(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 241 642 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
20.10.2010 Bulletin 2010/42

(21) Application number: **08833284.6**

(22) Date of filing: **26.09.2008**

(51) Int Cl.:
C21D 1/09 *(2006.01)* ***B23K 20/12*** *(2006.01)*
C21D 9/18 *(2006.01)*

(86) International application number:
PCT/JP2008/067565

(87) International publication number:
WO 2009/041665 (02.04.2009 Gazette 2009/14)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **27.09.2007 JP 2007250587**

(71) Applicants:
- **Osaka Municipal Technical Research Institute**
  Osaka-shi, Osaka 536-8553 (JP)
- **Osaka University**
  Suita-shi
  Osaka 565-0871 (JP)
- **Kabushikikaisha AMC**
  2-7-207 Shimaya 4-chome
  Konohana-ku
  Osaka-Shi, Osaka 554-0024 (JP)

(72) Inventors:
- **MORISADA, Yoshiaki**
  Osaka-Shi
  Osaka 536-8553 (JP)
- **NAGAOKA, Takashi**
  Osaka-Shi
  Osaka 536-8553 (JP)
- **FUKUZUMI, Masao**
  Osaka-Shi
  Osaka 536-8553 (JP)
- **FUJII, Hidetoshi**
  Suita-Shi
  Osaka 565-0871 (JP)
- **MIZUNO, Masashi**
  Osaka-Shi
  Osaka 554-0024 (JP)

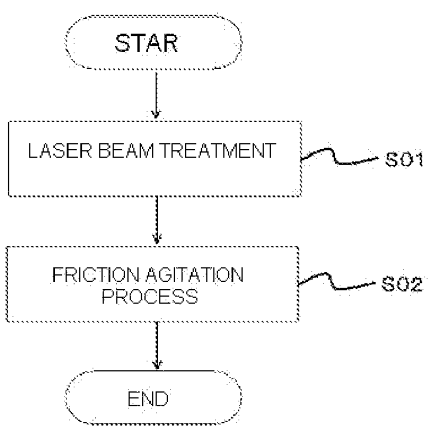
(74) Representative: **Einsel, Martin**
Patentanwälte Einsel & Kollegen
Jasperallee 1a
38102 Braunschweig (DE)

(54) METHOD FOR REFINING TEXTURE OF FERROUS MATERIAL, AND FERROUS MATERIAL AND BLADE HAVING MICROSCOPIC TEXTURE

(57) [PROBLEMS] To provide a method for refining the texture of a surface layer part in a ferrous material, to provide a ferrous material having a microscopic texture which can realize improved properties and prolonged service life of cutting tools, blades, and the like, and to provide a blade with a cutting edge formed by fabricating a microscopic texture region, wherein the expression "refining a texture" means the refinement of base metal crystal grains and the refinement of carbides.

[MEANS FOR SOLVING PROBLEMS] A method for refining the texture of a ferrous material, comprising a first step of forming a carbide refined region and a second step of forming a texture refined region. In the first step, the surface layer part in the ferrous material is locally and rapidly heated by a laser beam to form a melt reservoir which is then rapidly solidified to form a carbide refined region. In the second step, the carbide refined region formed in the first step is subjected to a friction agitation process to form a texture refined region.

【FIG. 1】



EP 2 241 642 A1

Description

[BACKGROUND OF THE INVENTION]

Technical Field of the Invention

[0001] The present invention is related to a method for surface reforming by refining the texture of a surface layer part in a ferrous material, also related to a ferrous material having a microscopic texture, especially related to a profitable method for manufacturing tool steels and blades having microscopic texture. Furthermore, the expression "refining a texture" means the refinement of crystal grains of a base metal material and the refinement of carbides existing in the base metal material.

Background Art

[0002] The demands for improved function and prolonged service life of cutting tools, blades, and the like are upraised in various field of industry and health care. From the point of sharpness, there is not only desire of having high hardness of the material that forms cutting tools and blades, but also requisite to refine the texture of the material for making a sharp cutting edge.

[0003] It is well known that the mechanical properties (such as hardness, strength) of metal material are largely influenced by the size of the diameter of the crystal which forms the metal. Generally, the smaller the diameter of crystal grain, the higher the mechanical properties of metal material. Although the methods for refining the crystal grain of the metal such as ECAP (Equal Channel Angular Pressing) or ARB (Accumulative Roll Bonding) etc. had been developed, (Japan Laid-open Pattern Publication No. 2003-096551, Japan Laid-open Pattern Publication No. 2000-073152), there still are problems that the refinement of ferrous material especially tool steel used for cutting tools and blades is extremely difficult. The technology of obtaining tool steel with microscopic texture by solidifying metallic powder of severe deformation has been published (**N**ew **E**nergy and Industrial Technology **D**evelopment **O**rganization 「Nanometal technology project」, report of 『Reach and Development on Super Strengthened and Super Anticorrosive Tool Steel by Nano Texture Control』), however it is not easy to obtain a material having necessary size for making cutting tools and blades by this method.

[0004] Furthermore, at the condition that there are demands of high hardness, high strength, and high wear resistance for various tools, blades, or die and mold, the carbide generating elements such as Cr, Mo, W, V etc., are added into the base material of ferrous material which forms tools and the like. The carbides are separated and diversified in the base material. Because large carbides may lead the sharpness of the cutting tools and blades decline with the shortage of the service life, the refining of the carbides is also important in aspect to the improved function, and prolonged service life of the cutting tools and blades.

[0005] From the point of view mentioned above, there were inventors who devised a method to refine texture of metal material through [using] locally melting [of] material surface by laser beam. (Japan Laid-open Pattern Publication No. 2005-146378). According to this technique, it is possible to refine the carbides in the surface layer part of the metal material. However, the refined carbides were separated from grain boundary of crystal grain of base metal material, and remarkably declined the strength of the grain boundary. Thus the desire of significantly improved properties and prolonged service life of cutting tools, and blades can not be achieved.

[0006]

[Pattern document 1] Japanese Laid-open Patent Publication No. 2003-096551 1

[Pattern document 2] Japanese Laid-open Patent Publication No. 2000-073152

[Pattern document 3] Japanese Laid-open Patent Publication No. 2005-146378

[Non- Pattern document 1] New Energy and Industrial Technology Development Organization 「Nanometal technology project」, report of 『Reach and Development on Super Strengthened and Super Anticorrosive Tool Steel by Nano Texture Control』

[BRIEF SUMMARY OF THE INVENTION]

Problems to be Solved by the Invention

[0007] In the field of traditional technology, it is difficult to achieve the refining of crystal grain of ferrous material and the refining of carbides simultaneously. Although some inventors had devised a technique to make the refining of carbides possible, there are still problems referring to the uniform dispersion of the carbides and the refining of crystal grain of ferrous material.

[0008] In the light of above problems, the present invention provides a method to [conduct] refine the texture of a surface layer part in a ferrous material, to provide a ferrous material having a microscopic texture with improved properties and prolonged service life of cutting tools, blades, and the like, and to provide a blade with a cutting edge formed by fabricating a microscopic texture region.

Means for Solving the Problems

[0009] **Fig. 1** is a conceptual diagram depicting the method for refining the texture of a ferrous material of the present invention. The method for refining the texture of a ferrous material of the present invention comprises a first step (S01) of forming a carbide refined region and a second step (S02) of forming a texture refined region. In the first step, the surface layer part in the ferrous material is locally and rapidly heated by a laser beam to form a melt reservoir which is then rapidly solidified to form a carbide refined region. In the second step, the carbide refined region formed in the first step is subjected to a friction agitation process to form a texture refined region.

[0010] A broader carbide refined region may be formed by operating the first step repeatedly to make the carbide refined region at least partially overlap. Further, a broader texture refined region may be formed by operating the second step repeatedly at the inner side of the carbide refined region.

[0011] A semiconductor laser is used as the laser beam using in the first step, thus forms an excellent carbide refined region without causing cleavage or defect. Moreover, it is favorable to use a ferrous material which contains more content by amount of carbon (such as 0.3% by weight), and more favorable to use a tool steel.

[0012] A ferrous material having microscopic texture of the present invention is a tool steel having base metal material crystal grain in 5μm ~ 50μm of diameter, also is a tool steel having reforming region in which base material crystal grain is refined to 10μm ~ 1μm of diameter. The reforming region and the non- reforming region are inseparably integrated as a whole, not posterior joining or adhesion. Further, the carbide in the reforming region is preferable to 10nm ~ 1μm of diameter.

[0013] The blade of the present invention is a blade having a cutting edge formed by fabricating a texture refined region. The texture refined region is manufactured by following process: the surface layer part of the ferrous material is locally and rapidly heated by a laser beam to form a melt reservoir which is then rapidly solidified to form a carbide refined region; the said carbide refined region is then subjected to a friction agitation process to form a texture refined region. It is favorable that the base metal material crystal grains of texture refined region are 10nm ~ 1μm in diameter, and the carbides dispersed in the texture refined region are 10nm ~ 1μm in diameter. However, some heat treatments such as apposite quenching or tempering etc. may be incorporated during the manufacturing of the blades, there is the condition that the diameter of the base metal material crystal grains of texture refined region and the diameter of the carbides may increase through the heat treatments.

