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METHOD OF TREATING A CUTTING TOOL AND A CUTTING TOOL

Abstract

The present disclosure relates to a cutting tool of a cemented carbide or a cermet substrate. The cutting tool typically has a rake face, a flank face and a cutting edge extending therebetween. A Vickers hardness as measured on the rake face is at least 25 HV 100 higher than a Vickers hardness as measured in a bulk area of the tool, and wherein the hardness is an average of 4 parallel measurements.

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Background/Summary

RELATED APPLICATION DATA [0001] This application is a divisional of U.S. patent application Ser. No. 17/252,994 filed Dec. 16, 2020, which is a § 371 National Stage Application of PCT International Application No. PCT/EP2019/067455 filed Jun. 28, 2019.

TECHNICAL FIELD

[0002] The present disclosure relates to a method of treating a cutting tool comprising a cemented carbide or cermet substrate wherein the cutting tool is subjected to shot peening at an elevated temperature. The present disclosure also relates to a cutting tool that has been subjected to shot peening at an elevated temperature.

BACKGROUND

[0003] Cutting tools for metal cutting applications are commonly composed of a substrate of cermet or cemented carbide and the substrate is often coated with a wear resistant coating to increase the life time and performance of the cutting tool. To further improve the cutting tool, it is known to treat the cutting tool in a sometimes called post treatment, including steps such as wet blasting, dry blasting, edge brushing and/or polishing. These processes typically change the surface roughness of the cutting tool and/or the residual stresses in the substrate and/or in the coatings.

[0004] Effects of shot peening of cemented carbide is described by Wang et al., "Effect of shot peening on the residual stresses and microstructure of tungsten cemented carbide", Materials and Design 95, year 2016, pages 159-164. It is shown that compressive residual stresses are induced in the surface layer, both in the Co and in the WC.

[0005] There is a continuous need of improving the life times and performance of cutting tools to save time in production and reduce the risks of failure due to broken cutting tools.

SUMMARY

[0006] It is an object of the present disclosure to provide a method of making a cutting tool with improved resistance to wear in metal cutting applications. It is a further object of the present disclosure to provide a method of making a milling tool with high resistance to chipping of a coating at the cutting edge.

[0007] The present disclosure relates to a method of treating a cutting tool comprising a cemented carbide or cermet substrate wherein the cutting tool is subjected to shot peening at a temperature of or above 100° C., for example, at a temperature of or above 200° C. or at a temperature of between 200° C. and 450° C. The portion of the substrate that is subjected to shot peening is at this temperature. It has unexpectedly been found that treating a cutting tool to shot peening when it is heated increases its lifetime in cutting.

[0008] In one embodiment of the present disclosure the cutting tool is subjected to shot peening at a temperature of between 150-250° C., for example, at a temperature of between 175-225° C.

[0009] In one embodiment of the present disclosure the cutting tool is subjected to shot peening at a temperature of between 300-600° C., for example, at a temperature of between 350-550° C. or of between 450-550° C.

[0010] The shot peening of the present disclosure is performed at an elevated temperature, and this temperature is herein defined as the temperature that the material (the portion of the cutting tool) that is shot peened is at during the shot peening. Several methods can be used to create the elevated temperature of the cutting tool portion, such as induction heating, resistance heating, pre-heating on a hot surface/oven, laser heating etc. The cutting tool can alternatively be heated in a separate step prior to the shot peening step.

[0011] In one embodiment of the present disclosure the cutting tool comprises a rake face, a flank face and a cutting edge there between, and wherein said shot peening is performed at least on the rake face. Rake face peening is advantageous in that it is at the rake face that the working material hits the cutting tool during the cutting operation and that the mechanisms during peening that is influencing the substrate is therefore applied at a relevant area or volume of the substrate. It is further advantageous to apply the shot peening at the rake face since for many cutting tool geometries this imply treating several cutting edges at the same time.

[0012] In one embodiment of the present disclosure an ER of at least a part of the cutting edge is between 10 μm and 50 μm, preferably between 20 μm and 40 μm. It has surprisingly been shown that the cutting tools made according to present method is performing well on cutting tools with this ER.

[0013] In one embodiment of the present disclosure the metallic binder phase content in the cemented carbide or cermet is 1-30 vol %, for example, 3-25 vol %. The binder phase content is to be high enough to provide a tough behaviour of the cutting tool. The metallic binder phase content is preferably not higher than 30 vol %, for example, not higher than 25 vol %. A too high content of binder phase reduces the hardness and wear resistance of the cutting tool.

[0014] In one embodiment of the present disclosure the metallic binder phase is an alloy comprising at least 80 wt % of one or more metallic elements selected from Co, Ni and Fe.

[0015] In one embodiment of the present disclosure the metallic binder phase is an alloy comprising one or more metallic elements selected from Co, Ni, Fe, Al, Cr, Mn, Ru, W, Mo, Re, Ti, Ta, Nb, Zr, Hf, Cu and Si, for example, selected from Co, Ni, Fe, Al, Cr, Ti and Ta, or selected from Co, Ni, Fe, Al and Cr.

[0016] In one embodiment of the present disclosure the cutting tool is provided with a coating.

[0017] The coating can be a colour layer or a wear resistant coating.

[0018] In one embodiment of the present disclosure the thickness of the coating is 2-20 μm, for example, 5-10 μm.

[0019] In one embodiment of the present disclosure the shot peening is performed with a peening media comprising beads of ZrO.sub.2, steel or cemented carbide, for example, beads of ZrO.sub.2.

[0020] In one embodiment of the present disclosure the shot peening is performed with a peening media of an average diameter of 70-150 μm. If the beads are too large the risk of damaging the cutting edge is increased. If the beads are too small the energy and impact transferred from the media to the substrate is less pronounced.

[0021] In one embodiment of the present disclosure the coating is a CVD coating or a PVD coating, preferably the coating comprising one or more layers selected from TIN, TiCN, TIC, TiAlN, Al.sub.2O.sub.3 and ZrCN. The coating may be a CVD coating having a TiCN layer and a Al.sub.2O.sub.3 layer.

