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

(11) EP 3 845 678 A1

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

(43) Date of publication:
07.07.2021 Bulletin 2021/27

(21) Application number: **19853931.4**

(22) Date of filing: **27.08.2019**

(51) Int Cl.:
C22C 38/00 *(2006.01)* ***B21B 1/00*** *(2006.01)*
C21D 9/46 *(2006.01)* ***C22C 38/26*** *(2006.01)*

(86) International application number:
PCT/JP2019/033548

(87) International publication number:
WO 2020/045449 (05.07.2020 Gazette 2020/10)

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

(30) Priority: **30.08.2018 JP 2018161900**

(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

(72) Inventors:
- **KARIYA Nobusuke**
  Tokyo 100-0011 (JP)
- **SHIIMORI Fusae**
  Tokyo 100-0011 (JP)
- **KOJIMA Katsumi**
  Tokyo 100-0011 (JP)
- **OOTANI Daisuke**
  Tokyo 100-0011 (JP)
- **JINGU Takafumi**
  Tokyo 100-0011 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) STEEL SHEET FOR CAN, AND METHOD FOR PRODUCING SAME

(57) Provided is a steel sheet for cans that has uniform deformability and excellent formability in addition to high strength and excellent ductility. A steel sheet for cans comprises a chemical composition containing, in mass%, C: 0.020-0.130 %, Si: ≤ 0.04 %, Mn: 0.10-1.20 %, P: 0.007-0.100 %, S: ≤ 0.030 %, Al: 0.001-0.100 %, N: > 0.0120 % and ≤ 0.0200 %, Nb: 0.0060-0.0300 %, and Cr: ≤ 0.040 %, with a balance being Fe and inevitable impurities, wherein a ratio of Nb content in precipitates of < 20 nm in size to Nb content in all precipitates is ≥ 40 %, an average interval of all precipitates is ≤ 30 nm, an upper yield stress is 500-640 MPa and a total elongation is ≥ 10 % after heat treatment at 210 °C for 10 min.

EP 3 845 678 A1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a high-strength steel sheet for cans and a method of producing the same.

BACKGROUND

[0002] Steel sheets are used in the bodies or lids of cans such as food cans and beverage cans. These cans are desired to be produced at lower costs, and reduction in thickness of steel sheets used in can production is promoted to reduce can material costs. Main parts subjected to steel sheet thickness reduction are the can body of a two-piece can formed by drawing, the can body of a three-piece can formed by cylinder forming, and their can lids. Since simply reducing the thickness of a steel sheet for cans causes a decrease in the strength of the body or lid of the can, it is desirable to use a high-strength and ultra-thin steel sheet for cans in a part such as the can body of a draw and redraw (DRD) can or a welded can.

[0003] Such a high-strength and ultra-thin steel sheet for cans is produced by a double reduction method (hereafter referred to as "DR method") that involves secondary cold rolling with a rolling reduction of 20 % or more after annealing. A steel sheet (hereafter also referred to as "DR material") produced using the DR method has high strength, but has poor formability because of low total elongation and poor ductility.

[0004] DR materials are increasingly used in straight-shaped can bodies. Meanwhile, can bodies having beads, can lids (easy open ends (EOE)) of food cans that open in a stay-on tab manner, and the like have complex shapes, and therefore the use of DR materials often causes cracks in sites that are complex in shape or results in failure to obtain highly accurate shapes. Specifically, a can lid (EOE) is produced by subjecting a steel sheet sequentially to blanking, shell forming, curling, and riveting by press forming. In particular, given that a flange portion of the can body and a curl portion of the can lid are seamed to ensure the hermeticity of the can, the curl portion of the can lid is required to be shaped with high accuracy. A DR material typically used as a high-strength and ultra-thin steel sheet has poor ductility. It is often difficult to use such a DR material in a can lid of a complex shape from the viewpoint of formability, and die adjustment is performed many times before yielding a product. Moreover, since the DR material is obtained by strengthening the steel sheet through strain hardening by secondary cold rolling, the strain hardening is non-uniformly introduced into the steel sheet depending on the accuracy of the secondary cold rolling, as a result of which local deformation occurs when forming the DR material. Local deformation is a phenomenon that needs to be prevented because the dimensional accuracy of the curl portion of the can lid decreases.