Results of the Invention

[0014] According to the method for refining the texture of a ferrous material of the present invention, there is an attempt to form a texture refined region by means of utilizing local and rapid heating as well as rapid cooling of ferrous material by laser beams, and locally agitating effect by friction agitation process as well as crystal grain refining effect; thus it is able to achieve refining of the texture of any region of immediate vicinity of the surface layer of the ferrous material in a simple way.

Because only the cutting edge of cutting tools, blades, and the like is fabricated to be a refining texture, it is possible to realize improved properties and prolonged service life of cutting tools, blades, and the like with low cost. Moreover, the ferrous material would be possibly applied to broader spectrum wherein high hardness, high strength, high wear resistance are demanded for ferrous material.

The tool steel having microscopic texture of the present invention, holds a reforming region wherein the base metal material crystal grains and the carbides are refined, thus it is possible to realize improved properties and prolonged service life of cutting tools, blades, and the like with low cost by adopting the said reforming region as cutting edge of cutting tools, blades, and the like. Moreover, the tool steel would be possibly applied to broader spectrum wherein high hardness, high strength, high wear resistance are demanded for tool steel.

The blades in accordance with the present invention, holds a reforming region wherein the base metal material crystal grains and the carbides are refined, and is realized with improved properties and prolonged service life with low cost. At the time the cutting edge having high hardness and high malleability demonstrates excellent cutting function, also demonstrates that maintaining the said cutting function for a long period is possible. Moreover, the carbides existing in the cutting edge is refined so that dropout of the said carbides has only extremely small influence to the service life of the blades.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0015]

FIG. 1 is a conceptual diagram depicting the method for refining the texture of a ferrous material of the present invention.

FIG. 2 is a conceptual diagram depicting the first step of the method for refining the texture of a ferrous material of the present invention.

FIG. 3 is a schematic diagram depicting the cross section of the ferrous material after carrying out the first step of the method for refining the texture of a ferrous material of the present invention.

FIG. 4 is a schematic diagram depicting the cross section of the ferrous material after carrying out multiple times the first step of the method for refining the texture of a ferrous material of the present invention.

FIG. 5 is a conceptual diagram depicting the second step of the method for refining the texture of a ferrous material of the present invention.

FIG. 6 is a schematic diagram depicting the cross section of the ferrous material after carrying out the second step of the method for refining the texture of a ferrous material of the present invention.

FIG. 7 is a schematic diagram depicting the cross section of the tool steel having microscopic texture of the present invention.

FIG. 8 is a schematic diagram depicting the cross section of the blade of the present invention.

FIG. 9 is an entire photo depicting a sample obtained from the first embodiment.

FIG. 10 is a photo of optical microscope of untreated DC53 plate material.

FIG. 11 is a photo of optical microscope depicting a melted, rapidly solidified region by the radiation of laser beam.

FIG. 12 is an enlarged photo of FIG. 11.

FIG. 13 is an entire photo depicting a sample obtained from the second embodiment.

FIG. 14 is a photo of optical microscope depicting the cross section of a sample obtained from the second embodiment.

FIG. 15 is a result of Vickers hardness test of a sample obtained from the second embodiment.

FIG. 16 is a photo of scanning electron microscope of the texture refined region.

FIG. 17 is a result of energy dispersive X-ray spectroscopy qualitative analysis of untreated DC53 plate material.

FIG. 18 is a result of energy dispersive X-ray spectroscopy qualitative analysis of the texture refined region.

FIG. 19 is an entire photo depicting a sample obtained from the third embodiment.

FIG. 20 is a photo of optical microscope depicting the cross section of a sample obtained from the third embodiment.

FIG. 21 is a result of Vickers hardness test of a sample obtained from the third embodiment.

FIG. 22 is a photo of a plane having a cutting edge formed by fabricating a texture refined region.

FIG. 23 is a photo of a cutting edge of a plane having a cutting edge formed by fabricating a texture refined region.

FIG. 24 is a photo of a plane having a cutting edge formed by fabricating a texture refined region after cutting test.

FIG. 25 is a photo of a plane having a cutting edge formed by fabricating a carbide refined region after the cutting test.

FIG. 26 is a photo of veneer slicer.

FIG. 27 is a photo of the texture of cutting edge of a veneer slicer.

FIG. 28 is a photo of cutting edge of a veneer slicer after cutting test.

FIG. 29 is a photo of cutting edge of a tailor-made scalpel after cut off test.

FIG. 30 is a photo of cutting edge of a scalpel on the market after cut off test.

Description of the Number

[0016]

10 laser beam source
12 laser beam
14 ferrous material
16 melt reservoir
18 tool steel
20 carbide refined region
22 texture refined region
30 tool

[DETAILED DESCRIPTION IF THE INVENTION]

Best Mode for Carrying Out the Invention

[0017] The method for refining the texture of a ferrous material according to the present invention, comprises a first step in which the surface layer part in the ferrous material is locally and rapidly heated by a laser beam to form a melt reservoir which is then rapidly solidified to form a carbide refined region; and a second step in which the carbide refined region formed in the first step is subjected to a friction agitation process to form a texture refined region. Further, in the first step microplasma welding may be utilized during the surface layer part of the ferrous material is locally and rapidly heated as well as rapidly solidified.

[0018] **FIG. 2** is depicting an embodiment of the first step of the present invention. A laser beam 12 emitted from laser beam source 10 is condensed at the immediate vicinity of the surface of a ferrous material 14. Because the ferrous material 14 is irradiated by the laser beam 12 in such way, the surface layer part of the ferrous material 14 is heated locally and rapidly, a melt reservoir 16 is formed at the surface layer part. Moreover, the laser beam 12 scans along scanning direction with a prescribed speed. When the laser beam 12 moves from the melt reservoir 16, the melt reservoir 16 is solidified rapidly due to heat diffusion to peripheral region. Therefore, inside of the surface layer part of the ferrous material 14, e.g. the region scanned by laser beam 12, is subjected to rapid heating and rapid solidification. Further, it would be desirable if the laser beam source 10 is a device that can generate laser beam to rapidly heat the surface layer part of the ferrous material 14 and form the melt reservoir 16; and/or it is favorable to use a semiconductor laser.

[0019] **FIG. 3** is a schematic diagram depicting the cross section of the ferrous material after carrying out the first step. The melt reservoir 16 mentioned above is rapidly solidified, a carbide refined region 20 is formed at the surface layer part of the ferrous material 14. If a broader carbide refined region 20 is demanded, it is necessary to operate the laser beam scan multiple times to at least make the carbide refined region 20 formed by one laser scan partially overlap, as depicting in **FIG. 4.** Then the broader carbide refined region 20 may be obtained.

[0020] The second step is a step that the carbide refined region formed in the first step is subjected to a friction agitation process. The said friction agitation process employs a friction agitation joining method which was devised in 1991 at TWI (The Welding Institute) England, as surface reforming method of metal material. The friction agitation joining is a kind of technique comprising press a rotating cylindrical tool at high speed into a joining region (a protruding called as "probe" is located on the bottom of the tool, press the said probe into); agitate a joined material softened by friction to complete the join while scanning along the direction of the joining region. In general the region that is agitated by rotating tool is called as "agitation part", wherein mechanical properties are improved with homogeneity of material as well as decrease of crystal grain diameter by the joining condition. The technique which employs improvement of mechanical properties with homogeneity of material as well as decrease of crystal grain diameter by means of friction agitation for surface reforming, is friction agitation process, and is largely studied in recent years.

[0021] **FIG. 5** is depicting an embodiment of step 2. A rotating cylindrical tool 30 is pressed into the carbide refined region 20, then texture refined region 22 is formed due to the scanning along the carbide refined region 20. It is desirable that the rotating speed of the tool 30 is 100 ~ 2000 rpm, moving speed is 10 ~ 1000mm/min, compression load is 4903 ~ 98066N (500 ω 10000 kgf); but not limited if friction agitation can be achieved. Moreover, if the pressed tool 30 goes out of the carbide refined region 20, rough and large carbides may be dragged into; thus it will be better that tool 30 is pressed into the inner side of the carbide refined region 20. It would be favorable if the shape of tool 30 is just suitable to complete the friction agitation process at the carbide refined region 20; and the existence or shape of the probe on the bottom of tool 30 is not under restriction.

[0022] **FIG. 6** is a schematic diagram depicting the cross section of the ferrous material after carrying out the second step. By means of performing friction agitation process in the carbide refined region 20, a texture refined region 22 is formed at surface layer part of ferrous material 14. If a broader texture refined region 22 is demanded, it is necessary to operate the laser scan multiple times to at least make the carbide refined region 20 formed by one laser scan overlap partially. After a broader carbide refined region 20 is obtained, it is favorable to perform the second step multiple times on the said carbide refined region 20

[0023] A tool steel having microscopic texture of the present invention as illustrating in **FIG. 7** demonstrates a cross section. The diameter of base metal material crystal grains of the tool steel 18 is 5μm ~ 50μm; the diameter of base metal material crystal grains in the texture refined region 22 is 10nm ~ 1μm. Moreover, the diameter of carbides in the texture refined region 22 is 10nm ~ 1μm. Tool steel 18 and the texture refined region 22 exist continuously through the medium of the carbide refined region 20, and no bonding agent or adhesive is between tool steel 18 and the texture refined region 22.