[0022] In one embodiment of the present disclosure the shot peening is performed on heated cutting tools, the method includes a step prior to the shot peening wherein the cutting tools are heated.

[0023] In one embodiment of the present disclosure the method further includes a step of shot blasting at least a portion of the cutting tool. The portion can include at least a section of the cutting edge or an area close to the cutting edge.

[0024] In one embodiment of the present disclosure the step of shot blasting is performed subsequent to the shot peening. The heat during the shot peening can reduce some positive effect from the shot blasting, such as residual stress induction in a coating, so by choosing to do the shot peening before the shot blasting both positive effects can be maintained.

[0025] In one embodiment of the present disclosure the shot blasting and the shot peening are performed on the same portions of the cutting tool. This is advantageous for example during a production in large scale due to a more effective loading of the cutting tools.
[0026] The present disclosure also relates to a cutting tool for a metal cutting application treated with the method of the present disclosure.
[0027] In one embodiment of the present disclosure the shot peening process can be applied to any cutting tool having a cemented carbide substrate with a Co binder phase where the cemented carbide substrate comprises Cr.
[0028] In one embodiment of the present disclosure the cemented carbide comprises at least 50 wt % WC, possibly other hard constituents common in the art of making cemented carbides, and between 3 to 20 wt % of a Co binder phase.
[0029] In one embodiment of the present disclosure the Co is the main constituent in the binder apart from elements that is dissolved in the Co binder during sintering e.g. Cr and W and C originating from the WC. Depending on what other types of hard constituents that are present, also other elements can be dissolved in the binder. The amount of Co in the cemented carbide is suitably between 3 to 20 wt %, for example, between 3 to 12 wt %.
[0030] In one embodiment of the present disclosure the other hard constituents is e.g. grain growth inhibitors, gamma phase formers etc. Common additives are carbides, nitrides or carbonitrides of Ti, Ta, Nb, Zr and V.
[0031] In one embodiment of the present disclosure, the Co binder phase comprises Cr in an amount such that the Cr/Co weight ratio is between 0.03 to 0.35, for example, 0.07 to 0.20.
[0032] In one embodiment of the present disclosure, the cemented carbide comprises M.sub.7C.sub.3 carbides, and possibly also M.sub.3C.sub.2 carbides, where M is Cr and possibly one or more of W, Co and any other elements added to the cemented carbide. By that is herein meant that the M.sub.7C.sub.3 carbides should be clearly visible in a SEM (scanning electron microscope) image using backscattering at a magnification enough to detect particles of a size of 100 nm.
[0033] In one embodiment of the present disclosure, the cemented carbide comprises M.sub.7C.sub.3 carbides in an amount given by the ratio vol % M.sub.7C.sub.3 carbides/vol % Co. Suitably the ratio vol % M.sub.7C.sub.3 carbides/vol % Co is between 0.01 to 0.5, for example, between 0.03 to 0.25. The vol % of M.sub.7C.sub.3 carbides and the Co binder can be measured by EBSD or image analysis using a suitable software, e.g., Image J.
[0034] In one embodiment of the present disclosure the method of treating a cutting tool includes a cemented carbide substrate having a metallic binder phase, wherein the cemented carbide has a substoichiometric carbon content, SCC, of −0.13 wt %≤SCC<0 wt %, or −0.30 wt %≤SCC≤−0.16 wt %, and wherein the cutting tool is subjected to a shot peening process at a temperature of or above 100° C., for example, at a temperature of or above 200° C., or at a temperature of between 200° C. and 450° C. The portion of the substrate that is subjected to shot peening is at the temperature. It has unexpectedly been found that treating a cutting tool to shot peening when it is heated increases its lifetime in cutting.
[0035] In one embodiment of the present disclosure the shot peening process can be applied to any cutting tool having a cemented carbide substrate including a metallic binder phase wherein the cemented carbide has a substoichiometric carbon content, SCC, of −0.13 wt %≤SCC<0 wt %, or −0.30 wt %≤SCC≤−0.16 wt %.
[0036] By cemented carbide is herein meant a material that has at least 50 wt % WC, possibly other hard constituents common in the art of making cemented carbides and between 3 to 20 wt % of a metallic binder phase.
[0037] In one embodiment the metallic binder phase is a binder phase where the main element(s) is selected from one or more of Fe, Co and Ni, for example, Co, in an amount of 3 to 20 wt % of the cemented carbide, or between 5 to 12 wt % of the cemented carbide.

