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(54) **HARD EXTRA-THIN STEEL SHEET AND METHOD FOR MANUFACTURING THE SAME**
HARTES EXTRA DÜNNES STAHLBLECH UND VERFAHREN ZU SEINER HERSTELLUNG
FEUILLE D'ACIER DURE EXTRA-MINCE ET SON PROCÉDÉ DE FABRICATION

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a thin steel sheet having a sheet thickness of 0.400 mm or less which also includes a surface treated steel sheet used for electric equipments, electronic parts, building materials and metallic containers, and to a method of manufacturing the same.

[0002] The present application claims the benefit of priority to Japanese Patent Application No. 2006-102766, the content of which is incorporated herein by reference.

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BACKGROUND ART

[0003] A thin steel sheet having a sheet thickness of 0.400 mm or less has been used for various purposes such as for electric equipments, electronic parts, building materials and metallic containers, and a process of making a steel sheet more thin has been carried out to lower the cost of raw material. When it is made thin, a member employing such material accordingly causes decrease in its strength, and thus hardening of material is also generally required at the time of thinning the material. One of obvious problem occurring in such an extra thin and hard material is deterioration in formability. In particular, contrary to a thick material used for automobiles and the like, a thin material immediately causes breakage when constriction is occurred, and thus it is extremely important to give a uniform deformation. According to a tensile test which is generally applied for evaluating characteristics of a steel sheet, it means that a sheet has to be hardened without turning down a uniform elongation. Among the thin materials, for a steel sheet for containers for which a heavy working such as drawing, ironing or tensile elongation is performed, methods disclosed in Patent Documents 1 to 3 or the like have been proposed to assure the formability.

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[0004] However, these methods are not particularly focusing on a uniform elongation, and although high ductility (total formability) is provided, the ductility is increased more likely by a local elongation. Therefore, in practice, they do not give answers to problems mentioned in this application, such as defect in surface quality due to breakage or constriction.

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[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. H02-118026

[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. H03-257123

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[Patent Document 3] Japanese Unexamined Patent Application, First Publication No. H10-72640

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

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[0005] An object of the present invention is to prevent breakage or constriction caused by lack of uniform deformation, which is a problem occurring upon using an extra thin, hard material. In specific, an object is to, for deterioration in elongation due to a hardening of material, consider the deterioration of local elongation on a priority basis so as to assure a uniform elongation and to prevent a local deformation (constriction) up to a high strained region even for the same total elongation. Furthermore, another object of the present invention is to make clear a material condition, and to provide a steel sheet employing such the condition and a manufacturing method thereof.

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Means for Solving the Problems

[0006] The present inventors have carried out a research on dispersing various second phases in a steel sheet for hardening the steel sheet. In specific, it belongs to a category of precipitation hardening and transformation hardening, and a material can be hardened by dispersing a second phase, according to which, of course, the formability deteriorates. However, after experimentation, the inventors found out that when a second phase having a specific morphology is dispersed in a steel sheet, hardening is achieved while preventing deterioration in uniform elongation. In addition, the inventors have in detail investigated morphology, amount and kind of second phase and also scopes of steel sheet materials for obtaining preferable properties, and thus completed the present invention. Key points of the present invention are as shown below.

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- (1) Controlling a morphology of the second phase: so as to give highly anisotropic acicular ones.
- (2) Controlling a size of the second phase: so as to give a relatively larger sized ones than that of usual precipitates.
- (3) Controlling a number density of the second phase: so as to give a relatively thin distribution.
- (4) A matrix is provided as a Fe ferrite phase, and an orientation of the second phase is arranged in a specific direction to the matrix.

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[0007] The inventors of the present invention have carried out keen investigation based on above-mentioned technical ideas, and as a result, they have achieved the present invention. Key points thereof are as described in the contents shown below.

- 5 (1) A hard extra-thin steel sheet having a sheet thickness of 0.400 mm or less, including: by mass%, C: 0 to 0.800%; N: 0 to 0.600%; Si: 0 to 2.0%; Mn: 0 to 2.0%; P: 0 to 0.10%; S: 0 to 0.100%; Al: 0 to 3.0%; and O: 0 to 0.200%. The hard extra-thin steel sheet contains 0.05% or more, by volume fraction, of a second phase having an average major axis of 0.10 μm or greater and an average minor axis of 0.05 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 .
- 10 (2) The hard extra-thin steel sheet according to (1) above, which further contains at least one of: Ti: 0 to 4.00%; Nb: 0 to 4.00%; REM: 0 to 4.00%; B: 0 to 0.0300%; Cu: 0 to 8.00%; Ca: 0 to 1.00%; Ni: 0 to 8.00%; and Cr: 0 to 20.00%.
- (3) The hard extra-thin steel sheet according to (1) above, wherein a number density of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is 0.01 pieces/ μm^2 or more.
- 15 (4) The hard extra-thin steel sheet according to (1) above, wherein a number density of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is 0.001 pieces/ μm^2 or more.
- (5) The hard extra-thin steel sheet according to (1) above, wherein a main phase is a ferrite phase of Fe and a volume fraction of which is 80% or more.
- 20 (6) The hard extra-thin steel sheet according to (1) above, wherein a direction of the average major axis of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is in a $\langle 100 \rangle$ orientation or $\langle 110 \rangle$ orientation of an Fe phase that is in contact with the second phase.
- (7) The hard extra-thin steel sheet according to (1) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is a simple substance of or a composite compound of oxide, sulfide, carbide, nitride or an intermetallic compound.
- 25 (8) The hard extra-thin steel sheet according to (7) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is an oxide including one or two kind(s) of Fe, Mn, Si, Al, Cr, REM, Ti and Nb.
- (9) The hard extra-thin steel sheet according to (7) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is a sulfide including one or two kind(s) of Ti, Mn, Cu, Ca and REM.
- 30 (10) The hard extra-thin steel sheet according to (7) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is a carbide including one or two kind(s) of Fe, Ti, Nb, Si and Cr.
- (11) The hard extra-thin steel sheet according to (7) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is a nitride including at least one or two kind(s) of Fe, Ti, Nb, Al, B and Cr.
- 35 (12) The hard extra-thin steel sheet according to (7) above, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is an intermetallic compound including at least one or two kind(s) of Fe, Ti, Nb, Al, Si and Mn.
- (13) The hard extra-thin steel sheet according to (1) above, wherein a volume fraction of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 satisfies (a volume fraction of 1/8 sheet thickness surface layer)/(a volume fraction of 1/4 sheet thickness center layer) ≥ 10 .
- 40 (14) The hard extra-thin steel sheet according to (1) above, wherein a number density of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 satisfies (a number density of 1/8 sheet thickness surface layer)/(a number density of 1/4 sheet thickness center layer) ≥ 10 .
- (15) The hard extra-thin steel sheet according to (1) above, which satisfies maximum strength ≥ 350 MPa and HR30T Rockwell hardness ≥ 54 , according to a tensile test carried out with the use of a tensile test specimen having a parallel part of 25 mm wide and 60 mm long with a distance between marks of 50 mm at a deformation rate of 5 mm/min.
- 45 (16) The hard extra-thin steel sheet according to (1) above, which satisfies uniform elongation/local elongation ≥ 1.0 according to a tensile test carried out with the use of a tensile test specimen having a parallel part of 25 mm wide and 60 mm long with a distance between marks of 50 mm at a deformation rate of 5 mm/min.
- (17) The hard extra-thin steel sheet according to (1) above, which satisfies yield stress/maximum strength ≤ 0.9

according to a tensile test carried out with the use of a tensile test specimen having a parallel part of 25 mm wide and 60 mm long with a distance between marks of 50 mm at a deformation rate of 5 mm/min.

(18) A method of manufacturing the hard extra-thin steel sheet according to (8) above, which includes: upon hot rolling a bloom of steel having a thickness of 50 mm or more and containing oxide with an average diameter of 10 μm to 25 μm, at 600°C or above, performing rolling at a total real strain of 0.4 or more under conditions of 1,000°C or above and a strain rate of 1/sec or more; and then performing rolling at a total real strain of 0.7 or more under conditions of 1,000°C or less and a strain rate of 10/sec or more.

(19) A method of manufacturing the hard extra-thin steel sheet according to (9) above, which includes: upon hot rolling a bloom of steel having a thickness of 50 mm or more and containing sulfide with an average diameter of 10 μm to 25 μm, at 600°C or above, performing rolling at a total real strain of 0.4 or more under conditions of 1,000°C or above and a strain rate of 1/sec or more; and then performing rolling at a total real strain of 0.7 or more under conditions of 1,000°C or less and a strain rate of 10/sec or more.

(20) A method of manufacturing the hard extra-thin steel sheet according to (10) above, which includes, after cold rolling, performing a carburization treatment at a temperature ranging between 600 and 700°C under a condition of giving $\{(\text{carburization time (sec)}) * (\text{carburization temperature (}^\circ\text{C)})\} / \{(\text{carburizing gas concentration (\%)}) * (\text{cooling rate in carburization treatment (}^\circ\text{C/sec)})\} \geq 20$, simultaneously with or after a recrystallization annealing, thereby increasing a C amount by 0.0002% or more.

(21) A method of manufacturing the hard extra-thin steel sheet according to (11) above, which includes, after cold rolling, performing a nitriding treatment at a temperature ranging between 600 and 700°C under a condition of giving $\{(\text{nitriding time (sec)}) * (\text{nitriding temperature (}^\circ\text{C)})\} / \{(\text{nitriding gas concentration (\%)}) * (\text{cooling rate in nitriding treatment (}^\circ\text{C/sec)})\} \geq 20$, simultaneously with or after a recrystallization annealing, thereby increasing an N amount by 0.0002% or more.

(22) A method of manufacturing the hard extra-thin steel sheet according to (12) above, which includes performing cooling from a temperature of 900°C or above for the step of manufacturing a steel sheet, wherein cooling from 900°C down to 500°C is performed at a cooling rate of 20°C/sec or lower, thereby increasing a volume fraction of the intermetallic compound by 2.0-fold or more.

[0008] Herein, a sign "*" in this specification represents multiplication (x).

[0009] The present invention relates to a thin steel sheet having a sheet thickness of 0.400 mm or less and a manufacturing method thereof. As a part of manufacturing method of an enameling steel sheet, there is a conventional technique in which a hot rolling condition is limited thereby controlling the morphology of oxide.

[0010] However, rolling and elongation of oxide in the present invention completely differs from those provided with a limit of hot rolling condition for an enameling steel sheet. More specifically, it had been very difficult to get an idea to put a rolled and elongated oxide into practical use for a thin steel sheet aimed by the present invention, according to an extension technique provided with a limit of hot rolling condition for an enameling steel sheet. These will be explained in detail below.

[0011] In general, inclusion of oxide in a thin steel sheet as for the present invention is controlled because it is an extremely unfavorable substance. This is because deformation concentrated around the oxide gives highly sensitive effect in breaking a base material as the base material itself is thin.

[0012] A good example can be shown by flange formability in a process of manufacturing cans. In regard to a steel material used for such purpose, an oxide amount is strictly controlled and its production is given at a very low level. An adverse effect of oxide on a thin material does not just stay on as the oxide problem, and when a rolled and elongated oxide as in an enameling steel sheet cracks in a cold rolling process and forms voids therearound, those voids give a cutting effect, thereby causing a further deterioration in formability of the base material.

[0013] Therefore, in the past, it was impossible to get an idea to put an oxide, even more a rolled and elongated oxide that may crack in cold rolling, into practical use for the purpose of improving the property for a thin material aimed by the present invention.

[0014] A technical difference in regard to a manufacturing method of enameling steel sheet and the present invention are mentioned as follows.

[0015] First, in a production of enameling steel sheet, an oxide is temporarily rolled and elongated at a hot rolling step but the oxide cracks in the following cold rolling step thereby forming many voids around the cracked oxide. All oxides in an end product are finely cracked and are in an isotropic form.

