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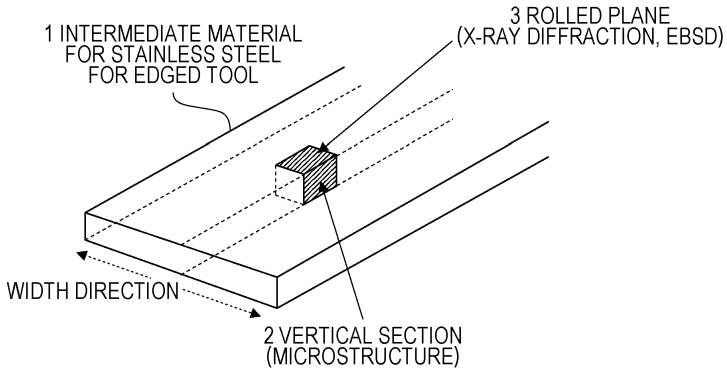
(54) **INTERMEDIATE MATERIAL FOR STAINLESS STEEL FOR KNIVES**

(57) There is provided an intermediate material for stainless steel for edged tools having an excellent carbide distribution, enabling hardness to be increased by heat treatment for a short time during hardening. The intermediate material for stainless steel for edged tools substantially includes an FCC phase, and has a composition of, in % by mass, 0.46 to 0.72% of C, 0.15 to 0.55% of Si, 0.45 to 1.00% of Mn, 12.5 to 13.9% of Cr, 0 to 2.0% of Mo+W/2, and a remainder of Fe and impurities. Furthermore, a KAM value in a position at 1/4 in depth of a plane thickness from a surface of a rolled plane is 0.5° or more.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to an intermediate material for stainless steel for edged tools, which is used in, for example, razors, cutters, kitchen knives, and knives.

BACKGROUND ART

[0002] Martensitic stainless steel has been widely used as a material for edged tools such as razors, cutters, kitchen knives, and knives. In particular, a strip of high-carbon martensitic stainless steel containing approximately 13% by mass of Cr and approximately 0.65% by mass of C is known to be most suitable as a material for razors. The high-carbon martensitic stainless steel used in such applications (hereinafter referred to as "stainless steel for edged tools") is usually subjected to hardening and tempering before use. The stainless steel for edged tools is required to have high hardness when in use.

[0003] The stainless steel for edged tools is usually manufactured through the following manufacturing processes.

[0004] First, a raw material is melted and cast thereby to manufacture a material. Next, the material is hot-rolled thereby to manufacture an intermediate material. The material may be hot-forged or hot-rolled through a blooming process.

[0005] Next, the intermediate material is subjected to an initial annealing thereby to manufacture an annealed material. The annealed material is repeatedly subjected to cold rolling followed by strain-removal annealing the necessary number of times thereby to manufacture a cold-rolled steel strip having an intended thickness. Then, the cold-rolled steel strip is subjected to hardening and tempering to produce stainless steel for edged tools.

[0006] Furthermore, the stainless steel for edged tools is subjected to processing processes such as sharpening and cutting, and thus becomes an end-product. It is noted that, in general, trading in the market of stainless steel for edged tools is often conducted in the form of either an annealed material or a cold-rolled steel strip.

[0007] For the above-described stainless steel for edged tools, there has been proposed a technique of achieving high hardness by heat treatment for a short time during hardening. For example, as a representative example, JP-A-5-39547 (Patent Literature 1) discloses that heat treatment during hardening can be performed for a short time by controlling the carbide density of steel for stainless razors.

CITATION LIST

PATENT LITERATURE

[0008] Patent Literature 1: JP-A-5-39547

NON-PATENT LITERATURE

[0009] Non-Patent Literature 1: Transactions of the Japan Society of Mechanical Engineers (Series A), 2005, Vol. 71, No. 712, p. 1722

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010] As described above, with respect to the shortened hardening processing time and increased hardness of the stainless steel for edged tools, there have been proposed various techniques that focus on the features of the cold-rolled steel strip.

[0011] However, there have been few studies that focus on the features of the intermediate material after hot rolling and before annealing. The relationship between the features of the intermediate material and the properties of the annealed material for stainless steel for edged tools after annealing and before hardening, which is commercially available as a semi-finished product, has not been satisfactorily elucidated. The relationship between the features of the intermediate material and the carbide distribution of the cold-rolled steel strip has also not been satisfactorily elucidated.

[0012] For this reason, there has been a problem that poor knowledge on what the features of the intermediate material should be like inhibits excellent hardening properties that the stainless steel for edged tools originally has from being satisfactorily elicited.

[0013] An object of the present invention is to provide an intermediate material for stainless steel for edged tools having an excellent carbide distribution, of which the hardness can be increased by heat treatment for a short time during hardening.

SOLUTIONS TO THE PROBLEMS

[0014] The present inventors studied the relationship between the carbide distribution that influences the hardenability and hardness of stainless steel for edged tools and the intermediate material for stainless steel for edged tools that influences the carbide distribution.