[0005] To avoid such drawbacks of the DR material, high-strength steel sheet production methods using various strengthening techniques are proposed.

[0006] For example, JP H8-325670 A (PTL 1) proposes a steel sheet that achieves a balance between strength and ductility by combining strengthening by precipitation of Nb carbides and refinement strengthening by Nb, Ti, and B carbonitrides. JP 2004-183074 A (PTL 2) proposes a strengthening method using solid solution strengthening by Mn, P, N, etc. JP 2001-89828 A (PTL 3) proposes a steel sheet for cans that has a tensile strength of less than 540 MPa using strengthening by precipitation of Nb, Ti, and B carbonitrides and has improved weld formability by controlling the particle size of oxide-based inclusions. JP 5858208 B1 (PTL 4) proposes a steel sheet for high-strength containers that has high strength by solute N as a result of increasing the N content and has a tensile strength of 400 MPa or more and an elongation after fracture of 10 % or more by controlling the dislocation density in the steel sheet thickness direction.

CITATION LIST

Patent Literature

[0007]

PTL 1: JP H8-325670 A
PTL 2: JP 2004-183074 A
PTL 3: JP 2001-89828 A
PTL 4: JP 5858208 B1

SUMMARY

(Technical Problem)

[0008] As mentioned above, the strength needs to be ensured in order to reduce the thickness. Meanwhile, in the case where the steel sheet is used as a material of a can lid (for example, EOE) having a large amount of deformation, the steel sheet needs to have high ductility. Furthermore, for favorable dimensional accuracy of the curl portion of the can lid, local deformation when forming the steel sheet needs to be suppressed, i.e. the deformation in the forming needs to be uniform (hereafter referred to as "uniform deformability"). Thus, a steel sheet for cans that is intended for the foregoing uses is required to have high strength, high ductility (total elongation), and uniform deformability (dimensional accuracy of curl portion) simultaneously.

[0009] PTL 1 has no mention of local deformation of the steel sheet. It is desirable to impart uniform deformability to the steel sheet.

[0010] PTL 2 proposes achieving high strength by solid solution strengthening. However, strengthening the steel sheet by excessively adding P facilitates local deformation, making it impossible to obtain uniform deformability.

[0011] PTL 3 uses strengthening by precipitation and grain refinement by Nb, Ti, etc. However, from the viewpoint of weld formability and surface characteristics, not only Ti but also Ca and REM need to be added, and there is a problem of degradation in corrosion resistance. Moreover, PTL 3 has no mention of local deformation of the steel sheet. It is desirable to impart uniform deformability to the steel sheet.

[0012] PTL 4 has no mention of the shape of the curl portion of the can lid, and also has no mention of local deformation of the steel sheet. It is desirable to impart uniform deformability to the steel sheet.

[0013] It could therefore be helpful to provide a steel sheet for cans that has uniform deformability and excellent formability in addition to high strength and excellent ductility, and a method of producing the same.

(Solution to Problem)

[0014]

[1] A steel sheet for cans, comprising a chemical composition containing (consisting of), in mass%, C: 0.020 % or more and 0.130 % or less, Si: 0.04 % or less, Mn: 0.10 % or more and 1.20 % or less, P: 0.007 % or more and 0.100 % or less, S: 0.030 % or less, Al: 0.001 % or more and 0.100 % or less, N: more than 0.0120 % and 0.0200 % or less, Nb: 0.0060 % or more and 0.0300 % or less, and Cr: 0.040 % or less, with a balance being Fe and inevitable impurities, wherein a ratio of Nb content in precipitates of less than 20 nm in size to Nb content in all precipitates is 40 % or more, an average interval of all precipitates is 30 nm or less, an upper yield stress after heat treatment at 210 °C for 10 min is 500 MPa or more and 640 MPa or less, and a total elongation after the heat treatment is 10 % or more.