[0016] In contrast, in the present invention, the oxide has to be a rolled and elongated oxide at a final stage, and thus a hot rolling step is employed as a way for this. In other words, an oxide rolled and elongated under hot rolling is still kept as a rolled and elongated oxide even after the cold rolling and annealing, and an anisotropic form is necessarily maintained to an end product. When the same condition is employed for a hot rolling, this difference may be fundamentally exhibited by difference in the composition of oxides. In specific, for an enameling steel sheet, a compounded form of relatively soft Mn-containing oxide with hard Nb-, B-containing oxide works preferably in accelerating cracking. Mean-

while, for steel of the present invention, it is preferable that oxide be provided as a homogeneous substance and not as a compounded product including oxides of different composition, so as to give a uniform deformation at the time of cold rolling and avoid cracking.

[0017] Even if oxide is temporarily rolled and elongated as in an enameling steel sheet, if the oxide becomes isotropic by cracking afterwards, work hardenability which is the characteristic of the present invention, excellent uniform elongation resulted therefrom, specifically a control effect on local deformation cannot be exhibited at all.

[0018] As explained above, even if a technique of manufacturing an enameling steel sheet is understood, it is not easy, even for a person skilled in the art, to apply the technique of including a large amount of oxide to a target steel of the present invention and to a use application, so as to investigate the effect of its morphology.

[0019] The steel of the present invention is invented on the basis of new findings such as when an oxide is rolled and elongated to a specific form and maintained as it is, a work hardening behavior thereof dramatically changes, and when a local deformation is strongly controlled, it well acts on a practical elongation capacity even in the case of a thin steel sheet.

Advantages of the Invention

[0020] According to the present invention, a hard, extra thin material exhibiting more uniform elongation capacity up to a high strained region while preventing a local deformation (constriction) from occurring, even if the same strength and the same total elongation are employed, can be obtained. Thus, it becomes possible to prevent problems occurred when a thin material is used, such as breakage due to a lack of uniform deformation and a generation of constriction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 is a diagram showing a region in a thickness direction of a hard extra-thin steel sheet of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] Hereinafter, the present invention will be described in more detail.

[0023] First, components will be explained. All the components are in mass%. The C amount is set to 0.800% or less to avoid deterioration in formability. The amount is preferably 0.100% or less, more preferably 0.060% or less. Particularly, in case of using carbide as the second phase that provides the characteristic of the present invention, the amount is preferably from 0.0050 to 0.040%, more preferably from 0.0080 to 0.030%. In the steel of the present invention in which a material strength is increased by dispersion of various second phases, the content of C to be needed from the viewpoint of assuring the strength or the like may be low. The required strength can still be achieved at the C content of 0.0050% or less. The content of 0.0030% or less, as well as 0.0015% or less can also be employed. From the point of maintaining high drawability by improving an r value, it is preferable for the C amount to be small.

[0024] As in the case of C, the N amount is also set to 0.800% or less or 0.600% or less to avoid deterioration in formability. The amount is preferably 0.100% or less, more preferably 0.060% or less. Particularly, in case of using nitride as the second phase that provides the characteristic of the present invention, the amount is preferably from 0.0050 to 0.040%, more preferably from 0.0080 to 0.030%. In the steel of the present invention in which a material strength is increased by dispersion of various second phases, the content of N to be needed from the viewpoint of assuring the strength or the like may be low. The required strength can still be achieved at the N content of 0.0050% or less. The content of 0.0030% or less, as well as 0.0015% or less can also be employed. From the point of maintaining high drawability by improving an r value, it is preferable for the N amount to be small.

[0025] Si is set to 2.0% or less because at a too high content, formability or surface treatment property deteriorates. However, in the steel of the present invention, when oxide is used as the second phase, remaining of oxygen in the steel may become difficult or a rolled and elongated oxide which being the preferred characteristic for the present invention may be hardly obtained, as described later. In addition, when carburization or nitriding is carried out for forming the second phase, there may be a case where C or N entered in the steel forms coarse Si carbide or Si nitride in a crystalline grain boundary and thus causing brittle cracks. In order to avoid such the negative effects, the Si content may have to be 1.5% or less, further 1.0% or less. In particular, from the point of maintaining high formability, it is preferable for the Si amount to be small. The formability can be improved by setting the content to be 0.5% or less, further 0.1% or less, or even further 0.07% or less.

[0026] Mn is set to 2.0% or less because at a too high content, formability or surface treatment property deteriorates. Meanwhile, in the steel of the present invention, when oxide is used as the second phase, as described later, a rolled and elongated oxide which is preferable for the present invention is readily obtained. In addition, when sulfide is used for forming the second phase, a rolled and elongated sulfide can be readily obtained, and thus this element is useful. Consequently, a preferred range of Mn is from 0.05 to 1.0%, preferably from 0.15 to 0.8%, and even more preferably

from 0.25 to 0.7%.

[0027] P is set to 0.10% or less because at a too high content, not only the formability deteriorates, but also when carburization or nitriding are performed for forming the second phase, the carburization property or nitriding property of the steel sheet is obstructed. From the point of maintaining high formability, it is preferable for the P amount to be small.

[0028] S is set to 0.100% or less or otherwise deteriorates heat-rolling ductility and becomes the cause of obstructing the casting or hot rolling. However, when a large amount of Mn, Cu, Ti, REM or the like is added and a sulfide thereof is used as the second phase that is needed for the present invention, deterioration in hot-rolling ductility is small and thus this element is useful. Consequently, a preferred range of S is from 0.015 to 0.080%, preferably from 0.025 to 0.070%, and even more preferably from 0.035 to 0.060%.

[0029] Al is set to 3.0% or less because at a high content, there may be a problem such as casting becomes difficult or defects on the surface increase. However, since Al is a strong deoxidizing element, remaining of oxygen in the steel becomes difficult when oxide is used as the second phase. Thus, the Al content may sometimes have to be 0.010% or less, further 0.005% or less, even further 0.002% or less, or particularly further 0.001% or less. Alternatively, Al may serve as an element of forming an intermetallic compound such as Ni₃Al, and exhibits a preferable effect on the dispersion of the second phase needed for the present invention. The content may vary depending on the kind or amount of metallic element forming a compound together with Al, but in this case, the Al content is preferably 1.0% or more, further 1.5% or more, even further 2.0% or more.

[0030] O is preferably set to 0.010% or less when an oxide is not used as the second phase that provides the characteristic of the present invention because deoxidation via Al, Si, Ti or the like occurs. It is set so because when oxide in the steel becomes an isotropic form (spherical) which gives no effect for exhibiting advantages of the present invention, this element readily becomes the cause of cracking. Even in the case where an oxide is used as a useful second phase, excessive oxide may readily become the cause of cracking, and thus the O content has to be set to 0.200% or less, preferably 0.010 to 0.100%, more preferably 0.020 to 0.080%, even more preferably 0.030 to 0.050%.

[0031] Next, elements which may be added as necessary will be explained.

[0032] Ti causes the increase of recrystallization temperature of the steel sheet, and significantly deteriorates passability of extra thin steel sheet subjected in the present invention in annealing. Therefore, the Ti content is set to be 4.00% or less. When a Ti compound is not used as the second phase that provides the characteristic of the present invention, there is no need of adding Ti, and the content may be 0.04% or less, more preferably 0.01% or less. Meanwhile, oxides, sulfides, carbides, nitrides and intermetallic compounds, of Ti can be used as the second phase that provides the characteristic of the present invention. The content may vary depending on the kind or amount of an element forming the compound, but a sufficient effect can be exhibited at a content of 0.06% or more. More preferred is 0.100% or more.

[0033] Nb has the same effect as Ti that it causes the increase of recrystallization temperature, and significantly deteriorates passability of extra thin steel sheet subjected in the present invention in annealing. Therefore, the Nb content is set to be 4.00% or less. When an Nb compound is not used as the second phase that provides the characteristic of the present invention, there is no need of adding Nb, and the content may be 0.04% or less, more preferably 0.01% or less. Meanwhile, oxides, sulfides, carbides, nitrides and intermetallic compounds, of Nb can be used as the second phase that provides the characteristic of the present invention. The content may vary depending on the kind or amount of an element forming the compound, but a sufficient effect can be exhibited at a content of 0.06% or more. More preferred is 0.100% or more.

[0034] REM also has the same effect as Ti and Nb, and as it is an expensive element, the content is set to be 4.00% or less. When a REM compound is not used as the second phase that provides the characteristic of the present invention, there is no need of adding REM, and the content may be 0.04% or less, more preferably 0.01% or less. Meanwhile, oxides, sulfides, carbides, nitrides and intermetallic compounds, of REM can be used as the second phase that provides the characteristic of the present invention. The content may vary depending on the kind or amount of an element forming the compound, but a sufficient effect can be exhibited at a content of 0.06% or more. More preferred is 0.100% or more.

[0035] B also has the same effect as Ti and Nb. However, its ability to form carbonitride is less than that of Ti or Nb although it may vary depending on the added amount. When B is added simultaneously with those elements for the purpose of forming carbide or nitride as the second phase, it causes the increase of recrystallization temperature of the steel sheet, and significantly deteriorates passability of extra thin steel sheet subjected in the present invention in annealing. Therefore, B is useful in the case where Ti or Nb content is small. The upper limit is set to 0.0300% because an excessive amount results in notable cracks in a steel slab upon casting. When a B compound is not used as the second phase that provides the characteristic of the present invention, there is no need of adding B, and the content may be 0.0020% or less, more preferably 0.0010% or less. Meanwhile, oxides, sulfides, carbides, nitrides and intermetallic compounds, of B can be used as the second phase that provides the characteristic of the present invention. The content may vary depending on the kind or amount of an element forming the compound, but a sufficient effect can be exhibited at a content of 0.0040% or more. More preferred is 0.0100% or more.

[0036] Cu is set to 8.00% or less because at a too high content, not only the recrystallization temperature significantly

increases, but also defects in surface quality are occurred and formability or surface treatment property deteriorates. Meanwhile, in the steel of the present invention, a metallic Cu phase, an intermetallic compound phase or the like can also be used as the second phase. Furthermore, when a sulfide is used for forming the second phase, a rolled and elongated sulfide is readily obtained and thus this is element is useful. Consequently, a preferred range of Cu is from 0.10 to 4.00%, more preferably from 0.20 to 3.00%, even more preferably from 0.30 to 2.50%.

[0037] Ca is a useful element for the steel of the present invention as when a sulfide is used as the second phase, a rolled and elongated sulfide can be readily obtained. However, Ca is usually hardly contained in a large amount in the steel due to high reactivity, and thus the amount is set to 1.00% or less. A preferred range is from 0.01 to 0.50%, more preferably from 0.05 to 0.30%.

[0038] Ni is an expensive element, and its amount is set to 8.00% or less. In the present invention, Ni serves as an element of forming an intermetallic compound such as Ni_3Al , and it exhibits a favorable effect for the dispersion of the second phase needed for the present invention. The amount may vary depending on the kind or amount of metallic element forming a compound together with Ni, but is preferably 1.0% or more, further 1.5% or more, even further 2.0% or more.

[0039] Cr is also an expensive element, and its amount is set to 20.00% or less. When a Cr compound is not used as the second phase that provides the characteristic of the present invention, there is no need of adding Cr, and the amount may be 0.06% or less, more preferably 0.02% or less. Meanwhile, oxides, sulfides, carbides, nitrides and intermetallic compounds, of Cr can be used as the second phase that provides the characteristic of the present invention. The amount may vary depending on the kind or amount of an element forming the compound, but a sufficient effect can be exhibited at a content of 0.10% or more. More preferred is 0.50% or more, even more preferred is 1.5% or more, and further more preferred is 2.50% or more.