[0015] First, the present inventors have ascertained that, among the features of the intermediate material for stainless steel for edged tools, the strain amount before annealing influences the carbide distribution after annealing of the intermediate material.

[0016] Then, the present inventors have found that, by allowing strain to be retained in a final pass of hot rolling for the intermediate material for stainless steel for edged tools substantially including an FCC phase, the carbide distribution after annealing can be improved when a KAM value by an SEM-EBSD method is 0.5° or more or when a half-value width of a (200) plane of the FCC phase in X-ray diffraction becomes 0.3° or more, and thus have accomplished the present invention.

[0017] According to an aspect of the present invention, an intermediate material for stainless steel for edged tools, which substantially includes an FCC phase and is a material after hot rolling and before annealing, has a composition of, in % by mass, 0.46 to 0.72% of C, 0.15 to 0.55% of Si, 0.45 to 1.00% of Mn, 12.5 to 13.9% of Cr, 2:0 to 2.0% of Mo and W, and a remainder of Fe and impurities. In addition, a KAM value by an SEM-EBSD method in a position at 1/4 in depth of a plane thickness from a surface of a rolled plane is 0.5° or more.

[0018] According to another aspect of the present invention, in an intermediate material for stainless steel for edged tools which is a material after hot rolling and before annealing, a half-value width of a (200) plane of a FCC phase in X-ray diffraction in a position at 1/4 in depth of a plane thickness from a surface of a rolled plane is 0.3° or more.

EFFECTS OF THE INVENTION

[0019] The stainless steel for edged tools manufactured using the intermediate material for stainless steel for edged tools according to the present invention can be increased in hardness by heat treatment for a short time during hardening. Therefore, the intermediate material for stainless steel for edged tools according to the present invention is most suitable especially in applications such as razors having a thin thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 is a schematic diagram illustrating a position at which a test piece is sampled and an evaluated plane.

FIG. 2 is a drawing-substitute photograph illustrating an example of a metal structure of an annealed material of an intermediate material for stainless steel for edged tools according to the present invention.

FIG. 3 is a drawing-substitute photograph illustrating an example of a metal structure of an annealed material of an intermediate material for stainless steel for edged tools according to a comparative example.

FIG. 4 is a drawing-substitute photograph illustrating an example of a metal structure of an annealed material of an intermediate material for stainless steel for edged tools according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0021] As described above, one of the important characteristics of the present invention is that the carbide distribution in the intermediate material after annealing is improved by controlling the residual strain amount in the intermediate material before annealing.

[0022] First, the KAM (kernel average misorientation) value which is most characteristic is described below.

< KAM value by SEM-EBSD method is 0.50° or more>

[0023] In the present invention, the residual strain plays an important role. With respect to a KAM value defined in the present invention, for example, the KAM value by the SEM (scanning electron microscope)-EBSD (electron backscatter diffraction) method is described as a measurement method of the residual strain in Non-Patent Literature 1. According to the studies conducted by the present inventors, it has been confirmed that the KAM value by the SEM-EBSD method of the intermediate material for stainless steel for edged tools having the above-described composition is correlated with the carbide distribution of the annealed material for stainless steel for edged tools obtained using the above-described intermediate material.

[0024] Specifically, when the KAM value by the SEM-EBSD method of the intermediate material for stainless steel for edged tools is less than 0.50°, the intermediate material can be said to be in a state of having small residual strain. When annealing is thereafter performed, coarse carbides are likely to be precipitated at grain boundaries, compared to a material having a large residual strain amount. As a result, for example, toughness decreases after hardening and tempering performed when used in edged tools. Therefore, an average value of the KAM values by the SEM-EBSD method needs to be 0.50° or more. It is noted that the larger KAM value causes larger residual strain, and is therefore preferred. However, when the KAM value exceeds 2.00°, the residual strain is likely to become large in variation depending on the position. Therefore, the upper limit of the KAM value is preferably 2.00° or less.

[0025] Next, the half-value width is described below.

<Full-width at half maximum of (200) plane of FCC phase in X-ray diffraction is 0.3° or more>

[0026] In the present invention, the residual strain plays an important role. It is known that there is a correlation between the half-value width and the residual strain. According to the studies conducted by the present inventors, it has been confirmed that the half-value width in X-ray diffraction of the intermediate material for stainless steel for edged tools having the above-described composition is correlated with the carbide distribution of the annealed material for stainless steel for edged tools obtained using the above-described intermediate material.