[0038] In one embodiment the binder is mainly composed of one or more of Ni, Co and Fe, except from other elements that is dissolved in the binder during sintering, e.g., and W and C originating from the WC. Depending on what other types of hard constituents that are present, also other elements can be dissolved in the binder.
[0039] In one embodiment the other hard constituents common in the art is, e.g., grain growth inhibitors, gamma phase formers etc. Common additives are carbides, nitrides or carbonitrides of Ti, Ta, Nb, Zr, V and Cr.
[0040] The cemented carbide substrate according to one embodiment of the present disclosure has a substoichiometric carbon content (SCC) within certain ranges. Substoichiometric carbon is a measure of the carbon content in relation to the stoichiometric value of carbon. The substoichiometric value is a suitable value to use since it is not dependent on other parameters like binder phase content, other carbides etc.
[0041] The term substoichiometric carbon, as used herein, is the total carbon content determined by chemical analysis minus the calculated stoichiometric carbon content based on WC and possible other carbides present in the sintered cemented carbide.
[0042] When the stoichiometric carbon content is estimated on a sintered cemented carbide, e.g., consisting of Co and WC, it can either be done based on the amount of added WC raw material, assuming that the atomic ratio W:C is 1:1, or, from measurements on the sintered material, and then from the measured tungsten content calculate the stoichiometric carbon content assuming that the atomic ratio W:C is 1:1. If other constituents are added e.g. grain growth inhibitors, gamma phase formers etc. as has been described previously, those are also assumed to be stoichiometric.
[0043] One way to determine the substoichiometric carbon content (SCC) in a WC—Co substrate is to first measure the total carbon content by using a LECO WC-600 instrument, for this analysis, the sample was crushed prior to the analysis. The accuracy of the values is +0.01 wt %. The Co content is then measured with XRF (X-ray fluorescence) using a Malvern Panalytical Axios Max Advanced instrument. By subtracting the cobalt and carbon amounts from the total weight of the sample, the W content is achieved which is used to calculated the stoichiometric carbon content, assuming the WC has a 1:1 ratio.
[0044] As an example, if the stoichiometric carbon content for a particular cemented carbide is 5.60 wt %, and the same cemented carbide would be made, but with a carbon content of 5.30 wt %, the substoichiometric carbon would be −0.30 wt %.
[0045] The solubility of W in the binder phase is directly related to the carbon content. The amount of W in the binder increases with decreasing carbon content until the limit for eta phase formation is reached. If the carbon content would decrease even lower, the solubility of W in the binder will not increase further. In some cemented carbide grades where it is beneficial to obtain a high amount of W dissolved in the binder, the carbon content has been kept low but above the limit for eta phase formation.
[0046] In one embodiment, the cemented carbide has a substoichiometric carbon content −0.13 wt %≤SCC<0 wt %, for example, −0.13 wt %≤SCC≤−0.05 wt %, or −0.12 wt %≤SCC≤−0.10 wt %. In this embodiment the cemented carbide is free from at least large agglomerates of eta phase, alternatively free from eta phase in any form.
[0047] In one embodiment of the present disclosure, the cemented carbide substrate has an eta phase and a substoichiometric carbon of 0.30 wt %≤SCC<−0.16 wt %, for example, −0.28 wt %≤SCC≤−0.17 wt %. If the carbon content is higher than the upper limit in this embodiment, i.e., above −0.16 but still in the eta phase forming region, the formed eta phase will be unevenly distributed like in large agglomerates leading to a decrease in toughness of the cemented carbide. The cemented carbide according to this embodiment of the present disclosure, should have an evenly distributed eta phase, by that is herein meant that the cemented carbide is free from large agglomerates. For example, the amount of eta phase is between 2 to 10 vol %, between 4 and 8 vol % or between 4 to 6 vol %.

[0048] In one embodiment the cemented carbide has an eta phase having Me.sub.12C and/or Me.sub.6C carbides, where Me is one or more metals selected from W, Mo and the binder phase metals. The cemented carbide according to this embodiment has such a low carbon content so that eta phase is formed. This will result in a cemented carbide having both a high W content in the binder and eta phase. The eta phase formed is, however, not present as large agglomerates.
[0049] Commonly, eta phase has been considered as unwanted in cemented carbide due to that it has traditionally been present in large agglomerates of eta phase grains, which are brittle and detrimental to the cemented carbide properties. However, by providing the non-agglomerated eta phase by selecting a certain range of substoichiometric carbon content as in the cemented carbide of this embodiment, the cemented carbide shows good properties. The eta phase is present in the microstructure as a fine dispersed phase.
[0050] Common carbides of the eta phase are W.sub.6Co.sub.6C, W.sub.3Co.sub.3C, W.sub.6Ni.sub.6C, W.sub.3Ni.sub.3C, W.sub.6Fe.sub.6C, W.sub.3Fe.sub.3C.
[0051] In one embodiment the eta phase has both Me.sub.12C and Me.sub.6C.
[0052] In one embodiment, the cemented carbide has a substoichiometric carbon content −0.13 wt %≤SCC<0 wt %, for example, −0.13 wt %≤SCC≤−0.05 wt %, or −0.12 wt %≤SCC≤−0.10 wt %. In this embodiment the cemented carbide is free from at least large agglomerates of eta phase, alternatively free from eta phase in any form.
[0053] The present disclosure also relates to a cutting tool having a cemented carbide or a cermet substrate, wherein the cutting tool (**1**) includes a rake face (**2**), a flank face (**3**) and a cutting edge therebetween, and wherein the Vickers hardness as measured on the rake face is at least 25 HV 100 higher, for example, 30 HV 100 higher, or 40 HV 100 higher, than the Vickers hardness as measured in the bulk, wherein the hardness is an average of 4 parallel measurements. The hardness measured in the bulk is a hardness measurement performed at a cross section of the cutting tool.
[0054] In the cutting tool of the present disclosure the hardness is lower in the bulk area as compared to the surface area. An increased hardness in the surface area of the cutting tool, especially in the area of the cutting tool that is in contact with the work piece material during metal cutting applications, is advantageous in that the wear resistance of the cemented carbide or cermet is increased. Further, a coating applied on the substrate can withstand longer and thereby increase the life time of the cutting tool. In one embodiment of the present disclosure the cutting tool comprises a coating, and wherein the thickness of the coating in the area of the hardness measurement is 3-12 μm, for example, less than 6 μm.
[0055] In one embodiment of the present disclosure the grain size of the hard constituents in the substrate is evenly distributed such that no gradient in grain size distribution exists.
[0056] In one embodiment of the present disclosure the binder phase content in the surface area of the substrate is higher than or the equal to the binder phase content in the bulk area of the cutting tool.
[0057] In one embodiment of the present disclosure the composition of the cemented carbide or the cermet in the surface area corresponds to the composition in the bulk area.
[0058] The present disclosure also relates to a cutting tool including a rake face (**2**), a flank face (**3**) and a cutting edge therebetween, and wherein the residual stress as measured on the rake face is RS (original) and wherein the residual stress as measured after a heat treatment for 10 minutes at atmospheric pressure at 400° C. is RS (heat treated), and wherein the relation RS (heat treated)/RS (original) is ≥92%, for example, ≥95%, or ≥97%. The residual stress in the surface area is compressive after the shot peening process.
[0059] In one embodiment the relation RS (heat treated)/RS (original) is ≥1. A heat treatment at 400° C. clearly shows that the effect from the hot shot peening remains in the substrate even after a heat treatment. This is advantageous since an increased residual stress level in the surface area of the substrate can counteract the formation of cracks, and thereby increase the life time of the cutting tool. Cutting tools in use are exposed to heat since metal cutting creates heat. Cooling is

often applied, but in many applications the heat is utilised, softening the chip during its formation, since the cutting forces can be kept relatively low.