[0040] The content of elements other than those mentioned above is not particularly limited, but Sn, Sb, Mo, Ta, V and W are added each by an amount of 0.10% or less which in total giving a sum of amounts of 0.50% or less, so as to impart properties not provided by the present invention. With this amount, the effect of the present invention is not interfered in any way. However, it is necessary to give an attention as there may be a case where those elements form a coarse compound having an isotropic form and thus deteriorating the formability. If there is no particular purpose, the amount of each element is preferably set to 0.010% or less and a sum of amounts of 0.050% or less, more preferably set to 0.0020% or less and a sum of amounts of 0.0050% or less, and even more preferably set to 0.0010% or less and a sum of amounts of 0.0030% or less.

[0041] Next, the second phase which is the most important factor in the present invention will be described. First, an observation or the like of the second phase will be described. The observation method of the second phase is not particularly limited to those defined in the present invention. The morphology can be observed directly by a physical measuring equipment such as an electron microscope which allows the observation of micro regions. In case of observing a relatively large size, an observation can be made by a high-power optical microscope. With an optical microscope or a scanning electron microscope (SEM), steel sheets a cross section of which is polished and further subjected to etching can be observed, and with a transmission electron microscope (TEM), a thin film as well as an extracted replica obtained by a SPEED method, or the like can be observed. In addition, a residue in which a matrix is dissolved by an electrolysis extraction may also be observed. The observed second phase can be identified by EDX or electron beam diffraction patterns, but the technique is not limited to these and any analytical instrument currently providing a significantly improved performance may also be used. The point is that it is fine as long as a form, size and number density, or if necessary a kind, of the second phase can be determined according to an appropriate method. It is thought that there may be a case where a full identification is difficult in some kinds that provide a composition of various phases. However, since the effect of the present invention is achieved regardless of the kind by dispersing a second phase in a specific morphology, those difficult to be identified can also be included in the present invention. In regard to the volume fraction and the number density, when more fine nitrides are considered using more advanced analytical instrument, these values may be increased. However, the effect of the present invention still can be distinguished when a size of 0.02 μm or greater is used as an object with the use of a physical instrument of normal level.

[0042] The present invention has a feature of containing 0.05% or more of the second phase observed as above, having an average major axis of 0.10 μm or greater and an average minor axis of 0.05 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 . The size of average major axis is preferably 0.20 μm or greater, more preferably 0.50 μm or greater, even more preferably 1.00 μm or greater, even more preferably 2.00 μm or greater, even more preferably 5.00 μm or greater. However, if a too large second phase is existed, it becomes the cause of breakage in an early stage of work thereby significantly deteriorating the ductility. Therefore, the size is set preferably to 30 μm or less, more preferably to 20 μm or less. However, if the phase number is extremely small, a possibility of giving an adverse effect is very small even if the phase is large, and thus it cannot be said that an existence of the phase having a greater size than those mentioned above is outside the range of the present invention. The average major axis/average minor axis is preferably 3.0 or more, more preferably 5.0 or more, even more preferably 8.0 or more. The volume fraction is preferably 0.1% or more, more preferably 0.3% or more, even more preferably 1.0% or more, even further preferably

2.0% or more. However, if the amount of the second phase is too large, in some cases, breakage in an early stage of work may occur thereby significantly deteriorating the ductility. Therefore, the fraction is set preferably to 20% or less, more preferably to 10% or less.

[0043] In regard to the number density of the second phase, 0.01 pieces/ μm^2 or more when a cross section of the steel sheet is observed and 0.001 pieces/ μm^3 or more when a spatial dispersion is measured such as when a thin film is observed with extraction replica or transmission electron microscope, will exhibit a remarkable effects of the present invention. In the case of a cross-section observation, the number density is preferably 0.03 pieces/ μm^2 or more, more preferably 0.1 pieces/ μm^2 or more, even more preferably 0.3 pieces/ μm^2 or more. In the case of a spatial measurement, the number density is preferably 0.003 pieces/ μm^3 or more, more preferably 0.01 pieces/ μm^3 or more, even more preferably 0.03 pieces/ μm^3 or more. The number density correlates with the above-mentioned size and volume fraction, and it is necessary to be careful not to extremely increase or decrease the density within the scope of not deteriorating the formability as in the size and volume fraction.

[0044] As such, a mechanism of controlling the occurrence of local deformation by controlling the morphology of the second phase is not clear, but an attempt is made below.

[0045] The second phase in the present invention is harder than an Fe phase provided as a matrix, and thus a deformation of matrix occurs on a priority basis upon a deformation of steel sheet. In addition, since the deformation of matrix is restricted by the second phase, work-hardening of the matrix becomes significant. Consequently, it is believed that the strain transmissibility improves and the deformation continues while being covered in a larger area thereby giving a higher uniform elongation. When an anisotropic second phase is dispersed, it is believed that a restriction degree in the matrix becomes greater than that in a general isotropic second phase. Aside from this, it can be thought that a binding state between a strong anisotropic second phase and a matrix becomes weak, and thus the interface undergoes a sliding due to the deformation and additionally forms many voids, thereby allowing deformation. Accordingly, it is thought that a state in which deformation of a matrix itself is controlled is shown up to a higher strained region and thus a uniform deformation continues. In the steel of the present invention, there are many cases where a local formability is lowered at the same time of providing a large measure of work hardening, but a mechanism to fully explain the phenomenon is not yet clear.

[0046] The deformation of matrix that is a main phase making the most of the sheet by volume is definitely the reason for a uniform deformation in the steel of the present invention and not the second phase. It is natural that the main phase is Fe; and a main phase in the present invention is supposed as a ferrite phase of Fe. Its volume fraction is preferably 80% or more. In general, a pearlite, bainite or martensite is known as the phase mainly composed of Fe, but in the present invention, as strengthening the sheet is achieved by a dispersion of second phase, the main phase is preferably a soft and uniform phase from the viewpoint of formability. The volume fraction is preferably 85% or more, more preferably 90% or more, so as to avoid deterioration in elongation capacity due to a formation of second phase in excess.

[0047] Furthermore, an orientation relationship of the second phase and the main phase is also an important matter. As already mentioned in the mechanism above, the effect of the present invention is believed to correlate with a binding state of Fe phase and the second phase. In relation to this, an average major axis of the second phase is preferably in a $\langle 100 \rangle$ orientation or a $\langle 110 \rangle$ orientation of the ferrite phase that is in contact with the second phase. This orientation relationship can be determined by usual electron beam diffraction or the like.

[0048] A kind of second phase is described next. In the present invention, when the second phase is a simple substance of or a composite compound of oxide, sulfide, carbide, nitride or an intermetallic compound, a remarkable effect can be obtained. In the case of an oxide, oxides including one or two of Fe, Mn, Si, Al, Cr, REM, Ti and Nb can be employed. In the case of a sulfide, sulfides including one or two of Ti, Mn, Cu, Ca and REM can be employed. In the case of carbide, carbides including one or two of Fe, Ti, Nb, Si and Cr can be employed. In the case of a nitride, nitrides including one or two of Fe, Ti, Nb, Al, B and Cr can be employed. In the case of an intermetallic compound, intermetallic compounds including one or two of Fe, Ti, Nb, Al, Si and Mn can be employed. In regard to the carbide, a pearlite composition that is normally observed for steel, in specific, a layer composition including cementite and a ferrite phase generated due to a transformation of austenite at high temperature is excluded for the present invention as it cannot provide an effect of the present invention at all. As the metamorphic intermetallic compound, there are NiAl, Ni_3Al , $\text{Ni}_3(\text{Al}, \text{Ti})$, N_2TiAl , Ni_3T_1 , Ni_3Mo , Ni_4Mo , Ni_3Nb , Co_3W , Fe_2Mo , Fe_2Ti , $\text{Fe}_2(\text{Ni}, \text{Co})$ and the like.

Above-mentioned oxides, sulfides, carbides, nitrides and intermetallic compounds are a compound usually seen in a steel material, and a special compound is not necessarily employed. However, a special compound can still be formed to a morphology lying within the scope of the present invention. The kind of the phase is not limited to those mentioned above as only the representative elements are mentioned in the above. In addition, the second phase that exists in steel is not limited to one kind and a case where two or more kinds are combined is also included in the present invention. These may exist independently or may together form a composite compound. Moreover, a phase that is not included in the present invention from a morphological view can also be existed simultaneously.

[0049] The important matter is the morphological feature of the second phase. However, in reality, there is quite a difference in the effect depending on the second phase formed. This difference is thought to be affected by kind or

amount of the second phase that can be formed in a steel sheet; a morphology difference that can be controlled by manufacture conditions as described later; and kind of the second phase itself that also correlates with a binding state with the matrix.

5 [0050] Their effects are not fully classified yet, but from a phenomenon point of view, classification of preferred kind of the second phase and the element forming the second phase can be made as shown below. The kind can be ranked as follows: intermetallic compound>carbide \approx nitride>oxide>sulfide. However, this order is made only by estimating the effect assuming that the morphology and the amount are the same, and there may be a case where assuring the amount or controlling the morphology is difficult depending on the manufacturing method or the kind of the second phase. Thus, this order is only for a rough indication. In regard to the effect of elements, the following points can be mentioned. In the case of oxide, preferred are those including Fe, Mn and REM; while Si, Al, Cr, Ti and Nb provide a small effect. In the case of sulfide, preferred are Mn, Ca and REM; while Ti and Cu provide a small effect. In the case of carbide, preferred are Cr, Ti and Si; while Fe and Nb provide a small effect. In the case of nitride, preferred are Fe, Ti, B and Cr; while Nb and Al provide a small effect. In the case of an intermetallic compound, preferred are Fe, Al, Si and Mn; while Ti and Nb provide a small effect.

15 [0051] Now, a region in a thickness direction of the steel sheet employed in this specification will be described with reference to FIG 1. The terms '1/8 sheet thickness surface layer' and '1/4 sheet thickness center layer' indicate corresponding regions shown in FIG. 1. Here, a region corresponding to '1/8 sheet thickness surface layer' is present on both surfaces of the steel sheet, but those having only one '1/8 sheet thickness surface layer' on any side can also be included in the scope of the present invention. It is relatively easy to give different nitride distribution to front and back of the sheet by modifying a manufacturing method, and a steel sheet having different front and back layers as such can also be included for the present invention. This is because an effect of improving a uniform formability which is the target of the present invention can still be achieved by one layer. For the volume fraction and the number density mentioned above, measurement values can be taken as data as long as they do not seem to be abnormal, and those satisfying requirements for the present invention in specific regions of 1/8 surface layer and 1/4 center layer can be satisfactorily employed.

25 Herein, the '1/8 sheet thickness position' is also included in '1/8 sheet thickness surface layer'.

[0052] The second phase which is the characteristic of the present invention is not necessarily uniformly dispersed in a whole area when distribution in a direction of the steel sheet is taken into consideration, and it may be unevenly distributed in the sheet thickness direction. It is rather better to form a multilayer constitution including a layer with many second phases and a layer with less second phases in a thickness direction, from the viewpoint of effect of the present invention. A mechanism for this is not clear, but it is believed that a layer with many second phases and a layer with less second phases restrict the deformation of one another thereby increasing the measure of work hardening, and thus a local deformation is controlled. This can be thought alternatively that an effect similar to a restricting relationship between the second phase and the matrix is occurring in macro-spaces. In particular, it is possible to obtain a great part of the effect of the present invention by distributing the second phases intensively in a surface layer part of the steel sheet. In specific, regarding the volume fraction of the second phase, (a volume fraction of 1/8 sheet thickness surface layer)/(a volume fraction of 1/4 sheet thickness center layer) \geq 10 is preferable, or regarding the number density of the second phase, (a volume fraction of 1/8 sheet thickness surface layer)/(a volume fraction of 1/4 sheet thickness center layer) \geq 10 is preferable. The ratios are preferably 20 or more, more preferably 50 or more, even more preferably 100 or more, even further preferably 200 or more. However, it is necessary to be careful not to form too many second phases in the surface layer part because it may cause a surface defect or may cause the sheet to break readily.