[0024] The blade of the present invention as illustrating in **FIG. 8** demonstrates a cross section, The cutting edge is fabricated with texture refined region 22. It is desirable that the diameter of base metal material crystal grains of the ferrous material 14 is 5μm ~ 50μm, the diameter of base metal material crystal grains in the texture refined region 22 is 10nm ~ 1μm. Moreover, it is desirable that the diameter of carbides in the texture refined region 22 is 10nm ~ 1μm. Here, some heat treatments such as apposite quenching or tempering etc. may be incorporated during the manufacturing of the blades, and it may occur that the diameter of the base metal material crystal grains of texture refined region 22 and the diameter of the carbides may increase through the heat treatments. The ferrous material 14 and the texture refined region 22 exist continuously through the medium of the carbide refined region 20, and no bonding agent or adhesive is between the ferrous material 14 and the texture refined region 22.

Embodiments

[0025] Embodiments of the present invention will be described below with reference to the accompanying drawings. The specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all modifications are intended to be included within the scope of present invention. Further, the treated material e.g. DC 53, used in the embodiments is general-purpose cold-work steel which is a kind of tool steel with excellent malleability.

<u>First Embodiment</u>

[0026] In a DC 53 plate material, there is formed a carbide refined region by using semiconductor laser (output: 1kW). The laser beam is just focused at the surface of the DC 53 plate material (the diameter of laser beam on the surface of the DC 53 plate material is about 1mm), and the speed of the laser scan is 1000 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 5 times of laser scan. The photo of the obtained sample is depicting in **FIG. 9.** It can be confirmed whether the region formed by the radiation of laser beam at the surface of DC 53 plate material exists or not.

[0027] **FIG. 10** illustrates an optical microscope photo of untreated DC 53 plate material; and **FIG. 11** illustrates an optical microscope photo of melted, and rapidly solidified region by the radiation of laser beam, respectively. Further, at the time of optical microscope observation, each sample is treated with 3% of naithol solution (nitric acid in ethanol) to do etching treatment for sake of observation of the texture easily. It is confirmed that rough and large carbides are over 10μm in untreated region; but the carbides of the laser beam treated region are refined as small as 1μm and smaller. FIG 12 is depicting a result of observing a region of FIG. 11 with higher magnification, and confirms the existence of refined carbides which are arranged at crystal grain boundary of base metal material.

[0028] Table 1 indicates Vickers hardness of the region melted and rapidly solidified by the radiation of laser beam from surface towards depth direction. Vickers hardness is measured under the condition that the loading is 2.94N (300gf) with maintaining time of 15 seconds. The Vickers hardness of the untreated region is at level of 200 ~ 300 Hv, but the Vickers hardness of the region subjected to laser beam treatment is enhanced to around 500 Hv

[0029]

[Table 1]

Position from the surface(mm)	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Hardness(Hv)	423	474	456	486	553	495	426	458	486	425	289
□carbide refined region is from surface to depth of 0.9mm.											

Second Embodiment

[0030] The DC 53 plate material is subjected to laser beam treatment. After the carbide refined region is formed in the DC 53 plate material, the said carbide refined region is subjected to friction agitation process. A semiconductor laser (output: 1kw) is used to form the carbide refined region, and is just focused on the surface of DC 53 plate material (the diameter of the laser beam on the surface of DC 53 plate material is about 1mm). Yet the scanning speed of the laser is 1200 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 15 times of laser scan. In the friction agitation process a super hard alloy tool which is cylinder shape with 10 mm of diameter is used. The said tool rotating at a speed of 400 rpm is pressed into the carbide refined region with 2600kg of loading. The moving speed of the tool is 400 mm/min, and argon gas is flowed in to prevent the tool and the samples from oxidation. Moreover, the insert position of the tool is at the center of the carbide refined region; it should be noted that the untreated DC 53 plate material should not be agitate with the tool.

[0031] **FIG. 13** illustrates a photo of the surface of the obtained sample. The region treated by laser beam is subjected to a friction agitation process. It is confirmed that the friction agitation process has been performed in the region treated by laser beam; and untreated DC 53 plate material is not subjected to friction agitation.

[0032] **FIG. 14** is an optical microscope photo illustrating the cross section of the obtained sample. Still, at the time of optical microscope observation, the sample is treated with 3% of naithol solution (nitric acid in ethanol) to do etching treatment for sake of observation of the texture easily. There exists a carbide refined region formed by laser beam treatment from the surface of DC 53 plate material to the depth of about 1 mm; also there exists a texture refined region in the said carbide refined region from surface to the depth of about 200μm. In this embodiment because a cylindrical tool(without probe) is used in the friction agitation process, the press power of the tool is small for the carbide refined region and the influence of friction agitation can not extend to the whole area of the carbide refined region.

[0033] **FIG. 15** indicates the result about the measurement of Vickers hardness concerning the obtained sample. Vickers hardness is measured under the condition that the loading is 2.94N (300gf) over the time of 15 seconds. The Vickers hardness of the texture refined region formed by friction agitation process is largely enhanced compared with the hardness of the carbide refined region formed by only laser beam treatment.

[0034] **FIG. 16** is a scanning electron microscope photo indicating the texture refined region. Yet, at the time of scanning electron microscope observation, the sample is treated with 3% of naithol solution (nitric acid in ethanol) to do etching treatment for sake of observation of the texture easily. It is regarded that the diameter of the base material crystal grain is obviously lessened to 1μm, and the diameter of carbides is smaller than that of the base material crystal grain.

[0035] **FIG. 17** is a result of energy dispersive X-ray spectroscopy qualitative analysis concerning untreated DC 53 plate material, **FIG. 18** is a result of energy dispersive X-ray spectroscopy qualitative analysis concerning the texture refined region formed by laser beam treatment as well as friction agitation process, separately. It is unquestionable that the contexture elements of the untreated DC 53 plate material and the texture refined region are the same, and the method for refining the texture according to the present invention is no addition of other elements.

Third Embodiment

[0036] The DC 53 plate material is subjected to laser beam treatment. After the carbide refined region is formed in the DC 53 plate material, the said carbide refined region is subjected to friction agitation process. A semiconductor laser (output: 1kw) is used to form the carbide refined region, and is just focused on the surface of DC 53 plate material (the diameter of the laser beam on the surface of DC 53 plate material is about 1mm). Yet the scanning speed of the laser is 1200 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 15 times of laser scan. In the friction agitation process a super hard alloy tool which is cylinder shape with 10 mm in diameter is used. The said tool rotating at a speed of 400 rpm is pressed into the carbide refined region with 2600kg of loading. The moving speed of the tool is 400 mm/min, and argon gas is flowed in to prevent the tool and the samples from oxidation. Moreover, the insert position of the tool is adjusted to lead about half of the tool to touch the untreated DC 53 plate material from the carbide refined region; therefore the tool agitates the untreated DC 53 plate material as well as the carbide refined region simultaneously.

[0037] **FIG. 19** is a photo indicating the surface of the obtained sample. The friction agitation process is performed on laser beam treated region as well as untreated region simultaneously. It is confirmed that the near center of the tool used in friction agitation process has passed through the boundary vicinity of the laser beam treated region as well as untreated region.

[0038] **FIG. 20** is an optical microscope photo illustrating the cross section of the obtained sample. Still, at the time of optical microscope observation, the sample is treated with 3% of naithol solution (nitric acid in ethanol) to do etching treatment for sake of observation of the texture easily. There exists a carbide refined region formed by laser beam treatment from the surface of DC 53 plate material to the depth of about 1 mm; also there exists a texture refined region in the said carbide refined region from surface to the depth of about 200μm.

Further, because the friction agitation process is performed on laser beam treated region as well as untreated region simultaneously, a texture refined region may also exist beyond the carbide refined region. In addition, rougher and larger carbides may exist in surface vicinity of the texture refined region. It is regarded that rough and large carbides which exist in untreated DC 53 plate material by plastic flow due to the friction agitation process may mix into the texture refined region. In this embodiment because a cylindrical tool (without probe) is used in the friction agitation process, the press power of the tool is small for the carbide refined region and the influence of friction agitation can not extend to the whole area of the carbide refined region.

[0039] **FIG. 21** indicates the result about the measurement of Vickers hardness concerning the obtained sample. Vickers hardness is measured under the condition that the loading is 2.94N (300gf) with maintaining time of 15 seconds. The Vickers hardness of the texture refined region formed by friction agitation process is largely enhanced compared with the hardness of the carbide refined region formed by only laser beam treatment.