[2] A method of producing a steel sheet for cans, comprising: performing a hot rolling process of heating a steel material at 1200 °C or more, hot rolling the steel material under conditions of a finish temperature of 850 °C or more and a rolling reduction in a final stand of 8 % or more to obtain a rolled sheet, and coiling the rolled sheet in a temperature range of 640 °C or more and 780 °C or less, the steel material having a chemical composition containing (consisting of), in mass%, C: 0.020 % or more and 0.130 % or less, Si: 0.04 % or less, Mn: 0.10 % or more and 1.20 % or less, P: 0.007 % or more and 0.100 % or less, S: 0.030 % or less, Al: 0.001 % or more and 0.100 % or less, N: more than 0.0120 % and 0.0200 % or less, Nb: 0.0060 % or more and 0.0300 % or less, and Cr: 0.040 % or less, with a balance being Fe and inevitable impurities; performing, after the hot rolling process, a primary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 86 % or more; performing, after the primary cold rolling process, an annealing process of soaking the rolled sheet in a temperature range of 660 °C or more and 800 °C or less, subjecting the rolled sheet to primary cooling to a temperature range of 600 °C or more and 650 °C or less at an average cooling rate of 3 °C/s or more and less than 10 °C/s, and subjecting the rolled sheet to secondary cooling to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more; and performing a secondary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 0.1 % or more and 3.0 % or less.

(Advantageous Effect)

[0015] It is thus possible to obtain a high-ductility and high-strength steel sheet for cans that has uniform deformability and maintains corrosion resistance even against highly corrosive contents. Since the steel sheet has high strength, a can can be reduced in thickness while ensuring high strength of the can body. Moreover, since the steel sheet has high ductility, it is an optimal material for can body forming with a large amount of deformation such as beading or can expansion used for welded cans, or flanging. That is, the steel sheet having uniform deformability can be subjected to such forming to produce a can product and a can lid product with favorable formability and high dimensional accuracy.

DETAILED DESCRIPTION

[0016] A steel sheet for cans according to one of the disclosed embodiments will be described in detail below.

[0017] First, the chemical composition of the steel sheet for cans according to one of the disclosed embodiments will be described below. Herein, the unit "%" used with regard to the content of each component denotes "mass%" unless otherwise specified.

C: 0.020 % or more and 0.130 % or less

[0018] It is important that the steel sheet for cans according to one of the disclosed embodiments has an upper yield stress of 500 MPa or more and a total elongation of 10 % or more. To achieve this, it is important to use strengthening by precipitation of NbC formed as a result of Nb being contained. The C content in the steel sheet for cans is crucial in order to use strengthening by precipitation of NbC. Specifically, the lower limit of the C content needs to be 0.020 %. In detail, if the C content is less than 0.020 %, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %, and the uniform deformability or the dimensional accuracy of the height of the curl portion of the can lid degrades. If the C content is more than 0.130 %, hypo-peritectic cracking may occur in a cooling process during steelmaking. In addition, the proportion of the precipitates with a precipitate size of 20 nm or more increases, and the proportion of the precipitates with a precipitate size of less than 20 nm to all precipitates is less than 40 %, as a result of which the uniform deformability decreases. Further, the steel sheet becomes excessively hard, and the ductility decreases. The upper limit of the C content is therefore 0.130 %.

[0019] If the C content is 0.040 % or less, the increase of the deformation resistance in cold rolling is further reduced. This makes it unnecessary to lower the rolling rate in order to prevent surface defects after the rolling. Moreover, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is more uniform. Therefore, the C content is preferably 0.040 % or less from the viewpoint of productivity.

Si: 0.04 % or less

[0020] Si is an element that increases the strength of the steel by solid solution strengthening. To achieve this effect, the Si content is preferably 0.01 % or more. If the Si content is more than 0.04 %, the corrosion resistance decreases significantly. The Si content is therefore 0.04 % or less. The Si content is preferably 0.03 % or less.