35 [0053] Next, characteristics of the steel sheet which to be the target of the present invention will be described. First, there is a limit that the present invention applies only to a steel sheet having a sheet thickness of 0.400 mm or less. This is because there is no point of applying a technique limited to a uniform elongation to a steel sheet having a greater thickness as in the present invention because upon working, molding still takes place to a certain degree after the formation of constriction due to a local ductility. The technique can be used usefully to an extra thin steel sheet having a thickness of preferably 0.250 mm or less, more preferably 0.200 mm or less, even more preferably 0.150 mm or less.

45 [0054] Furthermore, even in the case of thin material, it is still possible to impart a certain degree of uniform elongation to a hard material, and thus the applicable scope of this technique includes a hard material. This is also because the second phase which provides the characteristic of the present invention causes hardening by quite a degree. A preferred applicable material is a steel sheet satisfying a maximum strength \geq 350 MPa and HR30T Rockwell hardness \geq 54, according to a tensile test (specifically, a tensile test carried out with the use of a tensile test specimen having a parallel part of 25 mm wide and 60 mm long under conditions of a distance between marks of 50 mm and a deformation rate of 5 mm/min) carried out with the use of a JIS5 tensile test specimen. More preferred is a steel sheet satisfying a maximum strength $400 \geq$ MPa and HR30T Rockwell hardness \geq 57, and even more preferred is a steel sheet satisfying a maximum strengths \geq 450 MPa and HR30T Rockwell hardness \geq 61. In addition, the steel sheet of the present invention provides the characteristic in satisfying (uniform elongation)/(local elongations) \geq 1.0, according to a tensile test carried out with the use of a JIS5 tensile test specimen. The ratio is preferably 1.5 or more, more preferably 2.0 or more, even more preferably 3.5 or more, even further preferably 5.0 or more. As mentioned before, it is also a characteristic of the present

invention that the steel has a large measure of work hardening. The steel satisfies yield stress/maximum strengths \leq 0.9, more preferably 0.8 or less, even more preferably 0.7 or less, even further preferably 0.6 or less, according to a tensile test carried out with the use of a JIS5 tensile test specimen.

[0055] Hereinbelow, one preferred example of the manufacturing method will be represented for each kind of the second phase in the steel of the present invention. First, a case where an oxide is used as a special second phase will be represented. A preferred embodiment includes rolling and elongating an oxide by rolling in a hot-rolling step to be modified into a preferable form. In order to do this, a certain degree of work amount is required, and a thickness of a steel slab subjected to casting is set to preferably 50 mm or more, more preferably 150 mm or more. In order for the rolled and elongated oxide to have an appropriate size, a size of the oxide before subjected to rolling and elongation is preferably between 10 μm and 25 μm . If the size is too small, rolling and elongation becomes difficult, and if the size is too big, a state of spatial dispersion after rolling becomes linear thus is not preferable from the viewpoint of exhibiting the effect of the present invention. Next, it is effective to perform rolling at a total real strain of 0.4 or more under conditions of 1,000°C or above and a strain rate of 1/sec or more; and then performing a rolling at a total real strain of 0.7 or more under conditions of 1,000°C and a strain rate of 10/sec or more. A mechanism for this is not clear, but it can be assumed as follows. At a high-temperature region of 1000°C, the oxide softens and gives a small hardness difference when compared with that of hardened ferrite. Therefore, the oxide is rolled and elongated by rolling and accordingly an acicular oxide which is preferable for the present invention is obtained. The oxide is hardly rolled and elongated at a temperature lower than 1000°C, such as at about 900°C or below, it partly cracks, and oxides having a reasonable acicular morphology disperse at an appropriate interval in the steel sheet. In order to appropriately roll, elongate and disperse in such a way, a temperature control upon hot-rolling, a strain amount for each temperature region and also a control of strain rate so as to control softening of work-hardened ferrite, also become important.

[0056] By applying the temperature, strain amount and strain rate conditions to the case of sulfide, a preferable effect as in the case of oxide can be obtained.

[0057] Next, a case where a carbide is used as the characteristic second phase will be illustrated.

[0058] In this case, it is possible to produce a carbide having a more preferable configuration from C and additive elements which are previously contained in a steel by heat treatment or the like in manufacturing processes. However, in the present invention, a method of using carburization will be illustrated as the more preferable configuration. By using the carburization, as described above, it is possible to disperse the characteristic second phase only on the surface of the steel plate and the concentration of C gradually increases; so that the carbide having anisotropic configuration grown in a preferential orientation can be formed easily. The condition includes after cold rolling, performing a carburization treatment at a temperature ranging between 600 and 700°C under a condition of giving $\{(\text{carburization time (sec)}) * (\text{carburization temperature (}^\circ\text{C)})\} / \{(\text{carburizing gas concentration (\%)}) * (\text{cooling rate in carburization treatment (}^\circ\text{C/sec)})\} \geq 20$, simultaneously with or after a recrystallization annealing, thereby increasing a C amount by 0.0002% or more. If the temperature is out of above range, carburization efficiency decreases at a low temperature side, and on the contrary if the temperature is too high, the configuration of the carbide may be easily isotropic. Under a condition in which $\{(\text{carburization time (sec)}) * (\text{carburization temperature (}^\circ\text{C)})\} / \{(\text{carburizing gas concentration (\%)}) * (\text{cooling rate in carburization treatment (}^\circ\text{C/sec)})\}$ is 20 or more, the preferable configuration of the second phase can be achieved. Basically, since the carbide can be sufficiently grown with a gradual cooling treatment at a high temperature for a long time while suppressing the growth of the deposition nucleus of the carbide in a low C concentration, the development of the anisotropic second phase is remarkable. However, when the carburization is performed at a high temperature for a long time, C entered into the steel from a surface of the plate reaches the center of a plate thickness by spreading so that the promotion of the effect of the present invention due to above-described multi-layered structure is disappeared. Therefore, according to the carburization condition, it is preferable to control the value of the above formula such that only surface part is carburized. This value may also depend on the plate thickness, and is preferably 500 or less, more preferably 200 or less. The condition of atmosphere including the type of carburizing gas may be the generally known condition. Furthermore, the carburizing method is not limited to the gas carburization illustrated herein, and the generally known carburizing method can be applied. Furthermore, 0.0002 % or more which is the increased amount of C may seem to be very small as the increased amount, but this amount is sufficient for exhibiting the effect of the present invention in consideration of the increased amount at a surface layer of the steel plate in an extra thin material.

[0059] Further, by applying the carburization condition to a condition where a nitride obtained by nitriding is used for the second phase, the preferable effect similar to the carbide can be obtained. Namely, the condition includes after cold rolling, performing a nitriding treatment at a temperature ranging between 600 and 700°C under a condition of giving $\{(\text{nitriding time (sec)}) * (\text{nitriding temperature (}^\circ\text{C)})\} / \{(\text{nitriding gas concentration (\%)}) * (\text{cooling rate in nitriding treatment (}^\circ\text{C/sec)})\} \geq 20$, simultaneously with or after a recrystallization annealing, thereby increasing an N amount by 0.0002% or more. The condition of atmosphere including the type of nitriding gas may be the generally known condition. Furthermore, the nitriding method is not limited to the gas nitration illustrated herein, and the generally known nitriding method can be applied similar to the case of carburization.

[0060] In the case where the intermetallic compound is used as the second phase, it is appropriate for obtaining the

preferable second phase in the present invention that by gradually cooling from a state in which the whole or most of the intermetallic compound is dissolved, the formation is progressed mainly by the growth of the intermetallic compound. Therefore, in the step of manufacturing a steel sheet, cooling from a temperature of 900°C or above, wherein cooling from 900°C down to 500°C is performed at a cooling rate of 20°C/sec or lower, thereby increasing a volume fraction of the intermetallic compound by 2.0-fold or more is performed. When the temperature before starting the cooling is too low, dissolving of the intermetallic compound becomes insufficient and the growth after that cannot be caused. Furthermore, the cooling speed is too rapid, the nucleus generation frequency of the intermetallic compound becomes high and the anisotropic growth is not occurred so that the isotropic intermetallic compound is formed with high density.

[0061] Of course, the manufacturing methods of various second phases illustrated herein are different depending on elements forming the objective second phase and amounts thereof and not limited to the above described ranges. If the kind of elements forming the second phase, the type and amount of the second phase to be formed, and the directionality of the configuration to be controlled are known, suitable conditions can be sought within in a general metallurgical category and it is not difficult for a person skilled in the art to identify the conditions through several trial.

[0062] In manufacture of a thin steel plate, a re-cold rolling may be performed after a recrystallization annealing for the hardness adjustment or plate thickness adjustment. The rolling reduction ranging from about several % near the skin-pass which is performed for the shape adjustment up to 50% or more similar to a cold rolling is practically used. In a case where a re-cold rolling method is applied to the present invention, the effect of the present invention is not damaged. However, if the rolling reduction is too high, an absolute value of uniform elongation becomes small. Furthermore, a work-hardened amount in a uniform elongation region becomes small so that it is not a preferable method considering the application of the effect of the present invention. The rolling reduction is preferably 30% or less, more preferably 20% or less, further preferably 10% or less, and most preferably 3% or less.

[0063] The effect of the present invention does not depend on the heat history and manufacturing history, after component adjustment and before annealing. Since a slab in case of performing a hot rolling is not limited to a manufacturing method such as a continuous casting process and does not depend on the heat history until reaching a hot rolling, the effect of the present invention-can be achieved even with a slab reheating method, CC-DR method directly heat rolling the cast slab without reheating, and a thin slab casting omitting the rough rolling or the like. Furthermore, the effect of the present invention can be obtained even with a dual phase region rolling having a finishing temperature of $\alpha + \gamma$ phases and a continuous hot rolling which rolls by connecting a rough bar, without depending on a hot rolling condition.

[0064] Furthermore, the steel of the present invention is particularly preferable when it is used for a member having a welded portion, because a uniform deformation property in a heat-affected portion is improved and the occurrence of a constricted part is suppressed.

[0065] The steel plate of the present invention can be used with any surface treatment. In the scope of the present invention, the steel plate is not damaged by applying the surface treatment. The surface treatment includes applying tin, chrome (tin-free), Ni, zinc, aluminum or the like which is generally performed for a metal plating. The effect of the present invention can be obtained with respect to a primitive plate for a laminate steel plate coated with an organic film which is used recently.

[0066] The steel plate of the present invention can be generally used for electric apparatuses, electronic components, architectural materials or metal containers, and also can be used in other applications if the use thereof includes the task similar to the above-described matter.

[EXAMPLES]

[0067] Steels including components as shown in Table 1 were subjected to hot rolling, cold rolling, recrystallization annealing and re-cold rolling to manufacture various steel sheets, and then various tests for evaluation were carried out. Observation of the second phase was done through a cross section of steel sheet, a thin film of steel sheet, extracted replica and extracted residue by electrolysis, with the use of SEM and TEM. In addition, elements contained in the second phase were subjected to a qualitative analysis using EDX. Properties of the material were measured by a tensile test in a rolling direction with JIS5 tensile specimen and a Rockwell surface hardness.

[0068] The measurement results and evaluations are shown in Tables 2 to 5. A meaning of the terms in Tables is as follows:

'Average major axis' and 'average minor axis': these are mean values each obtained when enough number of second phases satisfying conditions of an average major axis of 1.0 μm or greater, an average minor axis of 0.05 μm or greater and average major axis/average minor axis ≥ 2.0 was subjected to a measurement so as to avoid giving the bias.

[0069] 'Average major axis/average minor axis': it is a ratio of 'average major axis' to 'average minor axis'. The value is an index showing an anisotropy degree of oxide which is the root of providing effects of the present invention.

[0070] 'Contained elements': elements detected from the second phase representing characteristics of the present invention.

[0071] 'Orientation': relationship between a direction of average major axis of the second phase and a crystal orientation of a main phase that is in contact with the second phase. In case of relating with an orientation, it refers to a crystal orientation of the main phase.

