for the volume wear per unit of sliding distance were calculated from the three tests. The results are shown in table 2 below:

Sample	A	B	C	D	E	F	G	H
Volume wear (mm^3/m)	1.53E-03	8.95E-04	1.37E-03	1.06E-03	4.71E-04	2.65E-04	2.31E-04	1.41E-04
Standard deviation	1.05E-04	6.84E-05	7.59E-05	1.04E-04	7.16E-05	4.09E-05	1.95E-05	1.97E-05

Table 2: Wear rate (volume loss per meter of sliding distance) in abrasion wear test against granite counter surface.

Lower volume wear (higher wear resistance) was recorded for each of the inventive samples. In particular, material D was found to exhibit lower volume wear than material C, despite having the same nominal binder content, identical mean WC grain size, and a lower room temperature hardness. Material F was found to exhibit lower volume wear than material E despite having the same nominal binder content and identical mean WC grain size.

Example 4 – Field test

Top hammer bits were made having an initial bit diameter of about 49 mm with six peripheral inserts of 10 mm diameter and three front inserts of 8 mm. The insert geometry was conical with a semi-ballistic top of 3.5 mm radius. Three bits having sample E inserts on the peripheral and three bits have sample F inserts on the peripheral were tested. The front inserts were of a standard material (WC-6%Co) for all bits tested. During drilling one bit having sample E inserts was lost leaving two bits for comparison. The bits were tested in medium hard and medium abrasive granite at a construction site in Hammarby Sjöstad, Stockholm, Sweden. The drill rig was equipped with a COP3038 rock drill operating at full power with an impact power of 30kW and an impact frequency of 100Hz. The bits were drilled until the rate of penetration indicated the need for re-sharpening before drilling could be continued. The average results from the two-three bits are shown in table 3 below:

Sample	Average drilled depth before worn out (m)	Bit diameter loss (mm/m)	Drilled meters per mm of bit diameter lost (m/mm)
E	157	0.0037	289
F	280	0.0025	401

Table 3: Field trial results

It can be seen that the performance of the inventive inserts is improved over the comparative inserts.

Claims

1. A rock drill insert (2) comprising a body of cemented carbide comprising hard constituents of WC in a binder phase comprising cobalt;
wherein the cemented carbide comprises 4-18 wt % Co;
Cr such that the Cr/Co mass ratio in the innermost part of the rock drill insert is 0.04 -0.19;
a balance of WC and any unavoidable impurities;
wherein content of the binder phase of the cemented carbide is substantially equal throughout the rock drill insert;
a hardness of at least 800 HV20 wherein hardness is measured according to EN ISO 6507-1:2005 (E);
wherein a WC grain size mean value of the cemented carbide is above 0.7 µm but less than 18 µm as measured according to Jeffries method defined in the description;
characterized in that:
said insert has a corrected CoM / wt% Co ratio between 0.70 – 0.81 and is substantially free of eta-phase wherein eta-phase is M_6C or $M_{12}C$ where M = (Co, W, Cr);
wherein said corrected CoM / wt% Co ratio is calculated according to:

$$\text{Corrected CoM / wt\% Co} = (\text{magnetic-\% Co} + 1.13 * \text{wt\% Cr}) / \text{wt\% Co}$$

where magnetic-% Co is the weight percentage of magnetic Co and wt-% Co and wt-% Cr are the weight percentage of Co and Cr in the cemented carbide, respectively, which are measured according to the method defined in the description.

2. The rock drill insert (2) according to claim 1 wherein the cobalt content is between 8 – 18 wt%.

3. The rock drill insert (2) according to claim 1 wherein the cobalt content is between 4 – 8 wt%.

4. The rock drill insert (2) according to any of the previous claims wherein the corrected CoM / wt% Co is between 0.73 – 0.79.