Mn: 0.10 % or more and 1.20 % or less

[0021] Mn increases the strength of the steel by solid solution strengthening. To ensure the target upper yield stress, the Mn content needs to be 0.10 % or more. The lower limit of the Mn content is therefore 0.10 %. If the Mn content is more than 1.20 %, the corrosion resistance and the surface characteristics degrade. In addition, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %, so that local deformation occurs and the uniform deformability decreases. The upper limit of the Mn content is therefore 1.20 %. The Mn content is preferably 0.20 % or more and 0.60 % or less.

P: 0.007 % or more and 0.100 % or less

[0022] P is an element having high solid solution strengthening ability. To achieve this effect, the P content needs to be 0.007 % or more. Moreover, limiting the P content to less than 0.007 % requires dephosphorization for a long time, which considerably increases the production costs. The P content is therefore 0.007 % or more. If the P content is more than 0.100 %, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %, so that local deformation occurs and the uniform deformability decreases. Further, the corrosion resistance decreases. The P content is therefore 0.100 % or less. The P content is preferably 0.008 % or more and 0.015 % or less.

S: 0.030 % or less

[0023] The steel sheet for cans according to one of the disclosed embodiments has high C content and high N content, and also contains Nb that forms precipitates which cause slab cracking. Accordingly, slab edges tend to crack in a bending zone or straightening zone during continuous casting. To prevent such slab cracking, the S content is 0.030 % or less. The S content is preferably 0.020 % or less. Since limiting the S content to less than 0.005 % requires excessively high desulfurization costs, the S content is preferably 0.005 % or more.

Al: 0.001 % or more and 0.100 % or less

[0024] Al is an element contained as a deoxidizer. Al also forms AlN with N in the steel, thus reducing solute N in the steel. If the Al content is excessively high, the formation of AlN increases, and the amount of N that contributes to increased strength of the steel sheet as solute N described below decreases, so that the strength of the steel sheet decreases. The Al content is therefore 0.100 % or less. If the Al content is less than 0.001 %, its effect as a deoxidizer is insufficient, and solidification defects occur and the steelmaking costs increase. The Al content is therefore 0.001 % or more. To enable Al to sufficiently function as a deoxidizer and achieve the strengthening effect by solute N, the Al content is preferably 0.010 % or more and 0.060 % or less.

N: more than 0.0120 % and 0.0200 % or less

[0025] N is an element necessary for increasing the strength of the steel sheet by solid solution strengthening. To achieve the solid solution strengthening effect, the N content needs to be more than 0.0120 %. If the N content is excessively high, slab cracking tends to occur in a lower straightening zone in which the cast steel temperature decreases in continuous casting. Moreover, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %, so that local deformation occurs and the uniform deformability decreases. The N content is therefore 0.0200 % or less. The N content is preferably 0.0130 % or more and 0.0185 % or less.

Nb: 0.0060 % or more and 0.0300 % or less

[0026] Nb is an element having high carbide formability, and causes fine carbides to precipitate. This increases the upper yield stress. In one of the disclosed embodiments, the upper yield stress can be adjusted by the Nb content. This effect is achieved if the Nb content is 0.0060 % or more. The lower limit of the Nb content is therefore 0.0060 %. Meanwhile, Nb causes an increase in recrystallization temperature. If the Nb content is more than 0.0300 %, a large amount of non-recrystallized microstructure remains in the below-described annealing at a soaking temperature of 660 °C or more and 800 °C or less. In the case where a large amount of non-recrystallized microstructure remains, when the steel sheet deforms, strain is non-uniformly applied to the steel sheet, and the total elongation decreases. Moreover, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %, so that local deformation occurs and the uniform deformability decreases. The upper limit of the Nb content is therefore 0.0300 %. The Nb content is preferably 0.0080 % or more and 0.0200 % or less.

Cr: 0.040 % or less

[0027] Cr is an element that influences the composition of fine carbides and the average precipitate interval. In detail, if the Cr content is more than 0.040 %, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is less than 40 %. Moreover, the average interval of all precipitates is more than 30 nm, so that local deformation occurs and the uniform deformability decreases. In particular, the dimensional accuracy of the height of the curl portion of the can lid formed as a result of being processed a plurality of times is impaired significantly. The Cr content is therefore 0.040 % or less. The Cr content is preferably 0.037 % or less. Since limiting the Cr content to less than 0.001 % requires excessively high steelmaking costs, the Cr content is preferably 0.001 % or more.