[0060] Shot peening influences the residual stress in the substrate such that compressive stresses can be measured, for example by XRD, sin.sup.2 y-method, and studying the reflection from the 211 peak of WC. Hot shot peening has surprisingly shown to influence the residual stress in the substrate even further. It was realized that hot shot peening introduced residual stress that could withstand also a subsequent heat treatment. This is a promising property that is advantageous in cutting tools.

[0061] In one embodiment of the present disclosure the cutting tool includes a cemented carbide substrate, wherein the cutting tool (**1**) has a rake face (**2**), a flank face (**3**) and a cutting edge therebetween, and wherein the Vickers hardness as measured on the rake face is at least 25 HV 100 higher, for example, 30 HV 100 higher, or 40 HV 100 higher, than the Vickers hardness as measured in the bulk, wherein the hardness is an average of 4 parallel measurements, the cutting tool further includes a surface coating with thickness is 3-12 μm, the cemented carbide has 3-20 wt % binder phase having Co, and wherein the cemented carbide includes Cr such that a Cr/Co weight ratio is 0.03-0.35. In one embodiment this coating is a CVD coating, for example, a CVD coating including a layer of TiCN and a layer of Al.sub.2O.sub.3.

[0062] In one embodiment of the present disclosure the cutting tool includes a cemented substrate, wherein the cutting tool (**1**) has a rake face (**2**), a flank face (**3**) and a cutting edge therebetween, and wherein the residual stress as measured on the rake face is RS (original) and wherein the residual stress as measured after a heat treatment for 10 minutes at atmospheric pressure at 400° C. is RS (heat treated), and wherein the relation RS (heat treated)/RS (original) is ≥92%, for example, ≥95%, or ≥97%, the cutting tool is provided with a CVD coating with thickness 3-12 μm, the substrate includes at least 50 wt % WC, and between 3 to 20 wt % of a binder phase comprising Co, for example, 7-10 wt % Co, and optionally comprising TaC and NbC, the cutting tool can be provided with a CVD coating including a layer of TiCN and a layer of Al.sub.2O.sub.3.

[0063] The foregoing summary, as well as the following detailed description of the embodiments, will be better understood when read in conjunction with the appended drawings. It should be understood that the embodiments depicted are not limited to the precise arrangements and instrumentalities shown.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0064] FIG. **1** is a perspective view of a cutting tool insert.

[0065] FIG. **2** is a cross-section of a cutting edge.

DEFINITIONS

[0066] Cemented carbide and cermet are materials comprising hard constituents distributed in a continuous metallic binder phase. This kind of material has properties combining a high hardness from the hard constituents with a high toughness from the metallic binder phase and are suitable as substrate materials for metal cutting tools.

[0067] By “cemented carbide” is herein meant a material that comprises at least 50 wt % WC, possibly other hard constituents common in the art of making cemented carbides and a metallic binder phase preferably selected from one or more of Fe, Co and Ni.

[0068] By “cermet” is herein meant a material comprising a hard constituent and metallic binder phase where the hard constituent is one or more of titanium carbonitride, titanium carbide and titanium nitride. The metallic binder phase in cermet is preferably selected from one or more of Fe, Co and Ni, preferably Co. Other hard constituents common in the art of cermets are selected from carbides, nitrides or carbonitrides of Ti, Ta, Nb, Zr, V and Cr. The cermet material comprises no

free hexagonal WC. Cermet materials based on titanium carbonitride are the most common cermet materials of today.
[0069] The metallic binder of the cermet or the cemented carbide can comprise other elements that are dissolved in the metallic binder during sintering, such as W and C originating from the WC. Depending on what other types of hard constituents that are present, also other elements can be dissolved in the binder.
[0070] By "cutting tool" is herein meant a cutting tool for metal cutting applications such as an insert, an end mill or a drill. The application areas can be turning, milling or drilling.
[0071] "ER" is a value of the edge rounding intended to indicate the sharpness of the edge. Larger values of ER represent a rougher shape of the cutting edge while a smaller value of ER represent a sharp cutting edge.
[0072] ER is herein defined as a value as calculated according to the following: [0073] put the cutting tool on a flat surface on its bearing surface or the corresponding surface of the cutting tool. [0074] align a first plane along the side of the cutting tool perpendicular to the flat surface, in contact with the edge to measure, for example along the flank face **3** of the cutting tool **1**, [0075] align a second plane in parallel with the flat surface and intersecting at an intersection point the first plane, the second plane being in contact with the edge to measure at a contact point, for example the second plane is aligned along the rake face **2** of the cutting tool **1**.
[0076] The value "ER" is equal to the distance between the intersection point between the first and the second plane and the point of contact between the first plane and the cutting tool, close to the edge, see FIG. **2**.
[0077] "Shot blasting" is herein denoted a process using abrasive grains wherein material typically is removed from the treated surface by abrasive wear. Shot blasting is well known in the field of cutting tools and is for example known to introduce residual stresses in a coating on a cutting tool.
[0078] By "Shot peening" is herein meant that the surface of a cutting tool is bombarded with a media comprising particles, so called beads, that are non-abrasive and that typically have a round shape. The media can be beads of a hard material such as an oxide, steel or cemented carbide. By the term "bulk" is herein meant the innermost part (center) of the cutting tool and for this disclosure is the zone having the lowest hardness.
[0079] By the term "surface area" is herein meant the outer portion of the substrate which is influenced by the shot peening process disclosed herein.