5. The rock drill insert (2) according to any of the previous claims wherein the difference between an average hardness at 0.3 mm below the surface of the rock drill insert and an average hardness in the innermost part of the rock drill insert is at least 30 HV3 wherein hardness is measured according to EN ISO 6507-1:2005 (E).

6. The rock drill insert (2) according to any of the previous claims, wherein the difference between the hardness at any point 0.3 mm below the surface of the rock drill insert and the hardness at 1 mm below the surface of the rock drill insert is at least 20 HV3 wherein hardness is measured according to EN ISO 6507-1:2005 (E).

7. The rock drill insert (2) according to any of the previous claims, wherein a WC grain size mean value of the cemented carbide is above or equal to 1 μm but less than 10 μm.

8. The rock drill insert (2) according to any of the previous claims, wherein the mass ratio Cr/Co in the cemented carbide is between 0.05-0.17.

9. The rock drill insert (2) according to claim 8 wherein the mass ratio Cr/Co in the cemented carbide is between 0.065 – 0.16.

10. The rock drill insert (2) according to claim 9 wherein the mass ratio Cr/Co in the cemented carbide is between 0.075 – 0.15.

11. The rock drill insert (2) according to claim 8 wherein the mass ratio Cr/Co in the cemented carbide is between 0.05 – 0.12.

12. The rock drill insert (2) according to any of the previous claims, wherein said cemented carbide has a hardness in the innermost part of the rock drill insert of not higher than 1750 HV20.

13. The rock drill insert (2) according to any of the previous claims, wherein the corrected CoM / wt% Co ratio is substantially equal throughout the volume of the insert (2).