[0027] Specifically, when the half-value width of the (200) plane of the FCC phase in X-ray diffraction of the intermediate material for stainless steel for edged tools is less than 0.3°, the intermediate material can be said to be in a state of having small residual strain. When annealing is thereafter performed, coarse carbides are likely to be precipitated at grain boundaries, compared to a material having a large residual strain amount. As a result, for example, toughness decreases after hardening and tempering performed when used in edged tools. Therefore, the half-value width in X-ray diffraction of the (200) plane of the FCC phase needs to be 0.3° or more. It is noted that the larger half-value width causes larger residual strain, and is therefore preferred. However, when the half-value width exceeds 1.0°, the residual strain is likely to become large in variation depending on the position. Therefore, the upper limit of the half-value width is preferably 1.0° or less.

<Position at 1/4 in depth of plate thickness from surface of rolled plane>

[0028] In the present invention, the measurement of the KAM value by the SEM-EBSD method or the measurement of the half-value width of the (200) plane of the FCC phase in X-ray diffraction as described above is performed in a position at 1/4 in depth of the plane thickness from the surface of the rolled plane.

[0029] The "rolled plane" in the present invention refers to, as illustrated in FIG. 1, a plane with which a rolling roll is in contact during rolling of the intermediate material for stainless steel for edged tools. The reason why the rolled plane side is used for evaluation is that, since the strain amount introduced by rolling is non-uniform in a thickness direction, settling the evaluated plane and the thickness enables the evaluation to be performed under the same conditions.

[0030] In addition, the position at 1/4 in depth of the plane thickness from the surface is selected in the present invention because the vicinity of the surface has large strain introduced during hot rolling thereby to decrease the particle diameter of crystals generated by recrystallization, and is therefore not suitable for the measurement of the KAM value and the half-value width. It is also because the middle position of the plate thickness, on the other hand, has less rolling reduction during the final pass so that a difference in strain amount due to whether the final pass is performed or not is small compared to the position at 1/4 of the plate thickness, and accordingly, a difference in KAM value or in half-value width is unlikely to be produced.

[0031] With respect to the half-value width of the (200) plane of the FCC phase in X-ray diffraction, the position at 1/4 in depth of the plane thickness from the surface is selected from the same reason as described above. The vicinity of the surface has large strain introduced during hot rolling thereby to decrease the particle diameter of crystals generated by recrystallization, and is therefore not suitable for the measurement of the half-value width. On the other hand, the middle position of the plate thickness has less rolling reduction during the final pass so that a difference in strain amount due to whether the final pass is performed or not is small compared to the position at 1/4 of the plate thickness, and accordingly, a difference in half-value width is unlikely to be produced.

[0032] The (200) plane of the FCC phase is selected in the measurement of the half-value width because the above-described orientation has a peak that provides the highest intensity in X-ray diffraction in the alloy system of the composition defined in the present invention. The peak intensity is low outside the (200) plane, and therefore the effect by a difference in strain amount on the half-value width is smaller compared to the (200) plane. Thus, the measurement of the half-value width on the (200) plane is sufficient.

[0033] Next, the alloy composition that provides fundamental characteristics defined in the present invention is described below. The content of each element is in % by mass.

<C: 0.46 to 0.72%>

[0034] The C content is 0.46 to 0.72% for achieving the hardness sufficient as an edged tool and minimizing the crystallization of eutectic carbides during casting and solidification. When the C content is less than 0.46%, the hardness sufficient as an edged tool cannot be obtained. When the content exceeds 0.72%, the increase of the crystallization amount of the eutectic carbides in a balance with the Cr amount causes edge chipping during sharpening. The lower limit of the C content is preferably 0.50%, and more preferably 0.65%. The upper limit of the C content is preferably 0.70%.

<Si: 0.15 to 0.55%>

[0035] Si is added as a deoxidizing agent during smelting. For obtaining sufficient deoxidizing effect, Si is retained in an amount of 0.15% or more. On the other hand, when the content exceeds 0.55%, the increase of the inclusion amount causes edge chipping during sharpening. Therefore, the Si content is set to be 0.15 to 0.55%. Also, Si has the effect of increasing the tempering softening resistance. When Si is added in an amount of 0.20% or more, the hardness can be further increased. Therefore, the lower limit of the Si content is preferably 0.20%, and the upper limit of the Si content is preferably 0.35%.

<Mn: 0.45 to 1.00%>

[0036] Mn is added as a deoxidizing agent during smelting in a similar manner to Si. For obtaining sufficient deoxidizing effect, Mn is retained in an amount of 0.45% or more. On the other hand, when the content exceeds 1.00%, hot workability decreases. Therefore, the Mn content is set to be 0.45 to 1.00%. The lower limit of the Mn content is preferably 0.65%, and the upper limit of the Mn content is preferably 0.85%.

<Cr: 12.5 to 13.9%>

[0037] The Cr content is 12.5 to 13.9% for achieving sufficient corrosion resistance and minimizing crystallization of eutectic carbides during casting and solidification. When the Cr content is less than 12.5%, sufficient corrosion resistance as stainless steel cannot be obtained. When the content exceeds 13.9%, the increase of the crystallization amount of the eutectic carbides causes edge chipping during sharpening. The lower limit of the Cr content is preferably 13.0%, and the upper limit of the Cr content is preferably 13.6%.