DETAILED DESCRIPTION

[0080] FIG. **1** is a general view of a cutting tool insert **1**, provided with a rake face **2** and a flank face **3**. A cutting edge is provided therebetween. FIG. **2** is a general view of a cross-section of a cutting edge wherein the ER is indicated and also the width of the cutting edge, "w", is shown schematically.
[0081] The present disclosure relates to a method of treating a cutting tool **1** comprising a cemented carbide or cermet substrate, wherein the cutting tool is subjected to shot peening at a temperature of or above 100° C., for example, at a temperature of or above 200° C. or at a temperature of between 200° C. and 450° C. The portion of the substrate that is subjected to shot peening is at the temperature. It has unexpectedly been found that treating a cutting tool to shot peening when it is heated increases its lifetime in cutting.
[0082] The upper limit for the temperature where the shot peening is performed is preferably below the sintering temperature for the given cemented carbide or cermet, more preferably below 1200° C.
[0083] The shot peening of the present disclosure is performed at an elevated temperature, and this temperature is herein defined as the temperature that the material (the portion of the cutting tool) that is shot peened is at during the shot peening. Several methods can be used to create the elevated temperature of the cutting tool portion, such as induction heating, resistance heating, pre-heating on a hot surface/oven, laser heating etc. The cutting tool can alternatively be heated in a separate step

prior to the shot peening step.
[0084] The temperature is suitably measured on the substrate by any method suitable for measuring temperature. Preferably, an infrared temperature measurement device is used.
[0085] In one embodiment of the present disclosure the cutting tool **1** includes a rake face **2**, a flank face **3** and a cutting edge therebetween, and wherein the shot peening is performed at least on the rake face **2**. Rake face peening is advantageous in that it is at the rake face **2** that the working material hits the cutting tool during the cutting operation and that the mechanisms during peening that is influencing the substrate is therefore applied at a relevant area or volume of the substrate. It is further advantageous to apply the shot peening at the rake face **2** since for many cutting tool geometries this imply treating several cutting edges at the same time.
[0086] In one embodiment of the present disclosure an ER of at least a part of the cutting edge is between 10 μm and 50 μm, for example, between 20 μm and 40 μm. It has surprisingly been shown that the present method is performing well on cutting tools **1** with this ER.
[0087] In one embodiment of the present disclosure the metallic binder phase content in the cemented carbide or cermet is 1-30 vol %, for example, 3-25 vol %. The binder phase content is to be high enough to provide a tough behaviour of the cutting edge. The metallic binder phase content is preferably not higher than 30 vol %, for example, not higher than 25 vol %. A too high content of binder phase reduces the hardness and wear resistance of the cutting tool.
[0088] In one embodiment of the present disclosure the metallic binder phase is an alloy having at least 80 wt % of one or more metallic elements selected from Co, Ni and Fe.
[0089] In one embodiment of the present disclosure the metallic binder phase is an alloy comprising one or more metallic elements selected from Co, Ni, Fe, Al, Cr, Ru, W, Mo, Mn, Re, Ti, Ta, Nb, Zr, Hf, Cu, Si.
[0090] In one embodiment of the present disclosure the cutting tool is provided with a coating. The coating can be a colour layer or a wear resistant coating.
[0091] In one embodiment of the present disclosure the thickness of the coating is 1.5-25 μm, for example, 2-20 μm, or 2-10 μm.
[0092] The shot peening can be performed in a dry process using air with the beads in it. The beads can be made of any material known in the art of shot peening, such as ceramic beads, cemented carbide beads or metallic beads.
[0093] In one embodiment of the present disclosure the shot peening is performed with a peening media including beads of ZrO.sub.2, steel or cemented carbide.
[0094] In one embodiment of the present disclosure the shot peening is performed with a peening media of an average diameter of 70-150 μm. The impact or energy from the beads during the shot peening should not be too high since this would increase the risk of damaging the surface and the cutting edge of the cutting tool. The impact or energy from the beads should neither be too low since then the technical effect would not be achieved. If the beads are too large the risk of damaging the cutting edge is increased. If the beads are too small the energy and impact transferred from the media to the substrate is less pronounced. A suitable size of the beads is related to the material of the beads and is to be selected by the skilled person.
[0095] In one embodiment of the present disclosure the coating is a CVD coating or a PVD coating, wherein the coating has one or more layers selected from TIN, TiCN, TIC, TiAlN, Al.sub.2O.sub.3 and ZrCN.
[0096] The coated cutting tool subjected to the shot peening process according to the present disclosure can be provided with any coating common in the art of cutting tools, suitably a PVD or CVD coating, preferably a CVD coating.
[0097] In one embodiment of the present disclosure, the coating is a CVD coating comprising an inner TiCN layer and an outer a-Al.sub.2O.sub.3 layer.
[0098] In one embodiment of the present disclosure, the cemented carbide substrate is provided with a wear resistant PVD coating, suitably being a nitride, oxide, carbide or mixtures thereof of

one or more of the elements selected from Al, Si and groups 4, 5 and 6 in the periodic table.

[0099] In one embodiment of the present disclosure the shot peening is performed on heated cutting tools, the method includes a step prior to the shot peening wherein the cutting tools are heated.

[0100] In one embodiment of the present disclosure the method further includes a step of shot blasting at least a portion of the cutting tool. The portion includes at least a section of the cutting edge or an area close to the cutting edge.

[0101] In one embodiment of the present disclosure the step of shot blasting is performed subsequent to the shot peening. The heat during the shot peening can reduce some positive effect from the shot blasting, such as residual stress induction in a coating, so by selecting to do the shot peening before the shot blasting both positive effects can be maintained.

[0102] In one embodiment of the present disclosure the shot blasting and the shot peening are performed on the same portions of the cutting tool. This is advantageous for example during a production in large scale due to a more effective loading of the cutting tools.

[0103] In one embodiment of the present disclosure the peening is performed in a shot direction that is perpendicular to the surface of the cutting tool. A perpendicular shot peening is advantageous in that the depth of the impacted substrate is the largest when the heated shot peening is in this direction.

[0104] In one embodiment of the present disclosure, the cutting tool **1** is an insert, for example, a milling insert.

[0105] In one embodiment of the present disclosure the cemented carbide has a binder phase of Co, for example, 3-20 wt % Co in the cemented carbide, and wherein the cemented carbide includes Cr, with a Cr/Co weight ratio of 0.03-0.35, for example, a Cr/Co weight ratio of 0.07-0.20.

[0106] In one embodiment of the present disclosure the cemented carbide includes M.sub.7C.sub.3 carbides.