[0072] 'Flange formability': a body of three-piece cans each prepared by curling and welding a flat sheet into a cylindrical form was prepared by number of 10,000 pieces. Then, each of them was subjected to a flange forming using a die and mold. For a result, when all cans were successfully flange formed without causing breakage, it was ranked as 'pass', and when even 1 can was broken, it was ranked as 'failure'.

[0073] 'Evaluation': classified into Normal Level: C, Excellent: B, Remarkably Excellent: A. Those evaluated as A and B were accepted as the present invention.

[0074] (Example 1) Experimental results when oxide was used as the second phase are shown in Table 2. A form of the oxide was controlled mainly by a size of the oxide depending on a casting condition and a measure of rolling and elongation depending on a hot-rolling condition. "A number density" of oxide was determined by observing cross section with SEM. It was confirmed that good and uniform elongation is achieved by controlling the state of oxide to be within the scope of the present invention.

[0075] (Example 2) Experimental results when sulfide was used as the second phase are shown in Table 3. A form of sulfide was controlled mainly by a size of the sulfide depending on a casting condition and a measure of rolling and elongation depending on a hot-rolling condition. "A number density" of sulfide was determined by observing cross section with TEM. It was confirmed that good and uniform elongation is achieved by controlling the state of sulfide to be within the scope of the present invention.

[0076] (Example 3) Experimental results when carbide or nitride was used as the second phase are shown in Table 4. A form of carbide or nitride was controlled mainly by a carburizing condition or a nitriding condition. All "base sheet" in this Example are steel sheets subjected to recrystallization and annealing at 700°C. For comparison, properties of a sheet subjected to a re-cold rolling only and not to a carburizing or nitriding treatment and prepared to have the same hardness degree to those subjected to carburization or nitriding treatment were also shown. Observation of carbide or nitride was made at 1/8 sheet thickness and at the center of sheet thickness. The "number density" of carbide or nitride was determined by observing residue that remained when 1/8 sheet thickness surface layer or 1/4 sheet thickness center layer was electrolyzed, using SEM. In Table 4, the "volume fraction" and "number density" described regarding to the second phase and values described regarding to the main phase are values for the 1/8 sheet thickness layer surface. It was confirmed that a good and uniform elongation is achieved by controlling the state of sulfide to be within the scope of the present invention.

[0077] (Example 4) Experimental results when intermetallic compound was used as the second phase are shown in Table 5. Ni₃Al was used as the intermetallic compound. A form of Ni₃Al was controlled mainly by a recrystallization and annealing condition, particularly controlled by a fusing degree depending on an annealing temperature, and by nucleation/crystal growth caused by a cooling process carried out thereafter. All of the "base sheets" in this Example are cold-rolled steel sheets and nothing else. "A number density" of Ni₃Al was determined by observation with TEM. When comparison with steel sheets other than the sheets of Examples 1 to 4 was made, it was confirmed that good characteristics can be obtained by controlling the state of intermetallic compound to be within the scope of the present invention.

[0078] [Table 1]

TABLE 1

Steel	Components (mass%)													Note		
	C	Si	Mn	P	S	Al	N	O	Ti	Nb	B	REM	Cu		Ca	Ni
a1	0.0008	0.03	0.1	0.004	0.023	0.0009	0.0022	0.016	-	0.0025	-	-	0.02	-	0.01	0.03
a2	0.002	0.003	0.3	0.008	0.002	0.0018	0.0025	0.025	0.002	-	-	-	0.06	0.002	0.01	2.2
a3	0.0011	0.02	0.2	0.015	0.018	0.0088	0.0014	0.065	-	0.002	-	-	-	-	-	-
a4	0.0035	0.01	0.05	0.011	0.008	0.0032	0.002	0.048	0.003	0.075	-	-	0.01	-	-	-
b1	0.0006	≤2.0	0.77	0.016	0.039	0.023	0.0025	0.002	-	0.001	0.0002	0.12	0.25	0.01	0.3	-
b2	0.0015	1.8	≤2.0	0.033	0.093	0.044	0.0025	-	0.005	-	0.0009	-	-	0.25	0.05	-
b3	0.0095	0.58	0.34	0.005	0.048	0.068	0.0041	0.001	0.002	-	-	0.68	-	0.06	-	0.08
b4	0.0062	0.05	0.1	0.043	0.055	0.055	0.0018	0.005	0.011	0.002	-	-	1.5	-	0.8	-
c1	0.0288	0.01	0.1	0.024	0.011	0.001	0.0046	0.009	0.21	0.002	-	-	-	-	0.05	0.06
c2	0.002	0.01	0.1	0.024	0.011	0.001	0.0046	0.009	0.21	0.002	-	-	-	-	0.05	0.06
c3	0.086	0.07	0.2	0.013	0.015	0.046	0.0034	0.004	-	-	-	-	-	-	-	10.3
c4	0.0012	0.07	0.2	0.013	0.015	0.046	0.0034	0.004	-	-	-	-	-	-	-	10.3
c5	0.021	0.006	≤2.0	0.016	0.004	0.033	0.022	0.003	-	0.002	-	-	0.01	0.02	-	0.38
c6	0.021	0.006	≤2.0	0.016	0.004	0.033	0.0018	0.003	-	0.002	-	-	0.01	0.02	-	0.38
c7	0.046	0.02	1.3	0.011	0.009	1.7	0.085	-	0.013	0.015	-	-	-	-	0.03	3.79

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(continued)

Steel	Components (mass%)													Note			
	C	Si	Mn	P	S	Al	N	O	Ti	Nb	B	REM	Cu		Ca	Ni	Cr
c8	0.046	0.02	1.3	0.011	0.009	1.7	0.014	-	0.013	0.015	-	-	-	-	0.03	3.79	non-nitriding material of c7
d1	0.002	0.02	0.21	0.003	0.001	1.8	0.0021	-	0.01	0.003	-	-	-	-	3.8	-	
d2	0.0031	0.21	0.31	0.007	0.002	≤3.0	0.0022	-	0.03	-	-	-	-	-	6.6	0.52	

[Table 2]

No.	Steel	Slab		Hot rolling conditions		After cold rolling				The second phase					
		cast slab thickness	oxide diameter	*1	*2	cold rolling rate	annealing temperature	re-cold rolling	sheet thickness	average major axis	average minor axis	average major axis / average minor axis	volume fraction	number density	contained elements
1	a1	250	15	1.5	2.5	91.3	650	8.0	0.20	1.00	0.18	5.6	0.08	0.08	Fe, Mn, B
2	a1	250	15	0.2	0.5	92.0	650	8.0	0.20	0.57	0.22	2.6	0.02	0.02	Fe, Mn, B
3	a2	250	5	1.0	3.0	91.5	700	5.0	0.17	0.34	0.12	2.8	0.06	0.7	Fe, Mn, Cr
4	a2	250	20	1.0	3.0	91.5	700	5.0	0.17	0.44	0.09	4.9	0.15	3.1	Fe, Mn, Cr
5	a2	50	30	0.5	0.5	91.5	700	5.0	0.17	0.57	0.25	2.3	0.01	<0.01	Fe, Mn, Cr
6	a3	200	5	0.9	2.1	92.5	700	20.0	0.15	0.27	0.09	3.0	0.12	4	Fe, Mn
7	a3	200	20	0.9	2.1	92.5	700	20.0	0.15	1.38	0.24	5.8	0.35	0.11	Fe, Mn
8	a3	30	20	0.3	0.5	92.5	700	20.0	0.15	0.77	0.31	2.5	0.03	<0.01	Fe, Mn
9	a4	250	20	0.3	0.3	92.7	740	15.0	0.22	1.31	0.47	2.8	0.11	<0.01	Fe, Mn, Nb
10	a4	250	20	1.6	2.5	92.7	740	15.0	0.22	1.10	0.24	4.6	0.27	0.11	Fe, Mn, Nb

*1: Total real strain under conditions of 1000 $^{\circ}\text{C}$ or above and a strain rate of 1/sec or higher.*2: Total real strain under conditions of 1000 $^{\circ}\text{C}$ or below and a strain rate of 10/sec or higher.

TABLE 2 (Continued)

No.	Steel	Main phase		Characteristics										flange formability	evaluation
		volume fraction %	orientation	YS MPa	TS MPa	UEL %	LEL %	TEL %	HR30T	UEL/LEL	YS/TS				
1	a1	>95	-	300	360	17	18	35	54	0.94	0.83	good	B	inventive example	
2	a1	>95	-	310	340	8	24	32	53	0.33	0.91	bad	C	comparative example	
3	a2	>95	-	294	355	16	21	37	55	0.76	0.83	good	B	inventive example	
4	a2	>95	-	292	372	22	18	40	57	1.22	0.78	good	A	inventive example	
5	a2	>95	-	290	330	17	22	39	53	0.77	0.88	bad	C	comparative example	
6	a3	>95	-	455	465	2	3	5	65	0.67	0.98	good	B	inventive example	
7	a3	>95	-	440	460	6	2	8	65	3.00	0.96	good	A	inventive example	
8	a3	>95	-	438	438	1	2	3	62	0..50	1.00	bad	C	comparative example	
9	a4	>95	-	346	386	5	15	20	58	0..33	0.90	good	B	inventive example	
10	a4	>95	-	360	415	14	6	20	60	2.33	0.87	good	A	inventive example	

[Table 3]

No.	Slab		Hot rolling conditions		After cold rolling				The second phase					
	cast slab thickness	oxide diameter	*1	*2	cold rolling rate	annealing temperature	re-cold rolling	sheet thickness	average major axis	average minor axis	average major axis / average minor axis	volume fraction	number density	contained elements
11	b1	200	10	1.0	2.0	92.4	700	0.5	0.19	0.15	4.0	0.06	0.04	Mn, Cu
12	b1	200	10	0.2	0.4	92.4	700	0.5	0.19	0.20	2.0	0.04	0.01	Mn, Cu
13	b2	250	50	2.0	2.6	93.3	680	1.5	0.12	0.30	4.3	0.15	0.009	Mn, Ca
14	b2	250	50	1.0	1.3	93.3	680	1.5	0.12	0.30	3.7	0.13	0.006	Mn, Ca
15	b2	50	20	0.5	0.5	93.3	680	1.5	0.12	0.15	2.7	0.05	0.015	Mn, Ca
16	b3	100	30	1.0	2.0	80.0	650	1.0	0.24	0.15	7.0	0.09	0.032	REM, Mn
17	b3	100	30	0.0	0.0	80.0	650	1.0	0.24	0.36	2.4	0.01	<0.001	REM, Mn
18	b4	250	15	1.5	3.0	91.4	740	7.0	0.19	0.12	3.8	0.09	0.07	Cu, Ti, Mn
19	b4	250	15	0.0	3.0	91.4	740	7.0	0.19	0.12	2.1	0.05	0.06	Cu, Ti, Mn
20	b4	250	15	1.5	0.0	91.4	740	7.0	0.19	0.10	4.4	0.07	0.04	Cu, Ti, Mn
21	b4	250	15	0.0	0.0	91.4	740	7.0	0.19	0.19	2.1	0.02	0.007	Cu, Ti, Mn
22	b4	20	2	0.3	1.5	91.4	740	7.0	0.19	0.09	3.0	0.01	0.021	Cu, Ti, Mn

*1: Total real strain under conditions of 1000°C or above and a strain rate of 1/sec or higher.

*2: Total real strain under conditions of 1000°C or below and a strain rate of 10/sec or higher.