<Mo+W/2: 0 to 2.0%>

[0038] Mo and W may not be added (0%). However, these elements improve corrosion resistance, and therefore can be added as necessary to an upper limit of 2.0%. When the Mo+W/2 content exceeds 2.0%, solid solution strengthening and deformation resistance are increased. Accordingly, hot workability deteriorates. Therefore, the content of Mo+W/2 is set to be 0 to 2.0%.

[0039] Other than the elements described above, Fe and impurities are contained.

[0040] Examples of typical impurity elements include P, S, Ni, V, Cu, Al, Ti, N, and O. Mixing-in of these elements is unavoidable. However, the contents of the impurity elements are preferably controlled in the following ranges: P≤0.03%, S≤0.005%, Ni≤0.15%, V≤0.2%, Cu≤0.1%, Al≤0.01%, Ti≤0.01%, N≤0.05%, and O≤0.05%.

[0041] The following describes an intermediate material for stainless steel for edged tools according to the present invention and a typical method for manufacturing an annealed material using the intermediate material.

[0042] First, a material for stainless steel for edged tools is manufactured by melting and casting. Examples of the melting include vacuum melting, air melting, vacuum arc remelting, and electroslag remelting. Examples of the casting include die casting and continuous casting, by which the material is obtained. The obtained material may be subjected to homogenization heat treatment as necessary. The material may be further subjected to a blooming process by hot forging or hot rolling.

[0043] Thereafter, the material is subjected to hot rolling. The hot rolling is performed so that the rolling reduction is 80% or more, and the temperature of the material after hot rolling (material temperature) is 1000 to 1250°C. Then, in final hot rolling, hot rolling is performed at a material temperature of 900°C or less and a rolling reduction of 10% or more. Accordingly, an intermediate material for stainless steel for edged tools is manufactured.

[0044] The temperature in the final hot rolling is set at 900°C or less in order to introduce residual strain into the material. In the temperature range exceeding 900°C, dynamic recovery and recrystallization are likely to occur. For this reason, residual strain is unlikely to be introduced. Also, the rolling reduction is set at 10% or more because, at the rolling reduction less than 10%, residual strain is not sufficiently introduced, thereby causing carbides to concentrate on grain boundaries during annealing.

[0045] When such hot rolling is performed, pearlite transformation does not sufficiently occur. For this reason, the intermediate material is substantially an FCC phase. It is noted that "the intermediate material substantially includes an FCC phase" described in the present invention means that 80% by volume or more of the FCC phase is measured by an X-ray diffraction apparatus. At this time, the remainder is martensite formed during cooling. A specific evaluation method therefor is described below in later-described examples.
[0046] The intermediate material for stainless steel for edged tools manufactured by the above-described manufacturing method is subjected to an annealing process at 800 to 860°C for one to 100 hours. Accordingly, there is manufactured an annealed material of stainless steel for edged tools containing precipitated carbides.
[0047] Furthermore, a cold-rolled steel strip having a thickness of less than 0.5mm for stainless steel for edged tools can be manufactured using the above-described annealed material by repeating cold rolling and annealing.
[0048] When the cold-rolled steel strip for stainless steel for edged tools is subjected to hardening, tempering, and sharpening to provide an edged tool, the cold-rolled steep strip may be subjected to the sub-zero treatment after hardening and the coating of the surface after tempering, as necessary.

Examples

[0049] The present invention is further described below in detail with reference to the following examples.
[0050] A steel ingot (material) having a chemical composition shown in Table 1 was produced by melting.

[Table 1]

							(% by mass)
	C	Si	Mn	Cr	Mo	W	Remainder
Composition 1	0.69	0.33	0.75	13.22	0.01	0.02	Fe and unavoidable impurities
Composition 2	0.50	0.50	0.89	13.39	1.30	0.06	Same as above