Fourth Embodiment

[0040] The DC 53 plate material is subjected to laser beam treatment. After the carbide refined region is formed in the DC 53 plate material, the said carbide refined region is subjected to friction agitation process. A semiconductor laser (output: 1kw) is used to form the carbide refined region, and is just focused on the surface of DC 53 plate material (the diameter of the laser beam on the surface of DC 53 plate material is about 1mm). Yet the scanning speed of the laser is 1200 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 15 times of laser scan. In the friction agitation process a super hard alloy tool which is cylinder shape with 10 mm in diameter is used. The said tool rotating at a speed of 400 rpm is pressed into the carbide refined region with 2600kg of loading. The moving speed of the tool is 400 mm/min, and argon gas is flowed to avoid oxidation of the tool and the samples. After that, the region that is subjected to the friction agitation process (the texture refined region) is fabricated as a cutting edge, and then a plane is done. Again, a carbide refined region which is not subjected to the friction agitation process is fabricated as a cutting edge to make a plane for comparison.

[0041] **FIG. 22 and FIG.23** respectively depict a photo concerning the plane wherein a texture refined region is fabricated as a cutting edge and a photo about the texture of cutting edge. It is confirmed that the texture of the cutting edge part is extremely refined, and the diameter of the carbide grain spreading in the said region is smaller than 1μm.

[0042] A veneer board called LVL is cut with the fabricated plane to perform valuation of the characteristics of the plane. The cutting condition is as follow: cutting speed is 96 mm/min, cutting depth is 0.15 mm, angle of blade lathe is 35°, and angle of cutting edge of the blade is 31°. After cutting 5 pieces of LVL board in length of 1.8m, observe the shape of cutting edge by optical microscope. **FIG. 24 and FIG.25** respectively depict the photo concerning the plane wherein a texture refined region is fabricated as a cutting edge and a photo concerning the plane. The cutting edge of the plane wherein carbide refined region is fabricated as a cutting edge is largely out of shape; on the contrary, the cutting edge of the plane wherein a texture refined region is fabricated as a cutting edge is hardly deformed.

Fifth Embodiment

[0043] The DC 53 plate material is subjected to laser beam treatment. After the carbide refined region is formed in the DC 53 plate material, the said carbide refined region is subjected to friction agitation process. A semiconductor laser (output: 1kw) is used to form the carbide refined region, and is just focused on the surface of DC 53 plate material (the diameter of the laser beam on the surface of DC 53 plate material is about 1mm). Yet the scanning speed of the laser is 1200 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 15 times of laser scan. In the friction agitation process a super hard alloy tool which is cylinder shape, 10 mm in diameter, is used. The said tool rotating at a speed of 400 rpm is pressed into the carbide refined region with 2600kg of loading. The moving speed of the tool is 400 mm/min, and argon gas is flowed in to prevent the tool and the samples from oxidation. Afterward, the region subjected to the friction agitation process (the texture refined region) is fabricated as a cutting edge, and a blade (veneer slicer) for carpenter-use is made.

[0044] **FIG. 26 and FIG.27** respectively depict a photo concerning a veneer slicer wherein a texture refined region is fabricated as a cutting edge and a photo about the texture of cutting edge. It is confirmed that the texture of the cutting edge part is extremely refined, and the diameter of the carbide grain spreading in the said region is smaller than 1μm.

[0045] A cedar log is cut with the fabricated veneer slicer to perform the evaluation of the characteristics of the veneer slicer. The cutting condition is as follow: cutting speed is 23 mm/min, cutting depth is 0.3 mm, and angle of cutting edge of the blade is 20°. After cutting about 17m, observe the shape of cutting edge by optical microscope. **FIG. 28** depicts the photo of the cutting edge after cutting test. It is confirmed that there is no marked fragment of the shape of cutting edge at observation, and good shape keeps. Further, there is a limitation at level of 150μm on cutting to make a thin board of veneer (shaved thin board) with traditional veneer slicer; however, a thin board of veneer of about 75μm is obtained by using this fabricated veneer slicer.

Sixth Embodiment

[0046] The DC 53 plate material is subjected to laser beam treatment. After the carbide refined region is formed in the DC 53 plate material, the said carbide refined region is subjected to friction agitation process. A semiconductor laser (output: 1kW) is used to form the carbide refined region, and is just focused on the surface of DC 53 plate material (the diameter of the laser on the surface of DC 53 plate material is about 1mm). Yet the scanning speed of the laser is 1200 mm/min. In order to make the carbide refined region formed by each laser scan at least overlap partially, the radiating position of the laser beam will vertically move a distance of 0.7mm along the laser scan direction after each laser scan is finished, and performs totally 15 times of laser scan. In the friction agitation process a super hard alloy tool which is cylinder shape, 10 mm in diameter, is used. The said tool rotating at a speed of 400 rpm is pressed into the carbide refined region with 2600kg of loading. The moving speed of the tool is 400 mm/min, and argon gas is flowed in to prevent the tool and the samples from oxidation. Afterward, the region subjected to the friction agitation process (the texture refined region) is fabricated as a cutting edge, and then a scalpel is made.

[0047] General copy-paper (woodfree paper) is cut off by using the fabricated scalpel as well as scalpel on the market. Evaluation of the characteristics of the scalpels is performed by means of observing the amount of paper cut off and changes of cutting edge shape. A bundle of 950g copy-paper of 210 pieces is put on the top of a scalpel (the angle between cutting edge and copy-paper is 15°). Calculate the number of pieces of the copy-paper cut off during the said bundle is moved at a speed of 3000 mm/min. Cut off test about one scalpel is performed 20 times continuously; the change of the number of pieces cut off is observed. Yet, Cut off test about one sort of scalpel is performed 6 times of the 20 times continuous cut off test.

[0048] Table 2 and Table 3 respectively indicate the number of pieces cut off concerning fabricated scalpel and scalpel on the market. As to the whole cut off test, the number of pieces cut off by the fabricated scalpel is more than the number of pieces cut off by the scalpel on the market. Further, the number of pieces cut off by the scalpel on the market decreases with increase of the number of times of the cut off test; on the contrary, the number of pieces cut off by the fabricated scalpel hardly decreases. From this result, it is demonstrated that the fabricated scalpel is not only sharp but also durable.

[0049]

[Table 2]

number of times of cutting test	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Total
1	9	10	11	10	9	9	58
2	9	8	8	9	9	6	49
3	9	7	7	8	9	8	48
4	9	7	8	9	8	7	48
5	9	8	8	7	11	9	52
6	9	10	9	8	10	8	54
7	8	10	12	9	10	9	58
8	8	8	9	8	10	10	53

(continued)

number of times of cutting test	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Total
9	9	9	10	10	5	6	49
10	7	8	10	10	10	7	52
11	7	8	9	10	8	9	51
12	8	8	10	9	9	12	56
13	8	9	9	9	11	9	55
14	8	9	11	10	10	10	58
15	7	8	8	10	9	10	52
16	7	11	8	11	10	9	56
17	7	9	10	10	10	10	56
18	7	7	8	10	9	9	50
19	7	8	8	7	9	8	47
20	6	7	9	8	9	9	48
Total	158	169	182	182	185	174	1050

[0050]

[Table 3]

number of times of cutting test	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Total
1	6	7	6	7	8	6	40
2	6	7	7	6	6	7	39
3	6	5	6	6	5	5	33
4	6	6	6	5	5	5	33
5	4	5	5	5	4	4	27
6	4	4	5	5	4	4	26
7	4	4	4	4	4	3	23
8	3	5	4	5	4	3	24
9	4	3	4	4	3	3	21
10	3	3	3	3	3	3	18
11	3	3	3	4	3	2	18
12	2	3	3	3	3	3	17
13	2	3	2	3	3	2	15
14	2	2	3	3	2	3	15
15	2	2	3	3	3	2	15
16	2	3	3	3	2	2	15
17	3	3	3	4	3	2	18
18	2	3	3	3	3	2	16
19	2	3	3	3	2	2	15
20	3	3	3	3	3	2	17
Total	69	77	79	82	73	65	445

[0051] **FIG. 29 and FIG. 30** respectively indicate the shape of cutting edge of the fabricated scalpel after cut off test and he shape of cutting edge of the scalpel on the market after cut off test. The cutting edge of the scalpel on the market is largely collapsed in contraposition to that of the fabricated scalpel which the shape of cutting edge hardly changes. It is confirmed that the fabricated scalpel can maintain the sharpness of cutting edge after cut off test compared to the scalpel on the market.

Claims

1. A method for refining the texture of a ferrous material comprising:

   a first step, wherein the surface layer part in the ferrous material is locally and rapidly heated by a laser beam to form a melt reservoir which is then rapidly solidified to form a carbide refined region; and
   a second step, wherein the carbide refined region formed in the first step is subjected to a friction agitation process to form a texture refined region.

2. The method for refining the texture of a ferrous material according to claim 1, in order to make at least the aforementioned carbide refined region overlap partially,
   the aforementioned first step is performed multiple times as a characteristic of the method for refining the texture of a ferrous material.

3. The method for refining the texture of a ferrous material according to either of claim 1-2, the aforementioned second step is performed multiple times at the inner side of the aforementioned carbide refined region as a characteristic of the method for refining the texture of a ferrous material.

4. The method for refining the texture of a ferrous material according to any of claim 1-3, a semiconductor laser is used as the aforementioned laser beam
   as a characteristic of the method for refining the texture of a ferrous material.