[0107] In one embodiment of the present disclosure the cemented carbide has a substoichiometric carbon content, SCC, of −0.13 wt %≤SCC≤0 wt %, or −0.30 wt % %≤SCC<−0.16 wt %.

[0108] In one embodiment of the present disclosure the cemented carbide has a substoichiometric carbon content, SCC, of −0.28 wt %≤SCC≤−0.17 wt %, and further includes eta phase.

[0109] The shot peening process according to the present disclosure can also be combined with other process steps known in the art of making cutting tools such e.g. brushing, polishing, wet blasting, dry blasting etc.

[0110] The present disclosure also relates to a cutting tool **1** treated with the method of the present disclosure.

EXAMPLES

[0111] Exemplifying embodiments of the present invention will now be disclosed in more detail and compared to comparative embodiments. Coated cutting tools (inserts) were prepared, analyzed and evaluated in cutting tests.

Example 1 (Sample Preparations)

[0112] Cutting tools of cemented carbide were prepared by forming substrates from raw materials according to Table 1. The substrates were manufactured according to conventional methods including milling, spray drying, pressing and sintering. Cutting tools of the Insert type R 390-11T308M-PM and R 390-11T308M-MM were formed and used in the milling tests. Also cutting tools of Insert type SNUN 19 04 16 were formed and these were used in the hardness and the residual stress measurements. Tungsten metal was added to substrate 3A and 3B in order to adjust the carbon content.

TABLE-US-00001 TABLE 1 Substrate compositions Sub- Co Cr TaC NbC strate (wt %) (wt %) Cr/Co SCC (wt %) (wt %) WC 1A 9.14 — — 0.01 1.23 0.30 balance 1B 9.14 — — n.a. — — balance 1C 12.6 — — n.a. 1.17 0.28 balance 2A 7.92 1.23 0.155 n.a. — — balance 2B 8.2 0.41 0.05 n.a. — — balance 2C 7.75 0.775 0.1 n.a. — — balance 2D 8.24 1.65 0.2 n.a. — — balance

3A 9.4 — — −0.26 — — balance 3B 9.14 — — −0.13 — — balance n.a = not analyzed

[0113] The substrates were manufactured according to conventional methods including milling, spray drying, pressing and sintering. Cutting tools of the Insert type R 390-11T308M-PM and R 390-11T308M-MM were formed and used in the milling tests. Also cutting tools of Insert type SNUN 19 04 16 were formed and these were used in the hardness and the residual stress measurements. Tungsten metal was added to substrate 3A and 3B in order to adjust the carbon content.

[0114] The amount of eta phase in substrates 1A, 3A and 3B were determined by image analysis using the software Image J using the setup “Automatic”. The images used for the analysis was LOM images with a magnification of 1000× and 2000×, two measurements were done at each magnification and the value presented below is an average value of these. The value is an average from a total of four image analyses performed on two images, 2 measurements on each image. The substrate 3A contained 4 vol % eta phase, substrates 1A and 3B contained no eta phase. The substoichiometric carbon content (SCC) was calculated for substrates 1A, 3A and 3B. and are presented in Table 1. None of the substrate contained free graphite. Except for the substrate 3A, none of the other substrate contained eta phase in the bulk area of the substrate.

[0115] Substrates 1A, 1B, 2A, 2B, 2C, 2D, 3A, and 3B were coated in the same coating process, depositing the layers TiN/TiCN/a-Al.sub.2O.sub.3/TIN with CVD. The total coating thickness was about 6.6 μm.

[0116] Substrate 1C was coated in a coating process, depositing the layers TiN/TiCN/κ-Al.sub.2O.sub.3/TiN with CVD. The total coating thickness was about 4.2 μm.

[0117] Coated cutting tools of all the types of substrates were subjected to shot peening at elevated temperature forming samples Inventions 1A-1C, Inventions 2A-2D and Inventions 3A-3B.

[0118] Corresponding cutting tools of all the types of substrates were subjected to a shot peening at room temperature (25° C.), forming Comparatives 1A-1C, Comparatives 2A-2D and Comparative 3A-3B.

[0119] The shot peening of the samples later tested in Example 2 was performed in a IEPCO Micropeen Peenmatic 750 GSD equipment. A blasting media of ZrO.sub.2 ceramic beads with a spherical shape and an average diameter of about 100 μm was used, media IEPCO M S/Z 350 B. The grain size of the ZrO.sub.2 ceramic beads is 70-125 μm. The shot gun pressure was set to 5 bar, the working time was set to 20 seconds, the nozzle diameter was 8 mm and the stand-off distance was 100 mm. The peening was applied perpendicular to the rake face of the cutting tools. In the case of heated shot peening the cutting tools were heated at a resistance heater prior to the shot peening and the temperature of the cutting tools were measured with a temperature sensor. The shot peening of the samples later tested in Examples 3 and 4 was performed in an AUER Manual Blasting Cabinet ST 700 PS equipment. A blasting media of ZrO.sub.2 ceramic beads with a spherical shape and an average diameter of about 100 μm was used, media Microblast® B 120. The grain size of the ZrO.sub.2 ceramic beads is 63-125 μm. The shot gun pressure was set to 2 bar, the working time was set to 12 seconds, the nozzle diameter was 8 mm and the stand-off distance was 100 mm. The peening was applied perpendicular to the rake face of the cutting tools. In the case of heated shot peening the cutting tools were heated with an induction coil heater prior to the shot peening and the temperature of the cutting tools were measured with a temperature sensor. The induction heater was a Rimac induction heater, 1.5 kW.

[0120] Subsequent to the shot peening all the cutting tools except 1C were subjected to a wet shot blasting treatment on the rake face of the cutting tools. The shot blasting was performed with Al.sub.2O.sub.3 abrasive grains with a grain size of F220. The concentration of blasting media in water was 20 vol % and the pump pressure during blasting was 1.8 bar. The blasting pressure was 2.0 bar, the time of blasting per area was about 5 seconds and the direction of the blasting was perpendicular to the rake face of the cutting tools. The distance between the shot gun and the samples (cutting tools) was about 130 mm.