[0051] The steel ingot was subjected to a hot blooming process to produce a hot rolling material with a width of 350 mm and a thickness of 50 mm. There were produced two rolling materials having the composition of Composition 1, and one rolling material having the composition of Composition 2.
[0052] The hot rolling material of Composition 1 was heated to 1200°C, and was subjected to hot rolling at a total rolling reduction ratio of 95% (the temperature of the material after this hot rolling (material temperature) was 1050°C). Thereafter, final hot rolling was performed at a material temperature of 850°C and a rolling reduction ratio of 15% thereby to produce an intermediate material A according to the present invention.
[0053] As a comparative example, an intermediate material B was produced in a process in which the final hot rolling process was omitted. In this process, the hot rolling material of Composition 1 was heated to 1200°C to be subjected to hot rolling. As a result, the intermediate material B was produced in which the material temperature of hot rolling was 1050°C and the total rolling reduction ratio was 95%.
[0054] Furthermore, the hot rolling material of Composition 2 was heated to 1200°C, thereby subjected to hot rolling at a total rolling reduction ratio of 95% (the temperature of the material after this hot rolling (material temperature) was 1050°C). Thereafter, final hot rolling was performed at a material temperature of 850°C and a rolling reduction ratio of 15% thereby to produce an intermediate material C according to the present invention.
[0055] A test piece was sampled in the vicinity of the center in width for each of the intermediate materials 1A, B, and C for stainless steel for edged tools. The sampling position of the test piece is a position illustrated in FIG. 1. A vertical section 2 is an evaluated plane of a metal structure observation plane. A rolled plane 3 is an evaluated plane for the EBSD and the X-ray diffraction.
[0056] The metal structure was observed on the vertical section of the sampled test piece. Also, the position at 1/4 in depth of the plate thickness from the rolled plane of the test piece to be used in the EBSD and the X-ray diffraction was prepared by mirror polishing followed by electrolytic polishing. Table 2 shows the KAM value by the EBSD method, the half-value width, and the FCC amount by X-ray diffraction for each sample.
[0057] In the above-described metal structure observation, the vertical section of the test piece was polished to be a mirror finished surface and then corroded with an aqueous solution of ferric chloride to perform observation using an optical microscope.
[0058] The measurement of the KAM value was performed using an SEM (Model No. "ULTRA 55") manufactured by ZEISS, and an EBSD measurement and analysis system OIM (Orientation-Imaging-Micrograph) manufactured by TSL. In each region delimited in a hexagon as a measurement region, Kikuchi patterns formed by electrons reflected from electron beams incident on the sample surface were obtained to measure the orientations in the region. The measured

orientation data were analyzed using the analysis software OIM Analysis of the above-described system. The measurement area was 100 μm×100 μm. The distance between adjacent pixels was 0.2 μm. The boundary having a misorientation between adjacent pixels of 5° or more was considered as a crystal grain boundary.

[0059] It is noted that, as the KAM value, an average value of the misorientations between an individual measurement point and a proximate measurement point excluding the crystal grain boundary was calculated. This calculated average value was an average value in all regions constituting the whole measurement plane.

[0060] Also, the measurement of the amount of the FCC phase in X-ray diffraction was performed using RINT 2500 manufactured by Rigaku Corporation. Co was used as a line source. The amount of the FCC phase was calculated using a diffraction line intensity ratio obtained from each plane of (200)α, (211)α, (200)γ, (220)γ and (311)γ under the conditions of a voltage of 40 kV and a current of 200 mA.

[0061] Next, the intermediate materials A to C for stainless steel for edged tools were annealed at 840°C for 5 hours. Thereafter, from each of the annealed materials, a test piece was sampled such that the vicinity of the center in width of the rolled material illustrated in FIG. 1 was contained and the vertical section serving as the evaluated plane 2 became a metal structure observation plane. The photographs of the metal structures of the annealed intermediate materials A, B, and C are shown in FIG. 2 to FIG. 4 respectively.

[0062] In the metal structure observation, the evaluated plane was polished to be a mirror finished surface and then corroded with an aqueous solution of ferric chloride to perform observation using a scanning electron microscope.

[Table 2]

Material	KAM value (°)	Full-width at half maximum of (200) plane of FCC phase (°)	Amount of FCC phase (% by volume)	Remarks
Intermediate material A	0.77	0.340	100	Present invention
Intermediate material B	0.48	0.247	100	Comparative Example
Intermediate material C	1.11	0.395	84.24	Present invention

[0063] When the intermediate material for stainless steel for edged tools was annealed, more carbides after annealing were distributed in a grain, as seen from FIG. 2 and FIG. 4, in a case where a KAM value was 0.5° or more or a half-value width of the (200) plane of the FCC phase in X-ray diffraction was 0.3° or more. Thus, it can be understood that this intermediate material had a favorable structure. On the other hand, as seen from FIG. 3, in a case where a KAM value was less than 0.5 or a half-value width of the (200) plane of the FCC phase was less than 0.3°, coarser carbides were precipitated at a grain boundary. In this metal structure, carbides are unlikely to decompose during hardening. For this reason, it is concerned that the coarse carbides retained after hardening causes toughness to decrease.

[0064] From the results described above, it was confirmed that, when annealing is performed to the intermediate material for stainless steel for edged tools having a KAM value of 0.5° or more, or to the intermediate material for stainless steel for edged tools having a half-value width of the (200) plane of the FCC phase in X-ray diffraction of 0.3° or more, there can be achieved the metal structure of stainless steel for edged tools that is suitable for the edged tools such as razors.

INDUSTRIAL APPLICABILITY

[0065] Stainless steel for edged tools manufactured using an intermediate material for stainless steel for edged tools according to the present invention has a favorable carbide distribution. Therefore, the present invention is applicable to razors or the like.