5. The method for refining the texture of a ferrous material according to any of claim 1-4, a tool steel is used as the aforementioned ferrous material as a characteristic of the method for refining the texture of a ferrous material.

6. A tool steel wherein the base metal material crystal grain is 5μm-50μm in diameter;
   a tool steel has a reformed region wherein the aforementioned base metal material crystal grain is refined to 10nm-1μm.

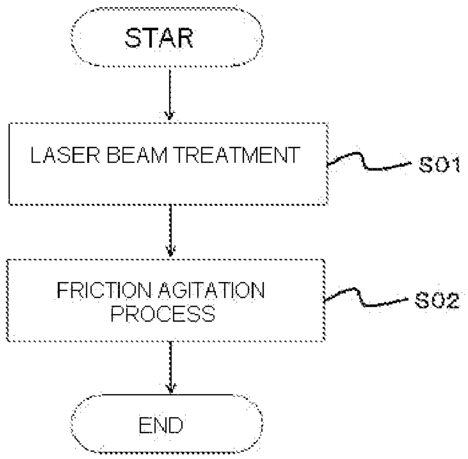
7. A tool steel according to claim 6, the grain diameter of the carbides in the aforementioned reformed region is 10nm-1μm.

8. A blade wherein the texture of the cutting edge part is refined by the method for refining the texture of a ferrous material according to any of claim 1-5.

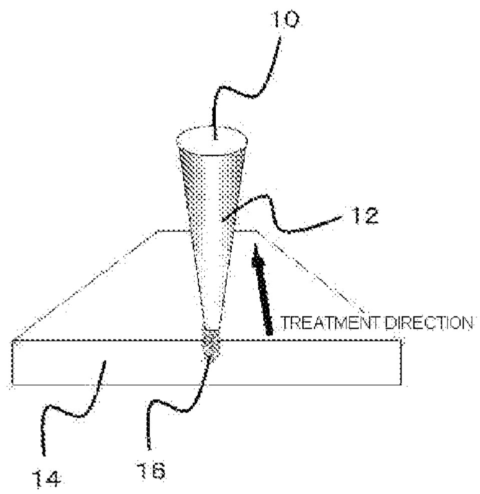
9. A blade comprising:

   a carbide refined region and a texture refined region;
   the aforementioned texture refined region is fabricated as cutting edge.