14. A rock drill bit body comprising one or more mounted rock drill inserts (2) according to any of the previous claims.

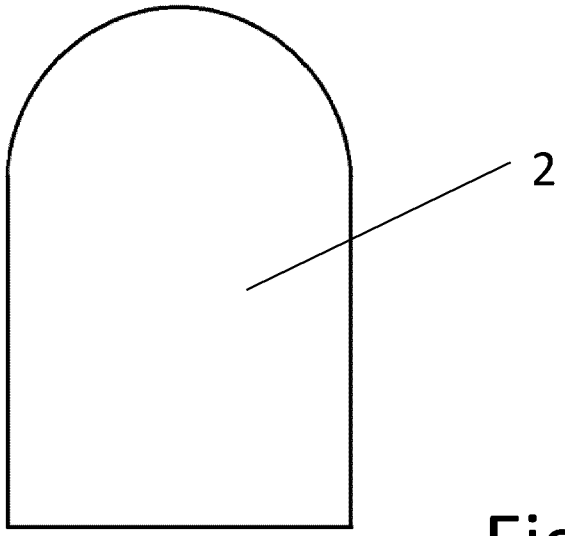

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Fig 1

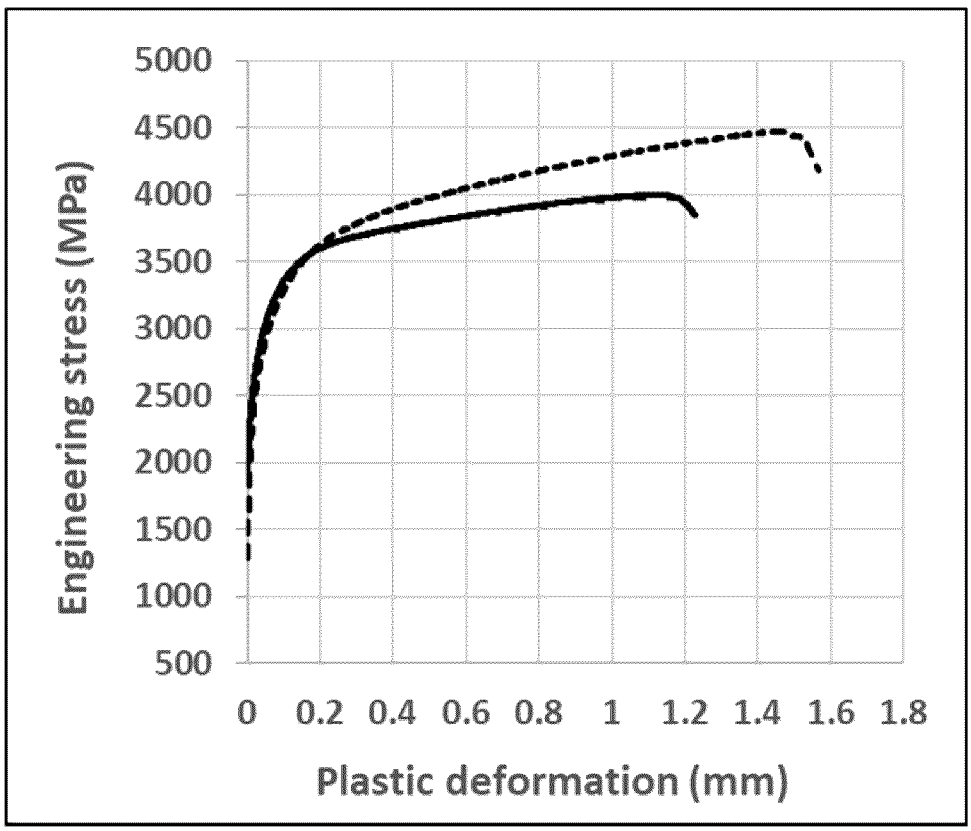

5000
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4000
3500
3000
2500
2000
1500
1000
500
Engineering stress (MPa)
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0.2
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0.6
0.8
1
1.2
1.4
1.6
1.8
Plastic deformation (mm)

Fig 2

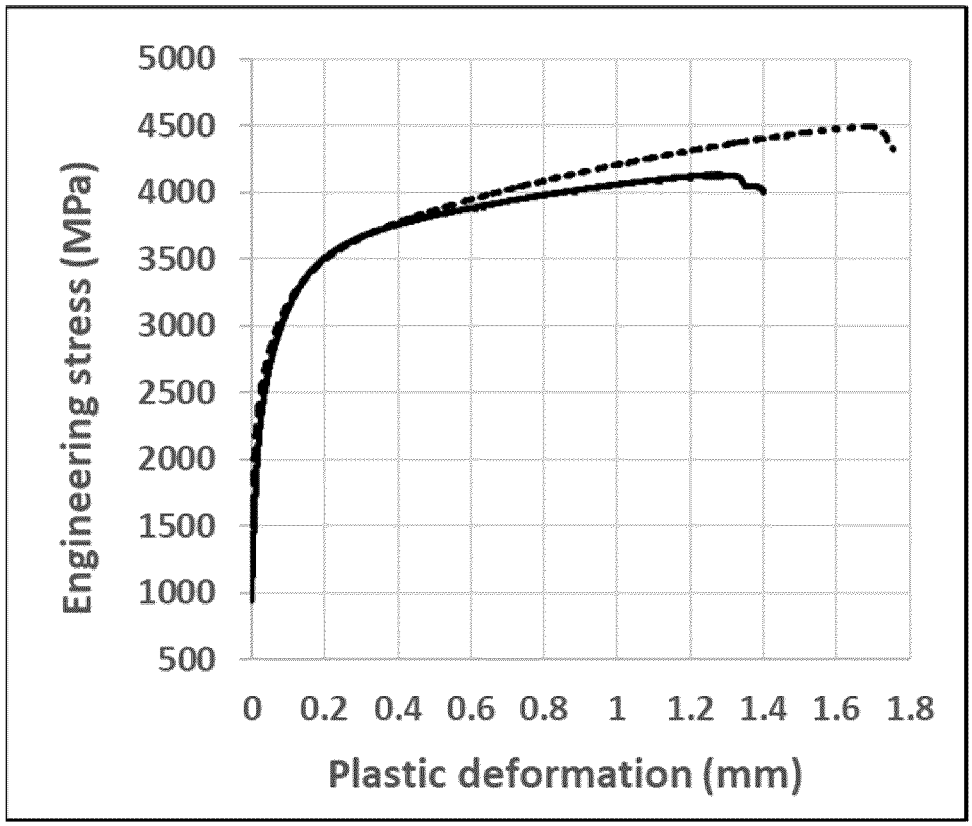

Engineering stress (MPa)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Plastic deformation (mm)