LIST OF REFERENCE NUMERALS

[0066]

1 Intermediate material for stainless steel for edged tools
2 Vertical section
3 Rolled plane

Claims

1. An intermediate material for stainless steel for edged tools, the intermediate material substantially including an FCC phase and being a material after hot rolling and before annealing, wherein
the intermediate material has a composition of, in % by mass, 0.46 to 0.72% of C, 0.15 to 0.55% of Si, 0.45 to 1.00% of Mn, 12.5 to 13.9% of Cr, 0 to 2.0% of Mo+W/2, and a remainder of Fe and impurities, and
a KAM value by an SEM-EBSD method in a position at 1/4 in depth of a plane thickness from a surface of a rolled plane is 0.50° or more.

2. An intermediate material for stainless steel for edged tools, the intermediate material substantially including an FCC phase and being a material after hot rolling and before annealing, wherein
the intermediate material has a composition of, in % by mass, 0.46 to 0.72% of C, 0.15 to 0.55% of Si, 0.45 to 1.00% of Mn, 12.5 to 13.9% of Cr, 0 to 2.0% of Mo+W/2, and a remainder of Fe and impurities, and
a half-value width of a (200) plane of the FCC phase in X-ray diffraction in a position at 1/4 in depth of a plane thickness from a surface of a rolled plane is 0.3° or more.

FIG. 1

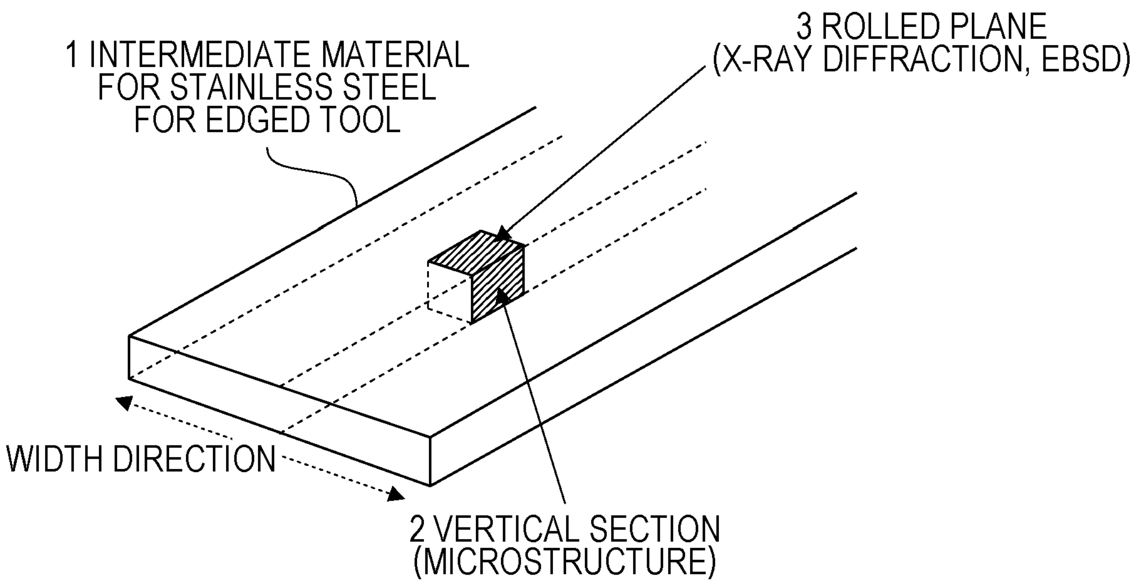
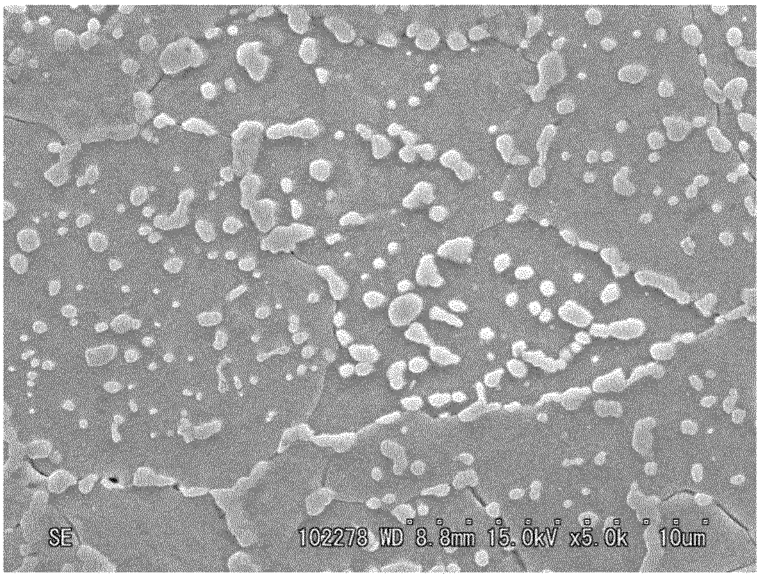
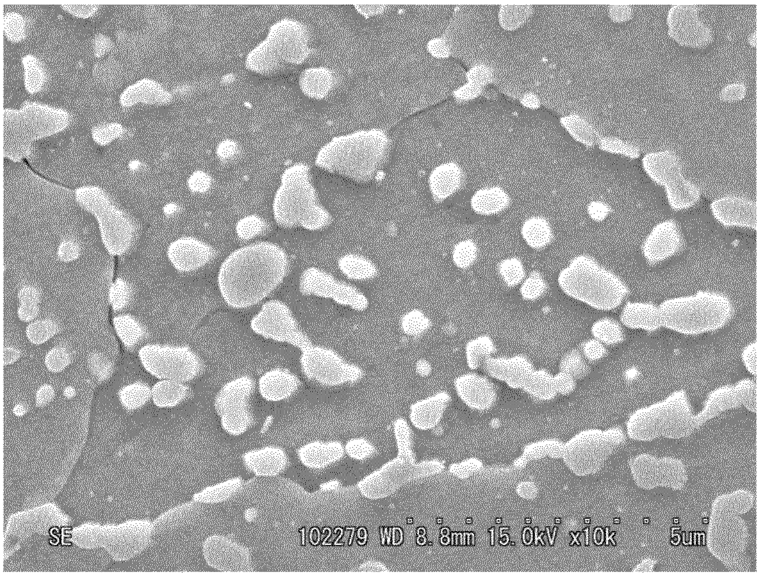