TABLE 3 (Continued)

No.	Steel	Main phase		Characteristics										flange formability	evaluation
		volume fraction %	orientation	YS MPa	TS MPa	UEL %	LEL %	TEL %	HR30T	UEL/LEL	YS/TS				
11	b1	> 95	-	498	693	9	6	15	74	1.50	0.72	good	A	inventive example	
12	b1	> 95	-	512	701	7	8	15	74	0.88	0.73	bad	C	comparative example	
13	b2	> 95	-	497	677	12	6	18	72	2.00	0.73	good	A	inventive example	
14	b2	> 95	-	523	665	9	6	15	71	1.50	0.79	good	A	inventive example	
15	b2	> 95	-	530	682	7	9	16	72	0.78	0.78	good	B	inventive example	
16	b3	> 95	-	229	382	19	11	30	57	1.73	0.60	good	A	inventive example	
17	b3	> 95	-	240	395	14	17	31	58	0.82	0.61	bad	C	comparative example	
18	b4	> 95	-	315	364	17	7	24	56	2.43	0.87	good	A	inventive example	
19	b4	> 95	-	320	377	9	14	23	55	0.64	0.85	good	B	inventive example	
20	b4	> 95	-	322	359	12	14	26	55	0.86	0.90	good	A	inventive example	
21	b4	> 95	-	316	344	5	16	21	53	0.31	0.92	bad	C	comparative example	
22	b4	> 95	-	300	340	5	15	20	54	0.33	0.88	bad	C	comparative example	

[Table 4]

TABLE 4

No.	steel	carburing condition and nitriding condition										after carburing or nitring		The second phase						
		base sheet thickness	tempe rature	time	gas type	gas conce ntrati on	cooling rate	*1	re-cold rolling	sheet thickness	average major axis	average minor axis	average major axis/ average minor axis	volume fraction	*2	number density	*3	contained elements		
		mm	°C	sec		%	°C/sec		%	mm	µm	µm	%		number/µm ³					
23	c1	0.20	550	10	CO	30	30	6	1.0	0.20	2.20	0.20	11.0	3.2	310	0.34	430	Fe, Ti		
24	c1	0.20	550	600	CO	10	10	>1000	1.0	0.20	2.50	0.70	3.6	4.1	5.3	0.03	7.9	Fe, Ti		
25	c2	0.24	-	-	-	-	-	-	15.0	0.20	0.30	0.11	2.7	<0.01	-	<0.001	-	-		
26	c3	0.10	600	5	CO	20	70	2	1.0	0.10	1.60	0.40	4.0	12.0	>1000	0.67	>1000	Cr		
27	c3	0.10	600	60	CO	2	2	>1000	1.0	0.10	2.10	0.50	4.2	6.0	120	0.08	80	Cr, Fe		
28	c4	0.11	-	-	-	-	-	-	10.0	0.10	0.15	0.07	2.1	<0.01	-	<0.001	-	-		
29	c5	0.15	600	2	NH ³	20	2	30	1.0	0.15	8.50	0.50	17.0	5.4	500	0.03	650	Fe		
30	c5	0.15	600	0.5	NH ³	40	0.2	38	1.0	0.15	5.30	1.20	4.4	2.5	50	0.002	30	Fe		
31	c6	0.18	-	-	-	-	-	-	15.0	0.15	0.22	0.09	2.4	<0.01	-	<0.001	-	-		
32	c7	0.33	650	20	NH ³	5	5	520	1.0	0.33	15.0	2.10	7.1	1.9	250	0.001	200	Fe, Al, Ti, Cr		
33	c7	0.33	650	1200	NH ³	0.2	2	>1000	1.0	0.33	11.0	3.00	3.7	0.9	1.5	<0.001	3	Fe, Al		
34	c8	0.39	-	-	-	-	-	-	15.0	0.33	0.15	0.06	2.5	0.02	1.0	0.34	1	Al, Ti		

*1: ((carburation time (sec)) * (carburation temperature (°C))) / ((carburing gas concentration (%)) * (cooling rate in carburation treatment (°C/sec)))
 *2: (a volume fraction of 1/8 sheet thickness surface layer) / (a volume fraction of 1/4 sheet thickness center layer)
 *3: (a number density of 1/8 sheet thickness surface layer) / (a number density of 1/4 sheet thickness center layer)

TABLE 4 (Continued)

No.	steel	main phase		characteristics										flange formability	evaluation
		volume fraction %	orientation	YS	TS	UEL	LEL	TEL	HR30T	UEL/LEL	YS/TS				
				MPa	MPa	%	%	%							
23	c1	90	<110>	302	442	16	8	24	62	2.00	0.68	good	A	inventive example	
24	c1	85	<100>	320	411	10	10	20	60	1.00	0.78	good	B	inventive example	
25	c2	>95	-	382	409	2	10	12	62	0.20	0.93	bad	C	comparative example	
26	c3	70	<110>	355	465	17	2	19	67	8.50	0.76	good	A	inventive example	
27	c3	90	<100>	386	405	15	6	21	65	2.50	0.95	good	B	inventive example	
28	c4	>95	-	399	434	10	15	25	65	0.67	0.92	bad	C	comparative example	
29	c5	95	<100>	551	638	18	2	20	70	9.00	0.86	good	A	inventive example	
30	c5	>95	<100>	544	600	12	6	18	70	2.00	0.91	good	B	inventive example	
31	c6	>95	-	570	588	5	12	17	70	0.42	0.97	bad	C	comparative example	
32	c7	>95	<100>	540	687	11	3	14	74	3.67	0.79	good	A	inventive example	
33	c7	>95	<100>	573	644	7	9	16	73	0.78	0.89	good	B	inventive example	
34	c8	>95	-	612	638	3	7	10	72	0.43	0.96	bad	C	comparative example	

[Table 5]

TABLE 5

No.	Steel	Annealing condition				After annealing		The second phase					
		base sheet thickness mm	temperature °C	time sec	cooling rate °C/sec	re-cold rolling %	sheet thickness mm	average major axis µm	average minor axis µm	average major axis/ average minor axis	volume fraction %	* 1	number density number/mm ³
35	d1	0.15	950	60	50	1.0	0.15	0.14	0.06	2.3	0.2	1.8	3.8
36	d1	0.15	950	60	10	1.0	0.15	0.32	0.08	4.0	0.8	2.9	4.6
37	d2	0.35	1100	30	20	1.0	0.35	0.27	0.08	3.4	1.1	5.3	7.2
38	d2	0.35	1100	30	5	1.0	0.35	0.82	0.13	6.3	2.4	8.8	1.7

*1: ratio of volume fraction increased after the recrystallization annealing

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TABLE 5 (Continued)

No.	Steel	Main phase		Characteristics										flange formability	evaluation
		volume fraction	orientation	YS	TS	UEL	LEL	TEL	HR30T	UEL/LEL	YS/TS				
				MPa	MPa	%	%	%							
35	d1	> 95	<110>	775	809	10	5	15	82	2.00	0.96	good	B	inventive example	
36	d1	> 95	<100>	476	624	14	3	17	73	4.67	0.76	good	A	inventive example	
37	d2	95	<100>	479	660	17	5	22	76	3.40	0.73	good	A	inventive example	
38	d2	91	<100>	370	531	22	3	25	70	7.33	0.70	good	A	inventive example	

INDUSTRIAL APPLICABILITY

[0079] According to the present invention, a hard extra-thin material exhibiting more uniform elongation capacity while preventing a local deformation (constriction) from occurring up to a high strained region, even if the same strength and the same total elongation are employed, can be obtained.

Claims

1. A hard extra-thin steel sheet having a sheet thickness of 0.400 mm or less comprising:

by mass%,

C: 0.800 % or less;

N: 0.600% or less;

Si: 2.0% or less;

Mn: 2.0% or less;

P: 0.10% or less;

S: 0.100% or less;

Al: 3.0% or less;

optionally one or more selected from

O: 0 to 0.200 %;

Ti: 0 to 4.00%;

Nb: 0 to 4.00%;

REM: 0 to 4.00%;

B: 0 to 0.0300%;

Cu: 0 to 8.00%;

Ca: 0 to 1.00%;

Ni: 0 to 8.00%;

Cr: 0 to 20.00%, and Sn, Sb, Mo, Ta, V and W each in an amount of 0.10% or less, and

the balance being Fe and unavoidable impurities, wherein

the hard extra-thin steel sheet contains 0.05% or more, by volume fraction, of a second phase having an average major axis of 0.10 μm or greater and an average minor axis of 0.05 μm or greater and satisfying average major axis/average minor axis ≥ 2.0

wherein the second phase is a simple substance or a composite compound of oxide, sulfide, carbide, nitride or an intermetallic compound.

2. The hard extra-thin steel sheet according to Claim 1, wherein the number density of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is 0.001 pieces/ μm^3 or more when spatial dispersion is measured, or 0.01 pieces/ μm^2 or more when a cross section of the steel sheet is observed.

3. The hard extra-thin steel sheet according to Claim 1, wherein the main phase is a ferrite phase of Fe the volume fraction of which is 80% or more.

4. The hard extra-thin steel sheet according to Claim 3, wherein the direction of the average major axis of the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is in the $\langle 100 \rangle$ orientation or $\langle 110 \rangle$ orientation of the ferrite phase that is in contact with the second phase.

5. The hard extra-thin steel sheet according to Claim 1, wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 is an oxide including one or two kind(s) of Fe, Mn, Si, Al, Cr, REM, Ti and Nb, wherein, the hard extra-thin steel sheet includes, by mass%,

Mn: 0.05 to 2.0%;

Al: 0.010% or less; and

Si: 1.5% or less.

6. The hard extra-thin steel sheet according to Claim 1,
 wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm
 or greater and satisfying average major axis/average minor axis ≥ 2.0 is a sulfide including one or two kind(s) of Ti,
 Mn, Cu, Ca and REM
 wherein, the hard extra-thin steel sheet includes, by mass%,

Mn: 0.05 to 2.0%; and
 S: 0.015 to 0.100%.

7. The hard extra-thin steel sheet according to Claim 1,
 wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm
 or greater and satisfying average major axis/average minor axis ≥ 2.0 is a carbide including one or two kind(s) of
 Fe, Ti, Nb, Si and Cr,
 wherein, the hard extra-thin steel sheet includes, by mass%,

C: 0.0050 to 0.100%, and
 Si: 1.5% or less.

8. The hard extra-thin steel sheet according to Claim 1,
 wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm
 or greater and satisfying average major axis/average minor axis ≥ 2.0 is a nitride including at least one or two kind(s)
 of Fe, Ti, Nb, Al, B and Cr,
 wherein, the hard extra-thin steel sheet includes, by mass%,

N: 0.0050 to 0.100%, and
 Si: 1.5% or less.

9. The hard extra-thin steel sheet according to Claim 1,
 wherein the second phase having an average major axis of 0.5 μm or greater and an average minor axis of 0.1 μm
 or greater and satisfying average major axis/average minor axis ≥ 2.0 is an intermetallic compound including at
 least one or two kind(s) of Fe, Ti, Nb, Al, Si and Mn.

10. The hard extra-thin steel sheet according to Claim 1,
 wherein a volume fraction of the second phase having an average major axis of 0.5 μm or greater and an average
 minor axis of 0.1 μm or greater and satisfying average major axis/average minor axis ≥ 2.0 satisfies either (a volume
 fraction of 1/8 sheet thickness surface layer)/(a volume fraction of 1/4 sheet thickness center layer) ≥ 10 or (a number
 density of 1/8 sheet thickness surface layer)/(a number density of 1/4 sheet thickness center layer) ≥ 10 .

11. The hard extra-thin steel sheet according to Claim 1,
 which satisfies maximum strength ≥ 350 MPa and HR30T Rockwell hardness ≥ 54 or uniform elongation/local
 elongation ≥ 1.0 or yield stress/maximum strength ≤ 0.9 , according to a tensile test carried out with the use of a
 tensile test specimen having a parallel part of 25 mm wide and 60 mm long with a distance between marks of 50
 mm at a deformation rate of 5 mm/min.

12. A method of manufacturing the hard extra-thin steel sheet according to claim 5, comprising:

upon hot rolling a bloom of steel having a thickness of 50 mm or more and containing oxide with an average
 diameter of 10 μm to 25 μm , at 600°C or above,
 performing rolling at a total real strain of 0.4 or more under conditions of 1,000°C or above and a strain rate of
 1/sec or more; and then
 performing rolling at a total real strain of 0.7 or more under conditions of 1,000°C or less and a strain rate of
 10/sec or more so as to reduce a sheet thickness to 0.400 mm or less.