[0121] The cutting tools **1**C were instead edge line brushed before the shot peening.
[0122] Also, coated cutting tools according to the above that were only shot blasted or only edge brushed, i.e. not shot peened, were prepared and are hereinafter called Reference 1, Reference 2 and Reference 3.
[0123] The cutting edges of the of the cutting tools after these post-treatments are about ER 40 μm.
Example 2 (Working Example)
[0124] Inserts were then tested in a milling operation at the following parameters: [0125] Work piece material: Dievar unhardened, PL 129 280×200×100, M C P3.0.Z.AN, CMC 03.11, Charge: M 10205 [0126] v.sub.c=140 m/min [0127] f.sub.z=0.15 mm [0128] a.sub.e=mm [0129] a.sub.p=3.0 [0130] z=1 [0131] length of cut=12 mm [0132] No cutting fluid was used. [0133] Insert type R 390-11T308M-PM
[0134] The tool life criterion was set to chipping of at least 0.5 mm of the edge line. Tool life is presented as the average number of cut entrances in order to achieve these criteria. The average tool life is presented in Table 2 and the tool life is the average number of cuts and it is an average of 8 parallel cutting test.
TABLE-US-00002 TABLE 2 Summary of cutting test results of Example 2 Name of sample Substrate Shot peening Average tool life Invention 1A 1A at 200° C. 25 Comparative 1A 1A at 25° C. 19 Reference 1A 1A no shot peening 9 Invention 2A 2A at 200° C. 85 Comparative 2A 2A at 25° C. 32 Reference 2A 2A no shot peening 10 Invention 3A 3A at 200° C. 83 Comparative 3A 3A at 25° C. 61 Reference 3A 3A no shot peening 8
[0135] As can been seen in the Table 2, the average tool life of the cutting tools that had been treated with the inventive method, shot peening at 200° C., was clearly higher as compared to no shot peening and also compared to shot peening at room temperature.
Example 3 (Working Example)
[0136] To study the bulk toughness inserts were prepared, and in this case the shot peeing was performed at 2 bar and for 12 seconds. The inserts were then tested in a milling operation at the following parameters: [0137] Work piece material: Toolox33 PK 158 600×200×100 mm MC P2.5.Z. CMC 02.2 Charge 111125 [0138] v.sub.c=100 m/min [0139] f.sub.z=0.25 mm [0140] a.sub.e=40 mm [0141] a.sub.p=2.0 [0142] z=1 [0143] length of 1 pass+100 mm [0144] No cutting fluid was used. [0145] Insert type R 390-11T308M-PM
[0146] The tool life criterion was set to chipping of at least 0.5 mm of the edge line. Tool life is presented as the average number of cuts in order to achieve this criteria. The presented average tool life is presented in Table 3 and the tool life is the average number of cuts of 8 parallel cutting test.
TABLE-US-00003 TABLE 3 Summary of cutting test results of Example 3 Shot peening at Average tool Name of sample Substrate temperature [° C.] life Comparative 1B 1B 25° C. 12.2 Invention 1B 1B 300° C. 16.6 Comparative 2A 2A 25° C. 7.8 Invention 2A 2A 300° C. 12.5 Comparative 2B 2B 25° C. 5.4 Invention 2B 2B 300° C. 14.2 Comparative 2C 2C 25° C. 7.0 Invention 2C 2C 300° C. 11.2 Comparative 2D 2D 25° C. 11.0 Invention 2D 2D 300° C. 19.3 Comparative 3A 3A 25° C. 10.7 Invention 3A 3A 300° C. 17.1 Comparative 3B 3B 25° C. 16.2 Invention 3B 3B 300° C. 30
Example 4 (Working Example)
[0147] To study the edge line toughness inserts were prepared, and in this case the shot peeing was performed at 2 bar and for 12 seconds. The inserts were then tested in a milling operation at the following parameters: [0148] Work piece material: Dievar unhardened, P3.0.Z.AN, Charge: F12168 [0149] v.sub.c=200 m/min [0150] f.sub.z=0.20 mm [0151] a.sub.e=12 mm [0152] a.sub.p=3.0 [0153] z=1 [0154] length of cut=12 mm [0155] No cutting fluid was used. [0156] Insert type R 390-11T308M-MM
[0157] The tool life criterion was set to chipping of at least 0.5 mm of the edge line. Tool life is presented as the average number of cut entrances in order to achieve these criteria. The presented average number of cuts is an average of 16 parallel cutting test and the average tool life is

presented in Table 4.

TABLE-US-00004 TABLE 4 Summary of cutting test results of Example 4 Substrate Shot peening at Average tool Name of sample No. temperature (° C.) life Reference 1C 1C Not shot peened 1.1 Comparative 1C 1C 25° C. 2.3 Invention 1C105 1C 105° C. 3.6 Invention 1C150 1C 150° C. 4.2 Invention 1C200 1C 200° C. 4.9 Invention 1C250 1C 250° C. 3.7 Invention 1C300 1C 300° C. 4.9 Invention 1C400 1C 400° C. 6.0 Invention 1C500 1C 500° C. 7.2

Example 5 (Vickers Measurements)

[0158] The relation between the hardness in the surface area and the hardness in the bulk area was analysed with Vickers measurements, making Vickers indentations on the rake face of the cutting tool and Vickers indentations on a cross section of the cutting tool. The outer alumina layer was removed to improve the measurements of the Vickers indents. The results are presented in Table 5.

[0159] Samples were polished using standard methods so that the TiCN layer was exposed on the rake face of the cutting tool. A bulk sample was prepared by cutting the insert perpendicular to the rake face using a diamond wheel and subsequently polishing using 9 μm diamond dispersed in oil on paper and then 1 μm diamond dispersed in oil. Hardness of the polished samples were then measured using a programmable hardness tester, K B 30S by K B Prüftechnik GmbH. The measurements were calibrated against HV 100 using test blocks issued by Euro Products Calibration Laboratory, UK. Hardness was measured according to ISO EN 6507.