1 INTERMEDIATE MATERIAL
FOR STAINLESS STEEL
FOR EDGED TOOL
3 ROLLED PLANE
(X-RAY DIFFRACTION, EBSD)
WIDTH DIRECTION
2 VERTICAL SECTION
(MICROSTRUCTURE)

FIG. 2

PHOTOGRAPH OF METAL STRUCTURE OF
INTERMEDIATE MATERIAL A AFTER ANNEALING



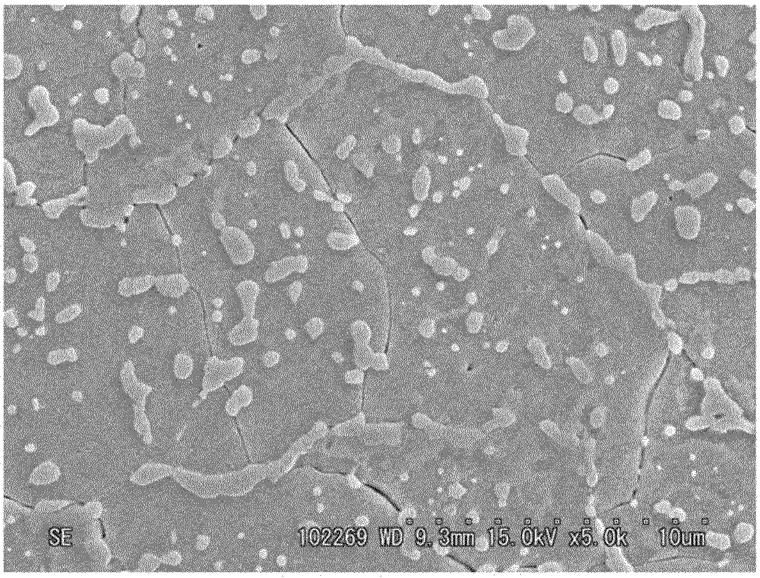
10μm



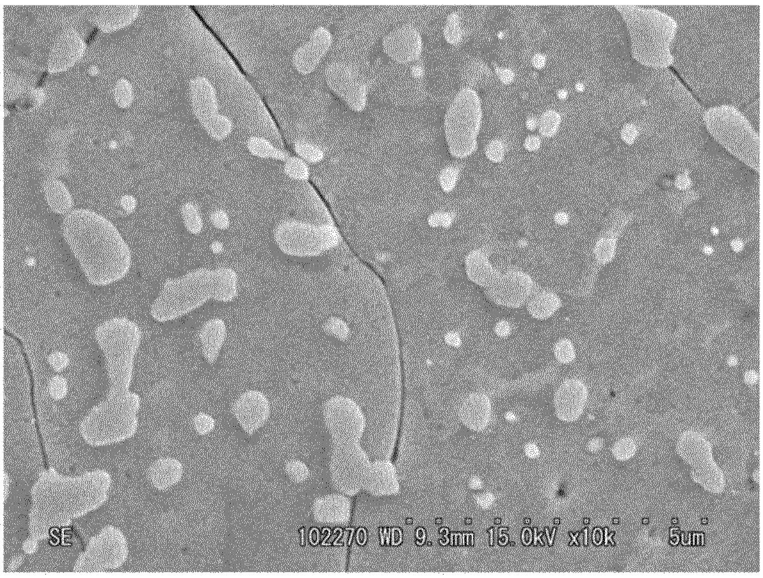
5μm

FIG. 3

PHOTOGRAPH OF METAL STRUCTURE OF INTERMEDIATE MATERIAL B (COMPARATIVE EXAMPLE) AFTER ANNEALING



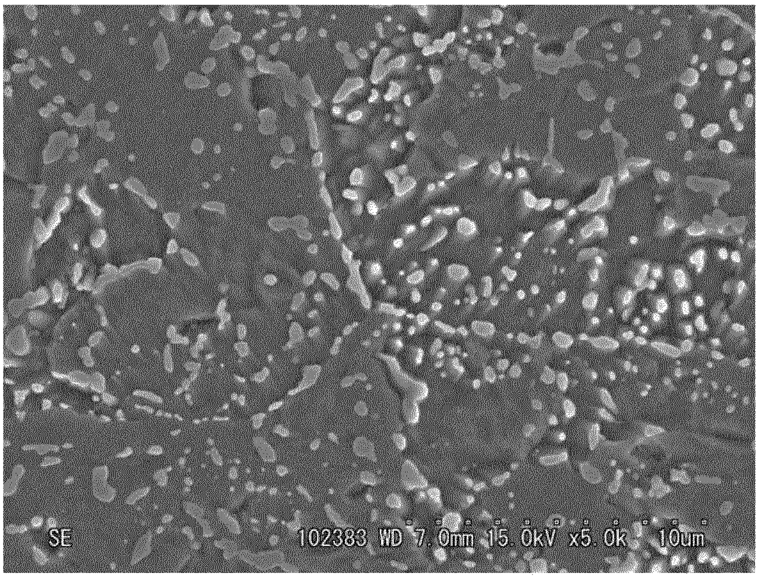
10μm



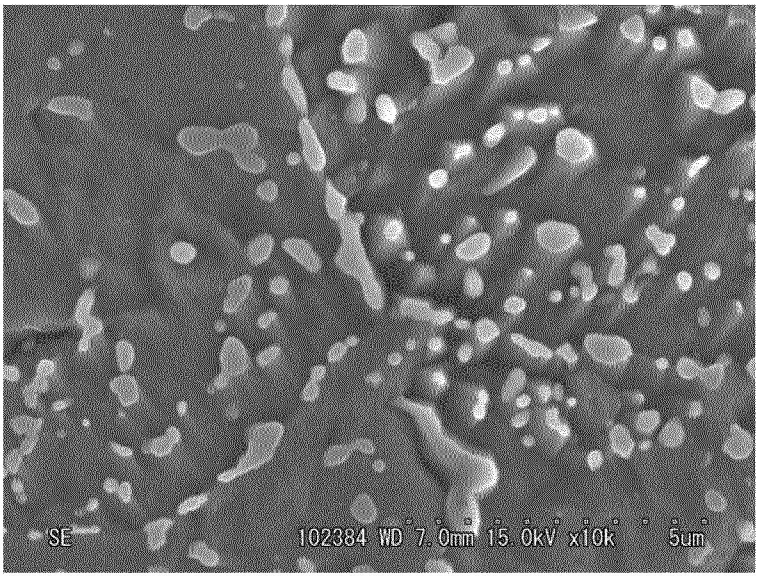
5μm

FIG. 4

PHOTOGRAPH OF METAL STRUCTURE OF INTERMEDIATE MATERIAL C (RELEVANT INVENTION) AFTER ANNEALING



10μm



5μm

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/057251

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C21D8/02*(2006.01)i, *C21D9/46*(2006.01)i, *C22C38/22* (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)
C22C38/00, C21D8/02, C21D9/46, C22C38/22

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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 9-87746 A (Sumitomo Metal Industries, Ltd.), 31 March 1997 (31.03.1997), claims; paragraphs [0018] to [0020]; examples (Family: none)	1,2
A	JP 9-20923 A (Sumitomo Metal Industries, Ltd.), 21 January 1997 (21.01.1997), claims; examples (Family: none)	1,2
A	JP 1-230714 A (Nippon Steel Corp.), 14 September 1989 (14.09.1989), claims; examples (Family: none)	1,2

☒ 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	Date of mailing of the international search report
24 April, 2014 (24.04.14)	13 May, 2014 (13.05.14)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2014/057251

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-155316 A (Nisshin Steel Co., Ltd.), 31 May 2002 (31.05.2002), claims; examples (Family: none)	1,2
E,X	JP 2014-70229 A (Hitachi Metals, Ltd.), 21 April 2014 (21.04.2014), claims; examples; fig. 1 (Family: none)	1,2
P,A	WO 2013/047237 A1 (Hitachi Metals, Ltd.), 04 April 2013 (04.04.2013), claims; examples & JP 5333695 B1	1,2

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 5039547 A **[0007] [0008]**

Non-patent literature cited in the description

- *Transactions of the Japan Society of Mechanical Engineers (Series A),* 2005, vol. 71 (712), 1722 **[0009]**