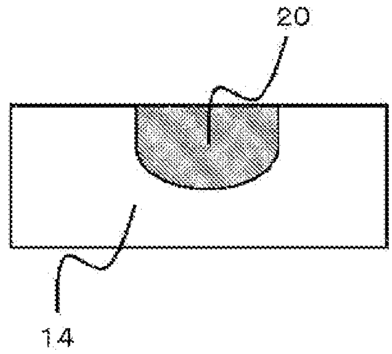
【FIG. 1】


STAR
LASER BEAM TREATMENT
S01
FRICTION AGITATION PROCESS
S02
END

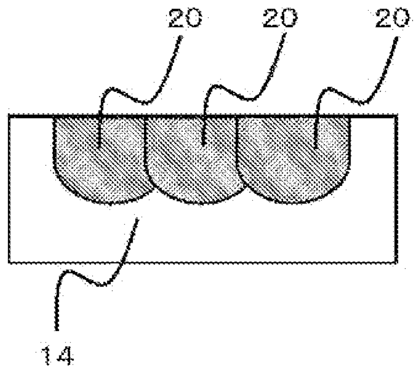
【FIG. 2】


10
12
TREATMENT DIRECTION
14
16

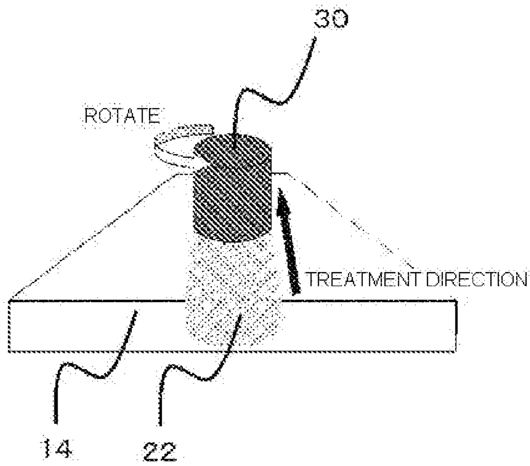
【FIG. 3】



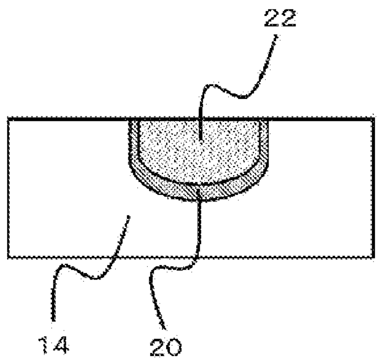
【FIG. 4】



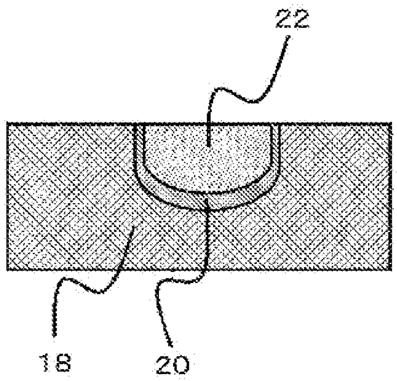
【FIG. 5】



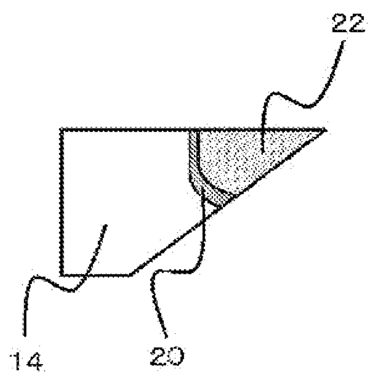
【FIG. 6】



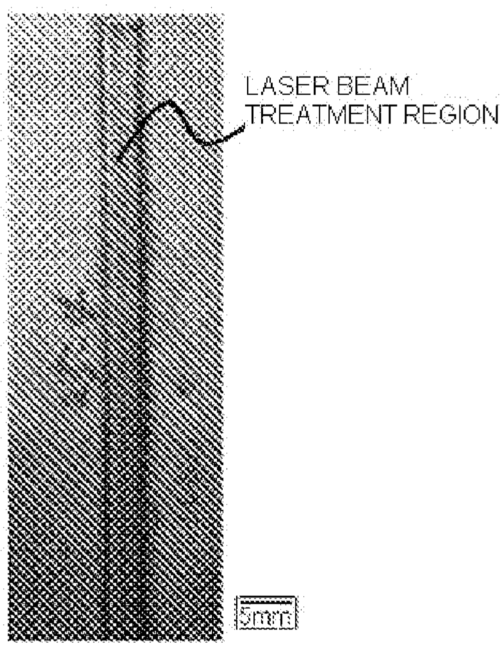
【FIG. 7】



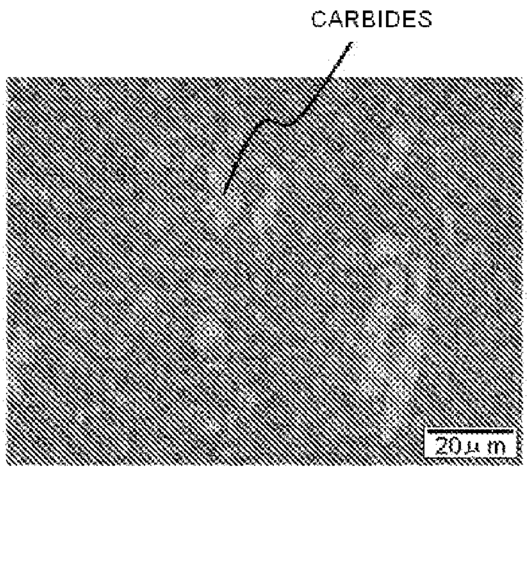
【FIG. 8】



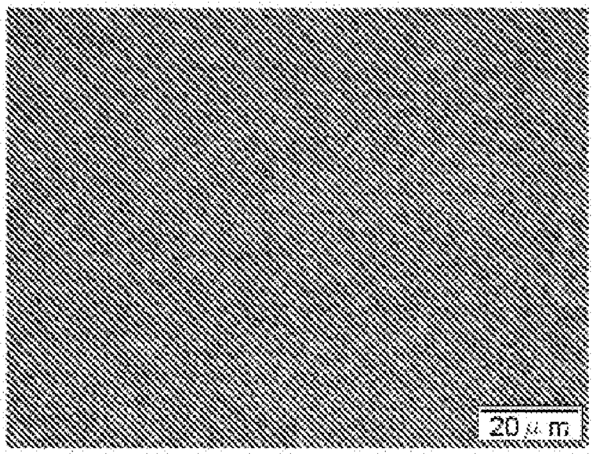
【FIG. 9】



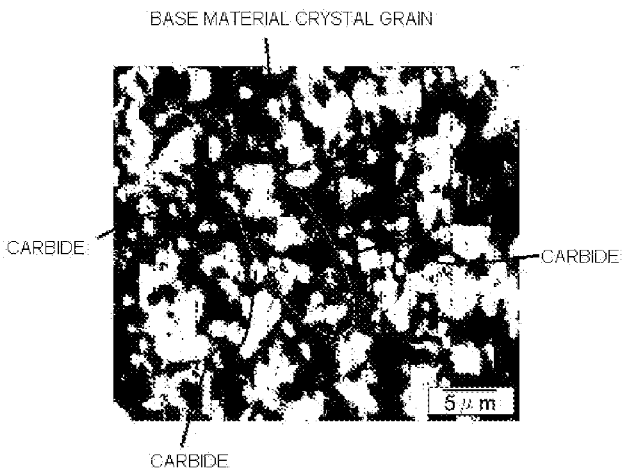
【FIG. 10】



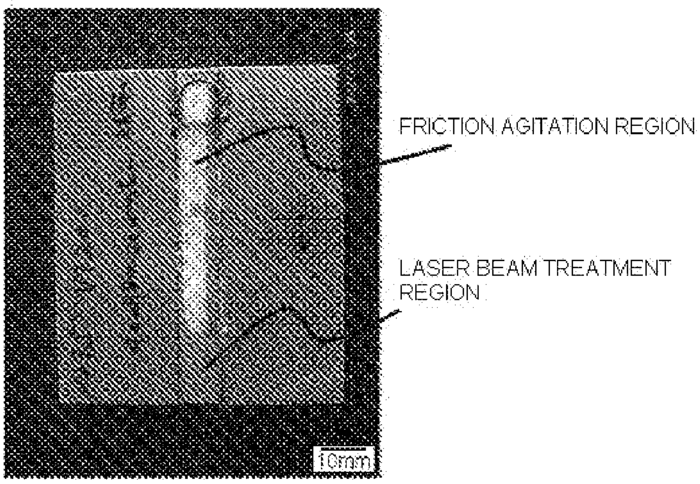
【FIG. 11】


20 μm

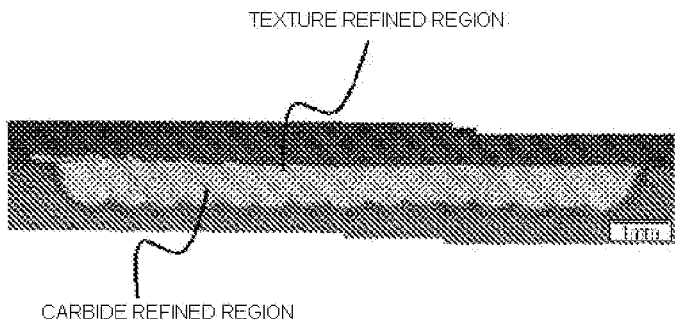
【FIG. 12】


BASE MATERIAL CRYSTAL GRAIN
CARBIDE
CARBIDE
5 μm
CARBIDE

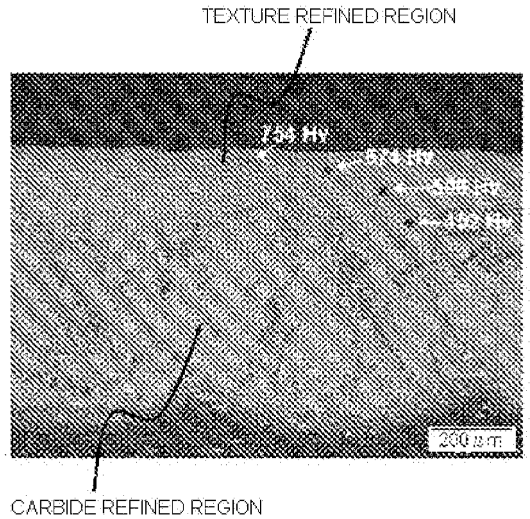
【FIG. 13】


FRICTION AGITATION REGION
LASER BEAM TREATMENT REGION