13. A method of manufacturing the hard extra-thin steel sheet according to claim 6, comprising:

upon hot rolling a bloom of steel having a thickness of 50 mm or more and containing sulfide with an average

diameter of 10 μm to 25 μm, at 600°C or above,
 performing rolling at a total real strain of 0.4 or more under conditions of 1,000°C or above and a strain rate of
 1/sec or more; and then
 performing rolling at a total real strain of 0.7 or more under conditions of 1,000°C or less and a strain rate of
 10/sec or more so as to reduce a sheet thickness to 0.400 mm or less.

14. A method of manufacturing the hard extra-thin steel sheet according to claim 7, comprising:

after cold rolling, performing a carburization treatment at a temperature ranging between 600 and 700°C under
 a condition of giving $\frac{\text{(carburization time (sec))} * \text{(carburization temperature (°C))}}{\text{(carburizing gas concentration (°C))} * \text{(cooling rate in carburization treatment (°C/sec))}} \geq 20$, simultaneously with or after a recrystallization
 annealing, thereby increasing a C amount by 0.0002% or more.

15. A method of manufacturing the hard extra-thin steel sheet according to claim 8, comprising:

after cold rolling, performing a nitriding treatment at a temperature ranging between 600 and 700°C under a
 condition of giving $\frac{\text{(nitriding time (sec))} * \text{(nitriding temperature (°C))}}{\text{(nitriding gas concentration (%))} * \text{(cooling rate in nitriding treatment (°C/sec))}} \geq 20$, simultaneously with or after a recrystallization annealing, thereby
 increasing an N amount by 0.0002% or more.

16. A method of manufacturing the hard extra-thin steel sheet according to claim 9, comprising:

performing cooling from a temperature of 900°C or above for the step of manufacturing a steel sheet, wherein
 cooling from 900°C down to 500°C is performed at a cooling rate of 20°C/sec or lower, thereby increasing a
 volume fraction of the intermetallic compound by 2.0-fold or more.

Patentansprüche

1. Ein hartes extra dünnes Stahlblech mit einer Blechdicke von 0,400 mm oder weniger, umfassend:

bezogen auf Massen-%,
 C: 0,800% oder weniger;
 N: 0,600% oder weniger;
 Si: 2,0% oder weniger;
 Mn: 2,0% oder weniger;
 P: 0,10% oder weniger;
 S: 0,100% oder weniger;
 Al: 3,0% oder weniger;
 gegebenenfalls ein oder mehrere, ausgewählt aus
 O: 0 bis 0,200%;
 Ti: 0 bis 4,00%;
 Nb: 0 bis 4,00%;
 REM: 0 bis 4,00%;
 B: 0 bis 0,0300%;
 Cu: 0 bis 8,00%;
 Ca: 0 bis 1,00%;
 Ni: 0 bis 8,00%;
 Cr: 0 bis 20,00%, und Sn, Sb, Mo, Ta, V und W jeweils in einem Anteil von 0,10% oder
 weniger, und
 wobei der Rest Fe und unvermeidbare Verunreinigungen ist, wobei
 das harte extra dünne Stahlblech 0,05% oder mehr, bezogen auf den Volumenanteil, einer zweiten Phase mit
 einer mittleren Hauptachse von 0,10 μm oder größer und einer mittleren Nebenachse von 0,05 μm oder größer
 und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, enthält,
 wobei die zweite Phase eine einfache Substanz aus oder eine Verbundverbindung aus Oxid, Sulfid, Carbid,
 Nitrid oder einer intermetallischen Verbindung ist.

2. Das harte extra dünne Stahlblech nach Anspruch 1,

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wobei die Anzahldichte der zweiten Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, $0,001 \text{ Teile}/\mu\text{m}^3$ oder mehr, wenn räumliche Streuung gemessen wird, oder $0,01 \text{ Teile}/\mu\text{m}^2$ oder mehr beträgt, wenn ein Querschnitt des Stahlblechs betrachtet wird.

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3. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die Hauptphase eine Ferritphase von Fe ist, dessen Volumenanteil 80% oder mehr beträgt.

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4. Das harte extra dünne Stahlblech nach Anspruch 3, wobei die Richtung der mittleren Hauptachse der zweiten Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, in der $\langle 100 \rangle$ Orientierung oder der $\langle 110 \rangle$ Orientierung der Ferritphase ist, die in Kontakt mit der zweiten Phase ist.

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5. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die zweite Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, ein eine oder zwei Art(en) von Fe, Mn, Si, Al, Cr, REM, Ti und Nb einschließendes Oxid ist, wobei das harte extra dünne Stahlblech, bezogen auf Massen-%,

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Mn: 0,05 bis 2,0%;
Al: 0,010% oder weniger; und
Si: 1,5% oder weniger umfasst.

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6. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die zweite Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, ein eine oder zwei Art(en) von Ti, Mn, Cu, Ca und REM einschließendes Sulfid ist, wobei das harte extra dünne Stahlblech, bezogen auf Massen-%,

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Mn: 0,05 bis 2,0%; und
S: 0,015 bis 0,100% umfasst.

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7. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die zweite Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, ein eine oder zwei Art(en) von Fe, Ti, Nb, Si und Cr einschließendes Carbid ist, wobei das harte extra dünne Stahlblech, bezogen auf Massen-%,

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C: 0,0050 bis 0,100% und
Si: 1,5% oder weniger umfasst.

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8. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die zweite Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, ein mindestens eine oder zwei Art(en) von Fe, Ti, Nb, Al, B und Cr einschließendes Nitrid ist, wobei das harte extra dünne Stahlblech, bezogen auf Massen-%,

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N: 0,0050 bis 0,100% und
Si: 1,5% oder weniger umfasst.

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9. Das harte extra dünne Stahlblech nach Anspruch 1, wobei die zweite Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer mittleren Nebenachse von $0,1 \mu\text{m}$ oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, eine mindestens eine oder zwei Art(en) von Fe, Ti, Nb, Al, Si und Mn einschließende intermetallische Verbindung ist.

10. Das harte extra dünne Stahlblech nach Anspruch 1, wobei ein Volumenanteil der zweiten Phase mit einer mittleren Hauptachse von $0,5 \mu\text{m}$ oder größer und einer

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mittleren Nebenachse von 0,1 μm oder größer und wobei mittlere Hauptachse/mittlere Nebenachse $\geq 2,0$ erfüllt, entweder (ein Volumenanteil von 1/8 Blechdicke der Oberflächenschicht)/(ein Volumenanteil von 1/4 Blechdicke der Mittelschicht) ≥ 10 oder (eine Anzahldicke von 1/8 Blechdicke der Oberflächenschicht)/(eine Anzahldicke von 1/4 Blechdicke der Mittelschicht) ≥ 10 erfüllt.

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11. Das harte extra dünne Stahlblech nach Anspruch 1, das maximale Festigkeit ≥ 350 MPa und HR30T Rockwell-Härte ≥ 54 oder gleichmäßige Dehnung/lokale Dehnung $\geq 1,0$ oder Streckfestigkeit/maximale Festigkeit $\leq 0,9$ erfüllt, entsprechend einem Zugversuch, der unter Verwendung einer Zugtestprobe mit einem parallelen Teil von 25 mm Breite und 60 mm Länge mit einem Abstand zwischen Markierungen von 50 mm bei einer Verformungsgeschwindigkeit von 5 mm/min durchgeführt wird.

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12. Ein Verfahren zur Herstellung des harten extra dünnen Stahlblechs nach Anspruch 5, umfassend:

beim Heißwalzen einer Stahlbramme mit einer Dicke von 50 mm oder mehr, die Oxid mit einem durchschnittlichen Durchmesser von 10 μm bis 25 μm enthält, bei 600°C oder darüber, Durchführen von Walzen bei einer realen Gesamtverformung von 0,4 oder mehr unter Bedingungen von 1000°C oder höher und einer Verformungsgeschwindigkeit von 1/sek oder mehr; und dann Durchführen von Walzen bei einer realen Gesamtverformung von 0,7 oder mehr unter Bedingungen von 1000°C oder weniger und einer Verformungsgeschwindigkeit von 10/sek oder mehr, um eine Blechdicke auf 0,400 mm oder weniger zu reduzieren.

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13. Ein Verfahren zur Herstellung des harten extra dünnen Stahlblechs nach Anspruch 6, umfassend:

beim Heißwalzen einer Stahlbramme mit einer Dicke von 50 mm oder mehr, die Sulfid mit einem durchschnittlichen Durchmesser von 10 μm bis 25 μm enthält, bei 600°C oder darüber, Durchführen von Walzen bei einer realen Gesamtverformung von 0,4 oder mehr unter Bedingungen von 1000°C oder höher und einer Verformungsgeschwindigkeit von 1/sek oder mehr; und dann Durchführen von Walzen bei einer realen Gesamtverformung von 0,7 oder mehr unter Bedingungen von 1000°C oder weniger und einer Verformungsgeschwindigkeit von 10/sek oder mehr, um eine Blechdicke auf 0,400 mm oder weniger zu reduzieren.

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14. Ein Verfahren zur Herstellung des harten extra dünnen Stahlblechs nach Anspruch 7, umfassend:

beim Kaltwalzen, Durchführen einer Karburierungsbehandlung bei einer Temperatur im Bereich zwischen 600 und 700°C unter einer Bedingung, die $\frac{\{(Karburierungszeit (sek)) * (Karburierungstemperatur (^{\circ}C))\}}{\{(Karburierungsgaskonzentration (\%)) * (Abkühlrate in der Karburierungsbehandlung (^{\circ}C/sek))\}} \geq 20$ ergibt, gleichzeitig mit oder nach einem Rekristallisationsglühen, wobei dadurch ein C-Anteil um 0,0002% oder mehr erhöht wird.

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15. Ein Verfahren zur Herstellung des harten extra dünnen Stahlblechs nach Anspruch 8, umfassend:

beim Kaltwalzen, Durchführen einer Nitrierbehandlung bei einer Temperatur im Bereich zwischen 600 und 700°C unter einer Bedingung, die $\frac{\{(Nitrierzeit (sek)) * (Nitriertemperatur (^{\circ}C))\}}{\{(Nitriergaskonzentration (\%)) * (Abkühlrate in Nitrierbehandlung (^{\circ}C/sek))\}} \geq 20$ ergibt, gleichzeitig mit oder nach einem Rekristallisationsglühen, wobei dadurch ein N-Anteil um 0,0002% oder mehr erhöht wird.

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16. Ein Verfahren zur Herstellung des harten extra dünnen Stahlblechs nach Anspruch 9, umfassend:

Durchführen von Abkühlen von einer Temperatur von 900°C oder höher für den Schritt der Herstellung eines Stahlblechs, wobei Abkühlen von 900°C auf 500°C bei einer Abkühlrate von 20°C/sek oder weniger durchgeführt wird, wobei dadurch ein Volumenanteil der intermetallischen Verbindung um das 2,0-fache oder mehr erhöht wird.

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Revendications

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1. Tôle d'acier dure extra-mince possédant une épaisseur de tôle de 0,400 mm ou moins, comprenant :

en % en masse,

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C : 0,800% ou moins ;
N : 0,600% ou moins ;
Si : 2,0% ou moins ;
Mn : 2,0% ou moins ;
P : 0,10% ou moins ;
S : 0,100% ou moins ;
Al : 3,0% ou moins ;

éventuellement un ou plusieurs éléments choisis parmi

O : 0 à 0,200% ;
Ti : 0 à 4,00% ;
Nb : 0 à 4,00% ;
REM : 0 à 4,00% ;
B : 0 à 0,0300% ;
Cu : 0 à 8,00% ;
Ca : 0 à 1,00% ;
Ni : 0 à 8,00% ;

Cr : 0 à 20,00%, et Sn, Sb, Mo, Ta, V et W chacun en une quantité de 0,10% ou moins, et le solde étant Fe et les impuretés inévitables, où

la tôle d'acier dure extra-mince contient 0,05% ou plus, en fraction volumique, d'une seconde phase possédant un axe principal moyen de 0,10 μm ou plus grand et un axe secondaire moyen de 0,05 μm ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$

dans laquelle la seconde phase est une substance simple de, ou un composé composite d'oxyde, sulfure, carbure, nitrure ou un composé intermétallique.