Fig 3

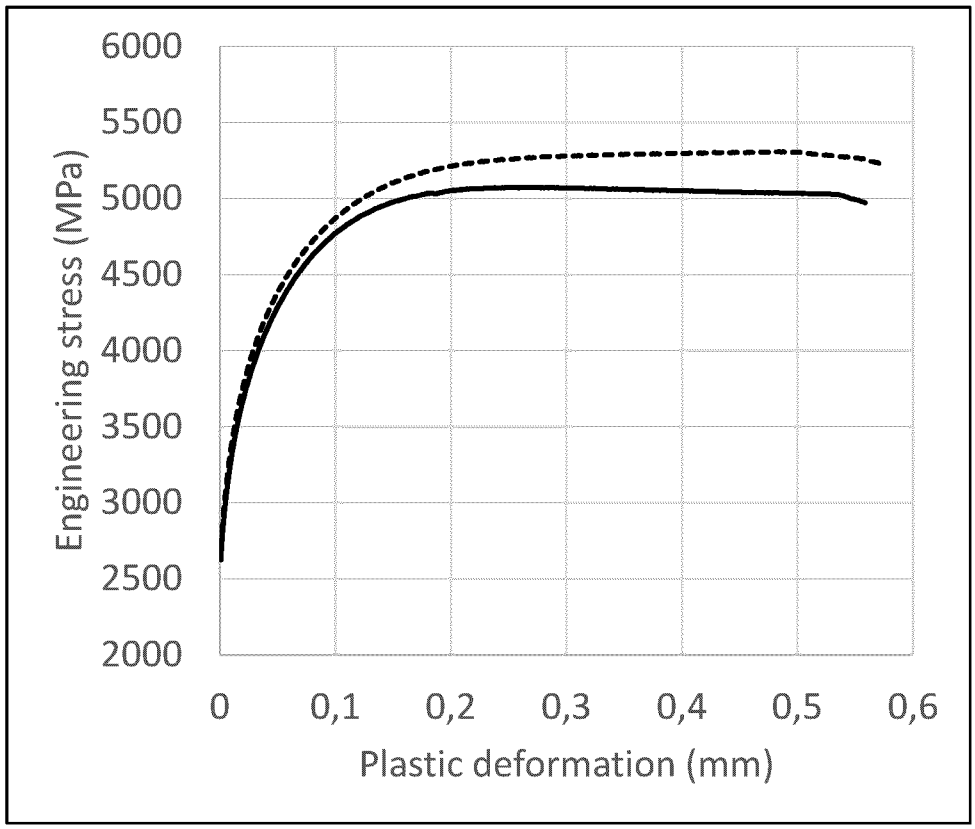

Engineering stress (MPa)
6000
5500
5000
4500
4000
3500
3000
2500
2000
0
0,1
0,2
0,3
0,4
0,5
0,6
Plastic deformation (mm)

Fig 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/068336

A. CLASSIFICATION OF SUBJECT MATTER
INV. C22C29/08 B22F3/15
ADD. B22F5/00

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)
C22C B22F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 011 890 A1 (SANDVIK INTELLECTUAL PROPERTY [SE]) 7 January 2009 (2009-01-07) paragraphs [0002], [0016], [0017], [0024], [0025]; claim 6; figure 1a	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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
27 July 2023	04/08/2023

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2023/068336

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