10mm

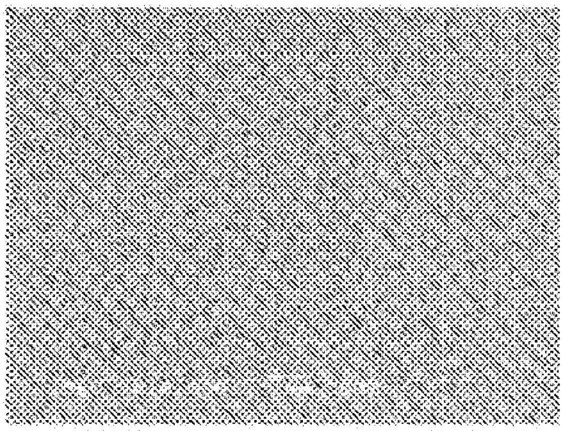
【FIG. 14】


TEXTURE REFINED REGION
CARBIDE REFINED REGION

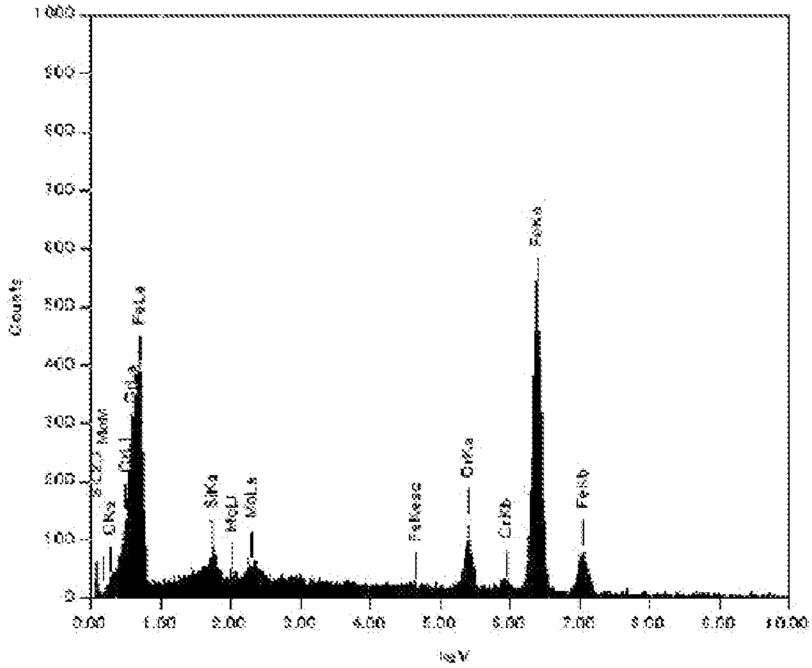
【FIG. 15】



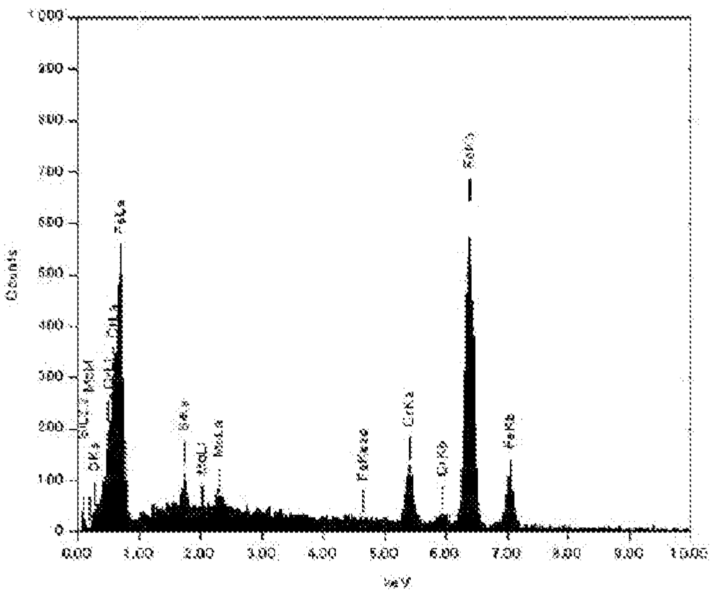
【FIG. 16】



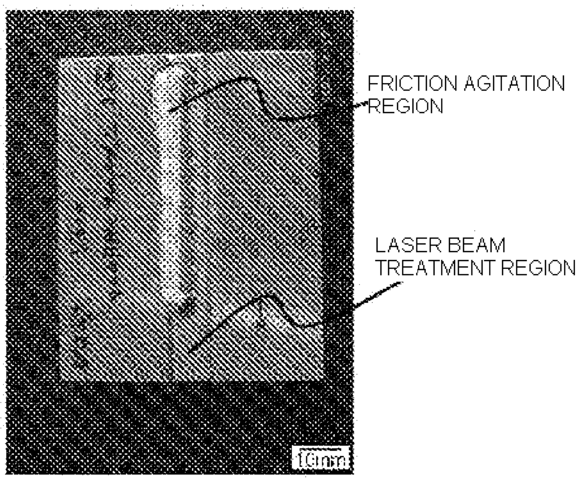
【FIG. 17】


Counts
keV
FeLa
CrLa
SiKa
MoLl
MoLa
FeKesc
CrKa
CrKb
FeKa
FeKb
CKa

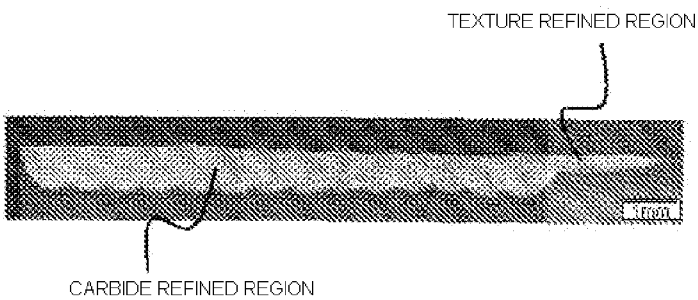
【FUG. 18】


Counts
keV
FeLa
CrLa
SiKa
MoLl
MoLa
FeKesc
CrKa
CrKb
FeKa
FeKb
CKa

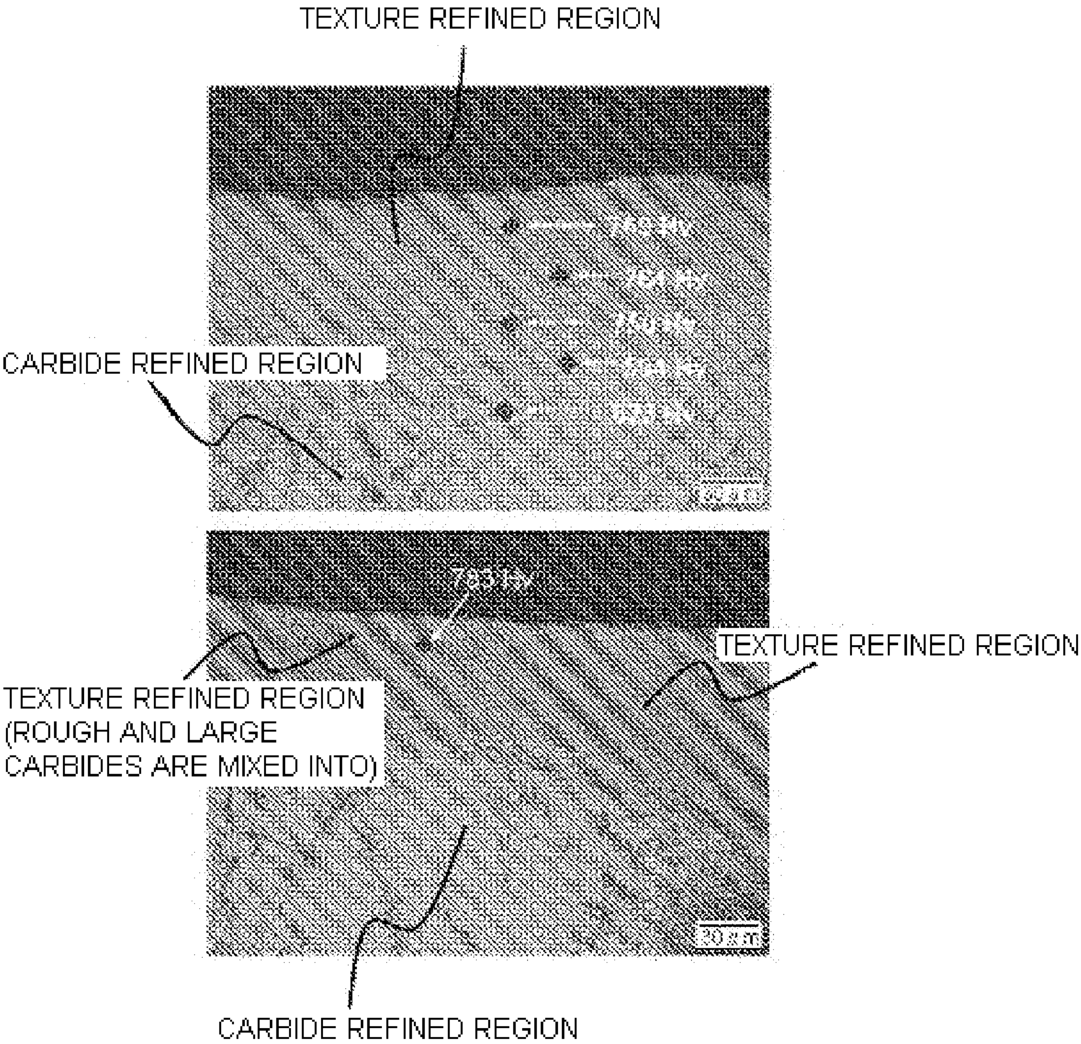
【FUG. 19】


FRICTION AGITATION REGION
LASER BEAM TREATMENT REGION
10mm

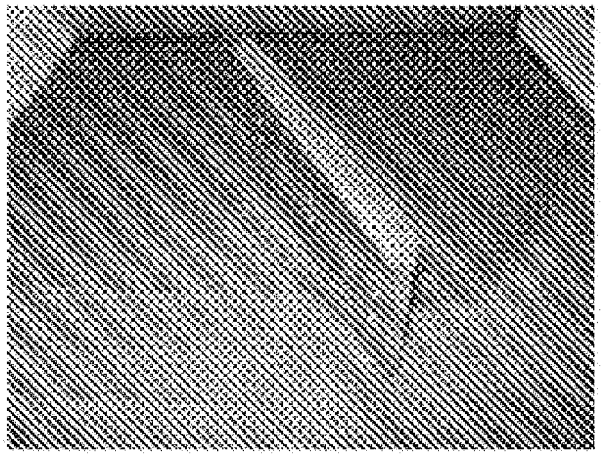
【FIG. 20】


TEXTURE REFINED REGION
CARBIDE REFINED REGION

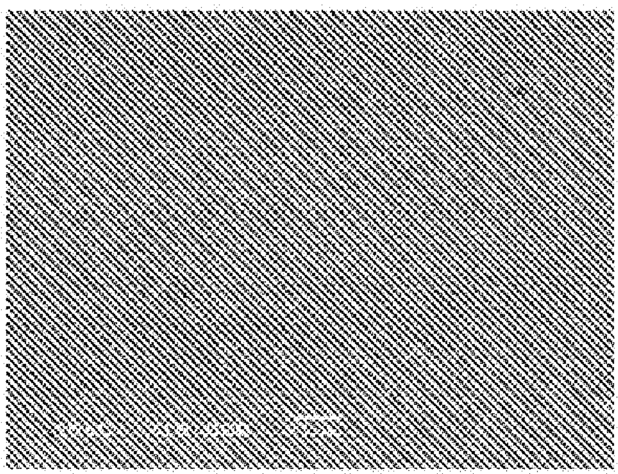
【FIG. 21】


TEXTURE REFINED REGION
CARBIDE REFINED REGION
783Hv
TEXTURE REFINED REGION
TEXTURE REFINED REGION
(ROUGH AND LARGE
CARBIDES ARE MIXED INTO)
CARBIDE REFINED REGION