2. Tôle d'acier dure extra-mince selon la revendication 1, dans laquelle la densité en nombre de la seconde phase possédant un axe principal moyen de 0,5 μm ou plus grand et un axe secondaire moyen de 0,1 μm ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est de 0,001 pièce/ μm^3 ou plus lorsque la dispersion spatiale est mesurée, ou 0,01 pièce/ μm^2 ou plus lorsqu'une coupe transversale de la tôle d'acier est observée.

3. Tôle d'acier dure extra-mince selon la revendication 1, dans laquelle la phase principale est une phase ferrite de Fe dont la fraction volumique est 80% ou plus.

4. Tôle d'acier dure extra-mince selon la revendication 3, dans laquelle la direction de l'axe principal moyen de la seconde phase possédant un axe principal moyen de 0,5 μm ou plus grand et un axe secondaire moyen de 0,1 μm ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est dans l'orientation $\langle 100 \rangle$ ou l'orientation $\langle 110 \rangle$ de la phase ferrite qui est en contact avec la seconde phase.

5. Tôle d'acier dure extra-mince selon la revendication 1, dans laquelle la seconde phase possédant un axe principal moyen de 0,5 μm ou plus grand et un axe secondaire moyen de 0,1 μm ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est un oxyde comprenant un ou deux type(s) parmi Fe, Mn, Si, Al, Cr, REM, Ti et Nb, où la tôle d'acier dure extra-mince comprend, en % en masse,

Mn : 0,05 à 2,0% ;
Al : 0,010% ou moins ; et
Si : 1,5% ou moins .

6. Tôle d'acier dure extra-mince selon la revendication 1, dans laquelle la seconde phase possédant un axe principal moyen de 0,5 μm ou plus grand et un axe secondaire moyen de 0,1 μm ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est un sulfure comprenant un ou deux type(s) parmi Ti, Mn, Cu, Ca et REM où la tôle d'acier dure extra-mince comprend, en % en masse,

Mn : 0,05 à 2,0% ; et
S : 0,015 à 0,100%.

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7. Tôle d'acier dure extra-mince selon la revendication 1,
dans laquelle la seconde phase possédant un axe principal moyen de $0,5 \mu\text{m}$ ou plus grand et un axe secondaire
moyen de $0,1 \mu\text{m}$ ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est un
carbure comprenant un ou deux type(s) parmi Fe, Ti, Nb, Si et Cr,
où la tôle d'acier dure extra-mince comprend, en % en masse,
- C: 0,0050 à 0,100%, et
Si : 1,5% ou moins .
8. Tôle d'acier dure extra-mince selon la revendication 1,
dans laquelle la seconde phase possédant un axe principal moyen de $0,5 \mu\text{m}$ ou plus grand et un axe secondaire
moyen de $0,1 \mu\text{m}$ ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est un
nitrure comprenant au moins un ou deux type(s) parmi Fe, Ti, Nb, Al, B et Cr,
où la tôle d'acier dure extra-mince comprend, en % en masse,
- N : 0,0050 à 0,100%, et
Si : 1,5% ou moins .
9. Tôle d'acier dure extra-mince selon la revendication 1,
dans laquelle la seconde phase possédant un axe principal moyen de $0,5 \mu\text{m}$ ou plus grand et un axe secondaire
moyen de $0,1 \mu\text{m}$ ou plus grand et satisfaisant la relation axe principal moyen/axe secondaire moyen $\geq 2,0$ est un
composé intermétallique comprenant au moins un ou deux type(s) parmi Fe, Ti, Nb, Al, Si et Mn.
10. Tôle d'acier dure extra-mince selon la revendication 1,
dans laquelle une fraction volumique de la seconde phase possédant un axe principal moyen de $0,5 \mu\text{m}$ ou plus
grand et un axe secondaire moyen de $0,1 \mu\text{m}$ ou plus grand et satisfaisant la relation axe principal moyen/axe
secondaire moyen $\geq 2,0$ satisfait l'une ou l'autre relation parmi (une fraction volumique de couche de surface de
 $1/8$ d'épaisseur de tôle)/(une fraction volumique de couche centrale de $1/4$ d'épaisseur de tôle) ≥ 10 ou (une densité
en nombre de couche de surface de $1/8$ d'épaisseur de tôle)/(une densité en nombre de couche centrale de $1/4$
d'épaisseur de tôle) ≥ 10 .
11. Tôle d'acier dure extra-mince selon la revendication 1,
qui satisfait la relation résistance maximale $\geq 350 \text{ MPa}$ et dureté Rockwell HR30T ≥ 54 ou allongement uniforme/al-
longement local $\geq 1,0$ ou limite d'élasticité/résistance maximale $\leq 0,9$, selon un essai de traction effectué en utilisant
un échantillon d'essai de traction possédant une partie parallèle de 25 mm de large et 60 mm de long avec une
distance entre marques de 50 mm à un taux de déformation de 5 mm/min.
12. Procédé de fabrication de la tôle d'acier dure extra-mince selon la revendication 5, comprenant :
- lors du laminage à chaud d'un bloom d'acier possédant une épaisseur de 50 mm ou plus et contenant un oxyde
avec un diamètre moyen de $10 \mu\text{m}$ à $25 \mu\text{m}$, à 600°C ou plus,
l'exécution d'un laminage à une déformation réelle totale de 0,4 ou plus dans des conditions de 1000°C ou plus
et un taux de déformation de 1/s ou plus ; puis
l'exécution d'un laminage à une déformation réelle totale de 0,7 ou plus dans des conditions de 1000°C ou
moins et un taux de déformation de 10/s ou plus de façon à réduire une épaisseur de tôle à 0,400 mm ou moins.
13. Procédé de fabrication de la tôle d'acier dure extra-mince selon la revendication 6, comprenant :
- lors du laminage à chaud d'un bloom d'acier possédant une épaisseur de 50 mm ou plus et contenant un sulfure
avec un diamètre moyen de $10 \mu\text{m}$ à $25 \mu\text{m}$, à 600°C ou plus,
l'exécution d'un laminage à une déformation réelle totale de 0,4 ou plus dans des conditions de 1000°C ou plus
et un taux de déformation de 1/s ou plus ; puis
l'exécution d'un laminage à une déformation réelle totale de 0,7 ou plus dans des conditions de 1000°C ou
moins et un taux de déformation de 10/s ou plus de façon à réduire une épaisseur de tôle à 0,400 mm ou moins.
14. Procédé de fabrication de la tôle d'acier dure extra-mince selon la revendication 7, comprenant :
- lors du laminage à froid, l'exécution d'un traitement de cémentation par le carbone à une température comprise

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entre 600 et 700°C dans une condition donnant $\{(\text{temps de cémentation carbone (s)})^* (\text{température de cémentation (°C)})\} / \{(\text{concentration en gaz de cémentation (\%)})^* (\text{vitesse de refroidissement dans le traitement de cémentation (°C/s)})\} \geq 20$, simultanément à, ou après, un recuit de recristallisation, ce qui permet d'augmenter une quantité de C de 0,0002% ou plus.

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15. Procédé de fabrication de la tôle d'acier dure extra-mince selon la revendication 8, comprenant :

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lors du laminage à froid, l'exécution d'un traitement de nitruration à une température comprise entre 600 et 700°C dans une condition donnant $\{(\text{temps de nitruration (s)})^* (\text{température de nitruration (°C)})\} / \{(\text{concentration en gaz de nitruration (\%)})^* (\text{vitesse de refroidissement lors du traitement de nitruration (°C/s)})\} \geq 20$, simultanément à, ou après, un recuit de recristallisation, ce qui permet d'augmenter une quantité de N de 0,0002% ou plus.

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16. Procédé de fabrication de la tôle d'acier dure extra-mince selon la revendication 9, comprenant :

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l'exécution d'un refroidissement à partir d'une température de 900°C ou supérieure pour l'étape de fabrication d'une tôle d'acier, dans lequel le refroidissement de 900°C jusqu'à 500°C est effectué à une vitesse de refroidissement de 20°C/s ou plus basse, ce qui permet d'augmenter une fraction volumique du composé intermétallique de 2,0 fois ou plus.

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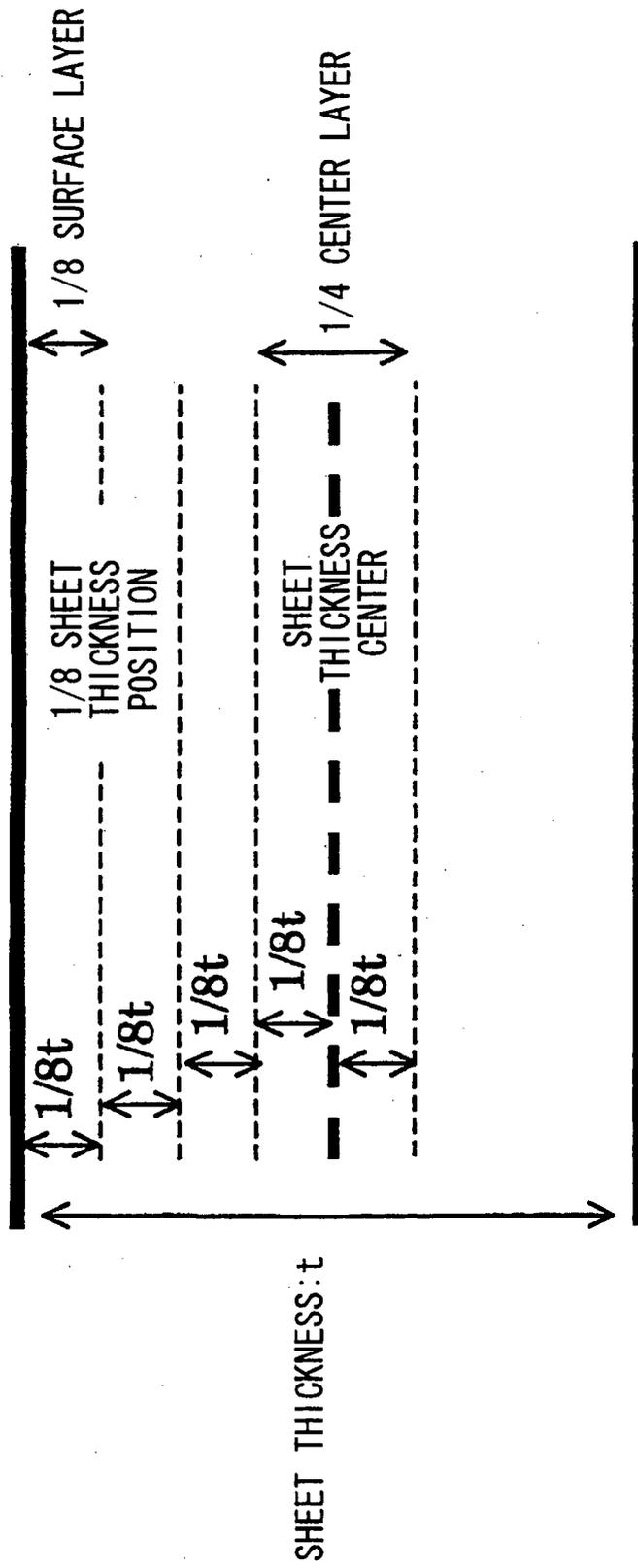
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FIG. 1



REFERENCES CITED IN THE DESCRIPTION

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