[0160] HV measurements were performed by programming the hardness tester to perform indentations at certain positions. Indentations are then performed using the specified load after which each indentation is automatically revisited. The computer auto adjusts light, auto focuses and then measures the size of each indentation, a photo is saved and the user inspects all the photos of the indentations for focus and other matters that might disturb the result. Four parallel HV 100 indentations were made with a distance from each other (center-center) of about 1.5 mm and the presented result is an average value.

TABLE-US-00005 TABLE 5 Coating Difference thickness between during bulk and Shot peening at Bulk Surface hardness surface temperature hardness hardness measurement hardness Sample [° C.] [HV100] [HV100] [μm] [Δ HV100] Comparative 2A 25 1497 1519 5.3 −22 Invention 2A200 200 1489 1532 5.3 −43 Invention 2A250 250 1494 1535 4.9 −41 Invention 2A300 300 1492 1536 5.5 −44 Invention 2A500 500 1497 1540 5.0 −43

Example 6 (Residual Stress Measurements)

[0161] X-ray diffraction was used to determine residual stresses in the aforementioned samples through the so-called sin.sup.2 ψ-method. In this method the shift of lattice spacings d (and hence the strains) are measured as a function of sample tilt angles w. The residual stresses are obtained from the linear slope of the strain vs sin.sup.2 ψ curve. Residual stresses are converted from strain values by using X-ray elastic constants.

[0162] The XRD measurements were performed on a Bruker Discover D8 diffractometer with Davinci design equipped with a IμS Microfocus Source (CuK.sub.α radiation, λ=1.5418 Å), a Våntec-500 area detector and an ¼ Eulerian cradle. The (2 1 1) reflection of WC located at 117.32° 2θ was used for strain measurements. The residual stress measurements were performed in 1 to 4 angular directions, φ: 0°, 90°, 180°, 270° and for each φ-direction 10 equidistant ψ-angles (0°-50°) were measured, measurement time 400 s. A collimator with 1.0 mm diameter was used in all measurements.

[0163] The resulting residual stresses were obtained from strain data by using X-ray elastic constants for WC, Bragg peak (2 1 1). The X-ray elastic constants where calculated from Poisson's ratio v=0.191 and Young's modulus=717.360 GPa.

[0164] The samples were mounted with adhesive tape to the sample holder.

[0165] The XRD data were analyzed with software DIFFRAC EVA (Bruker) and High Score Plus (Malvern Panalytical). Software LEPTOS 7 (Bruker) was used in the residual stress analysis.

[0166] The samples were heat treated at 400° C. for 10 minutes at atmospheric pressure in an oven

and in a flow of Ar gas.
[0167] The results are presented in Table 6.
TABLE-US-00006 TABLE 6 Residual Ratio of residual Original stress after stress heat Shot peening at residual heat treatment treated/residual temperature stress in 400° C. stress original Sample [° C.] [MPa] [MPa] [MPa] Comparative 1C 25 −3230 −2921 0.90 Invention 1C105 105 −3239 −2973 0.92 Invention 1C200 200 −3280 −3237 0.99 Invention 1C250 250 −3473 −3294 0.95 Invention 1C300 300 −3299 −3315 1.00 Invention 1C400 400 −3325 −3296 0.99 Invention 1C500 500 −3409 −3342 0.98
[0168] While the invention has been described in connection with various exemplary embodiments, it is to be understood that the invention is not to be limited to the disclosed exemplary embodiments, on the contrary, it is intended to cover various modifications and equivalent arrangements within the appended claims. Furthermore, it should be recognized that any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the appended claims appended hereto.

Claims

1. A cutting tool comprising a cemented carbide or a cermet substrate, wherein the cutting tool includes a rake face, a flank face and a cutting edge disposed therebetween, wherein a Vickers hardness as measured on the rake face is at least 25 HV 100 higher than a Vickers hardness as measured in a bulk area of the tool, and wherein the hardness is an average of 4 parallel measurements.
2. The cutting tool of claim 1, further comprising a coating, wherein a thickness of the coating in an area of the hardness measurement is 3 to 12 μm.
3. The cutting tool of claim 1, further comprising a coating, and wherein a thickness of the coating in an area of the hardness measurement is less than 6 μm.
4. The cutting tool according to claim 1, wherein a grain size of hard constituents in the substrate is evenly distributed such that no gradient in grain size distribution exists.
5. The cutting tool according to claim 1, wherein a binder phase content in a surface area of the substrate is higher than or equal to a binder phase in the bulk area of the cutting tool.
6. The cutting tool according to claim 1, wherein a composition of the cemented carbide or the cermet in a surface area of the substrate corresponds to a composition in the bulk area of the cutting tool.
7. The cutting tool according to claim 1, further comprising a surface coating with a thickness of 3 to 12 μm, and wherein the cemented carbide has a 3-20 wt % binder phase comprising Co, and wherein the cemented carbide comprises Cr such that a Cr/Co weight ratio is 0.03 to 0.35.
8. The cutting tool according to claim 1, wherein the cemented carbide or cermet substrate includes a CVD coating.
9. The cutting tool according to claim 1, wherein the cemented carbide or cermet substrate includes a CVD coating including a layer of TiCN and a layer of Al.sub.2O.sub.3.
10. The cutting tool according to claim 1, wherein the cemented carbide or cermet substrate includes a CVD coating including an inner layer of TiCN and an outer layer of a-Al.sub.2O.sub.3.
11. The cutting tool according to claim 1, wherein the cemented carbide is provided with a wear resistant PVD coating of a nitride, oxide, carbide or mixtures thereof of one or more of the elements selected from Al, Si, and groups 4, 5, and 6 in the periodic table.
12. The cutting tool according to claim 1, wherein the cutting tool is a milling insert.
13. The cutting tool according to claim 1, wherein the cemented carbide comprises M.sub.7C.sub.3 carbides.
14. The cutting tool according to claim 1, wherein the cemented carbide has a substoichiometric

carbon content, SCC, of −0.28 wt %≤SCC≤−0.17 wt % and further comprises eta phase.
15. The cutting tool according to claim 1, wherein the cemented carbide has a substoichiometric carbon content, SCC, of −0.13 wt %≤SCC≤0 wt % or −0.30 wt %≤SCC≤−0.16 wt %.