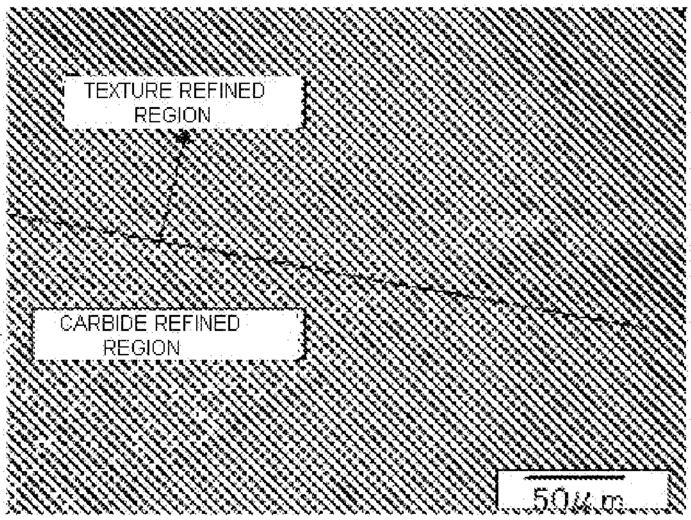
【FIG. 22】



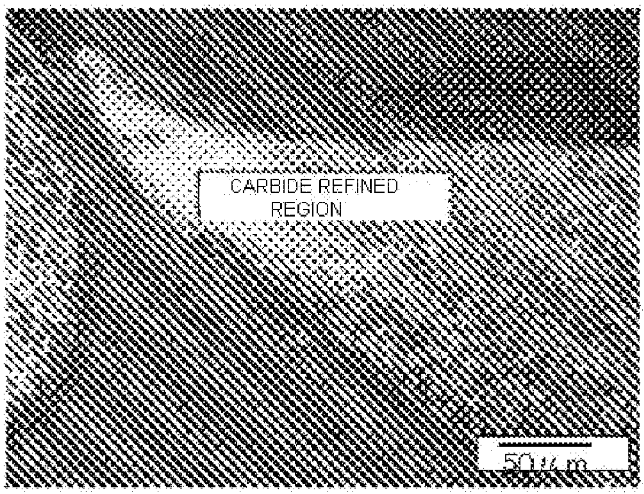
【FIG. 23】



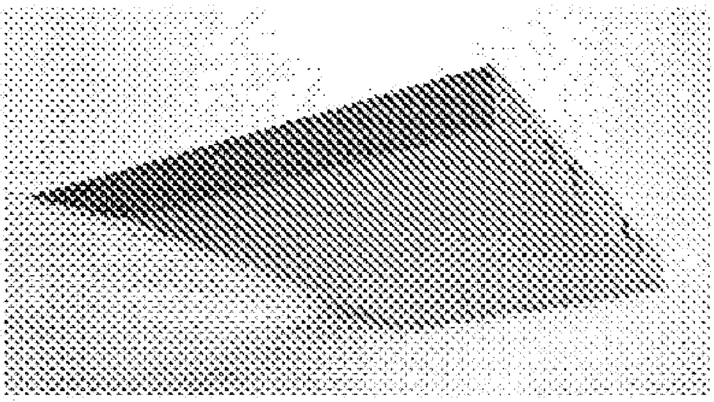
【FIG. 24】


TEXTURE REFINED REGION
CARBIDE REFINED REGION
50μm

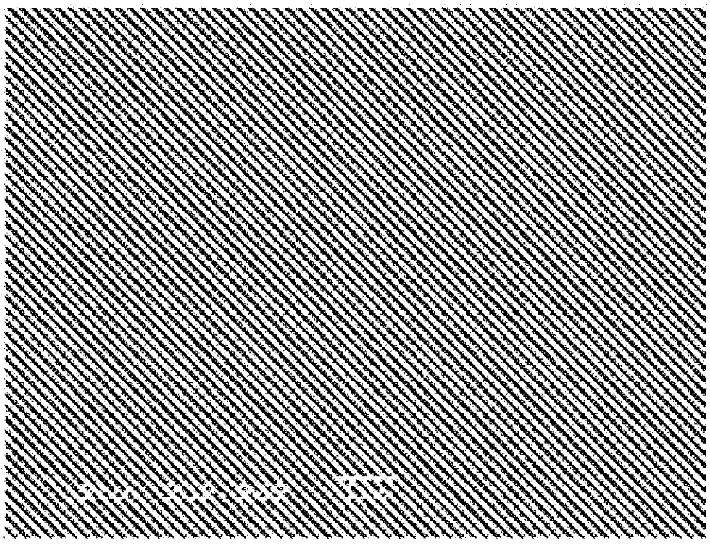
【FIG. 25】


CARBIDE REFINED REGION
50μm

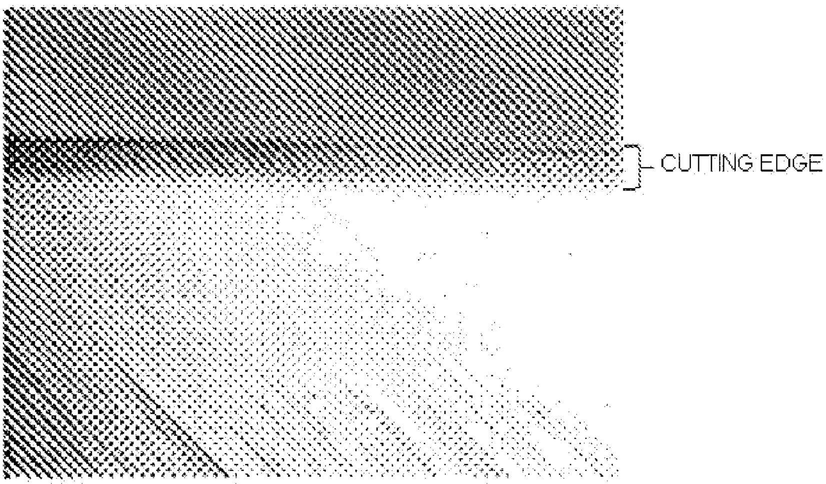
【FIG. 26】



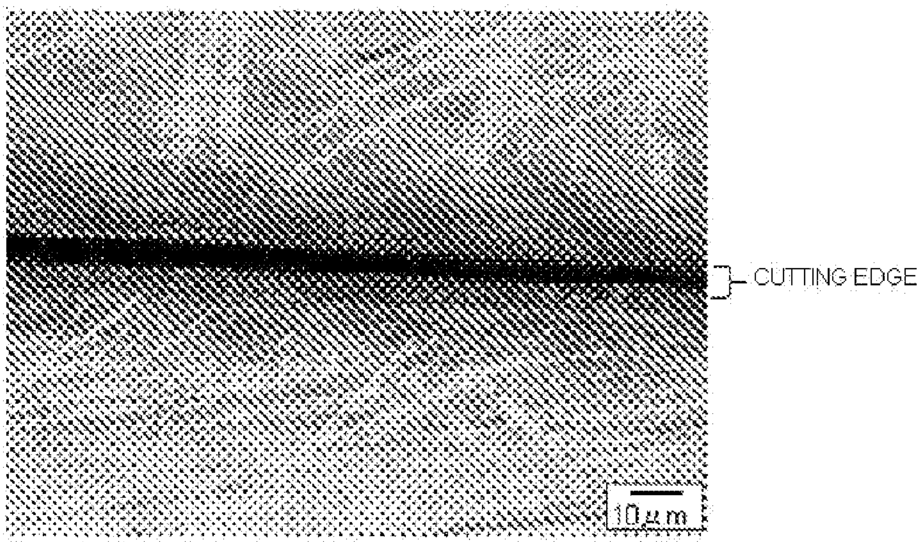
【FIG. 27】



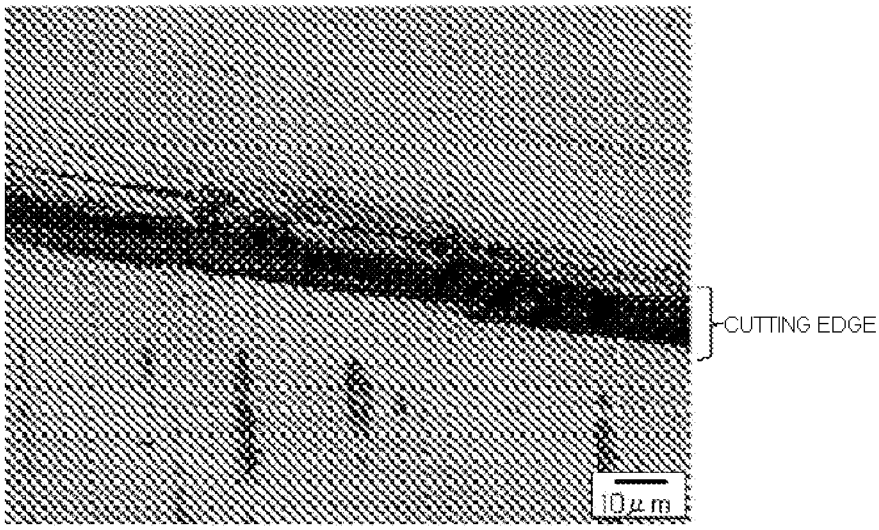
【FIG. 28】



【FIG. 29】



【FIG. 30】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/067565

A. CLASSIFICATION OF SUBJECT MATTER
C21D1/09(2006.01)i, *B23K20/12*(2006.01)i, *C21D9/18*(2006.01)i

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)
C21D1/09, B23K20/12, C21D9/18

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-88080 A (The Boeing Co.), 07 April, 2005 (07.04.05), Page 6, line 29 to page 12, line 31; Fig. 1 & US 2004/0046003 A1 & EP 1514632 A1	1-5,8
A	JP 2006-192452 A (Mitsubishi Heavy Industries, Ltd.), 27 July, 2006 (27.07.06), Page 7, line 11 to page 12, line 46; Figs. 1 to 17 (Family: none)	1-5,8
A	JP 2005-146378 A (Kabushiki Kaisha AMC), 09 June, 2005 (09.06.05), Full text; drawings (Family: none)	1-5,8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 12 December, 2008 (12.12.08)	Date of mailing of the international search report 22 December, 2008 (22.12.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/067565

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions of claims 1 to 5, and 8 relate to a method for refining a texture, comprising a first step of locally heating a surface layer part in a ferrous material to form a carbide refined region and a second step of subjecting the carbide refined region to a friction agitation process to form a texture refined region.

The inventions of claims 6 and 7 relate to a tool steel with a base metal crystal grain diameter of 5 μm to 50 μm and having a modified region where the base metal crystal grain diameter has been reduced to 10 nm to 1 μm.

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Claims 1 to 5, and 8

Remark on Protest the
- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/067565

Continuation of Box No.III of continuation of first sheet(2)

The invention of claim 9 relates to a blade having a carbide refined region and a texture refined region and comprising a cutting edge formed by fabricating the texture refined region.

Form PCT/ISA/210 (extra sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2003096551 A **[0003]**
- JP 2000073152 A **[0003] [0006]**
- JP 2005146378 A **[0005] [0006]**
- JP 2003965511 A **[0006]**