[0028] The balance other than the components described above consists of Fe and inevitable impurities.

[0029] The metallic microstructure of the steel sheet for cans according to one of the disclosed embodiments will be described below. It is important that, in the metallic microstructure, the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates is 40 % or more and the average interval of all precipitates is 30 nm or less.

[Ratio of Nb content in precipitates of less than 20 nm in size to Nb content in all precipitates: 40 % or more]

[0030] The steel sheet for cans according to one of the disclosed embodiments has a microstructure of mainly ferrite microstructure with precipitates of Nb-based carbides. Regarding the Nb content of the precipitates, it is important to limit the ratio of the Nb content in the precipitates of less than 20 nm in size to the Nb content in all precipitates (hereafter also referred to as "Nb content fraction of the precipitates of less than 20 nm in size") to 40 % or more.

[0031] If the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, it is difficult to ensure the uniform deformability or the dimensional accuracy of the height of the curl portion of the can lid. Although the mechanism behind this is not clear, it is presumed that, if the Nb content fraction of the precipitates of less than 20 nm is less than 40 %, coarse precipitates increase and the local strength variation of the steel sheet increases, and consequently the dimensional accuracy in curling decreases. The Nb content fraction of the precipitates of less than 20 nm in size is therefore limited to 40 % or more. The Nb content fraction of the precipitates of less than 20 nm in size is preferably 45 % or more.

[0032] The Nb content fraction of the precipitates of less than 20 nm in size is preferably 70 % or less. If the Nb content fraction of the precipitates of less than 20 nm in size is 70 % or less, excessive strengthening of the steel sheet by precipitation is prevented and the total elongation is further improved, without its effect being saturated.

[0033] The Nb content in the precipitates of less than 20 nm in size can be measured by the following method.

[0034] After a certain amount of a sample is electrolyzed in an electrolytic solution, the test piece is taken out of the electrolytic solution and immersed in a solution having dispersibility. Following this, precipitates contained in the solution are filtered using a filter with a pore size of 20 nm. Precipitates that have passed through the filter with a pore size of 20 nm together with the filtrate are precipitates of less than 20 nm in size. The Nb content is then analyzed for each of the residue on the filter after the filtering and the filtrate, to determine the Nb content in the precipitates of 20 nm or more in size and the Nb content in the precipitates of less than 20 nm in size. For the analysis of the Nb content, an analysis method selected as appropriate from inductively coupled plasma (ICP) emission spectrometry, ICP mass spectrometry, atomic absorption spectrometry, and the like may be used. Taking the sum of the Nb content in the precipitates of 20 nm or more in size and the Nb content in the precipitates of less than 20 nm in size to be the Nb content in all precipitates, the ratio of the Nb content in the precipitates of less than 20 nm in precipitate size to the Nb content in all precipitates is calculated.

[Average interval of all precipitates: 30 nm or less]

[0035] If the average interval of all precipitates is more than 30 nm, local deformation occurs in the below-described can lid forming, causing the height of the curl portion to be non-uniform and resulting in a decrease in the dimensional accuracy of the curl portion. The average interval is therefore 30 nm or less. The average interval is preferably 25 nm or less.

[0036] The dimensional accuracy of the curl portion is evaluated as follows: First, a circular blank with a diameter of 67 mm is collected from the steel sheet, and sequentially subjected to shell forming and curling by press forming to produce a can lid. The height of the curl portion of the produced can lid is measured at eight locations in the circumferential direction using a height gauge, and the standard deviation σH of the height of the curl portion is calculated. In the case where σH is 0.07 mm or less, the dimensional accuracy of the curl portion is evaluated as good.

[0037] Although the mechanism by which the average interval of all precipitates influences the dimensional accuracy of the height of the curl portion is not clear, it is presumed that, by reducing the average interval of all precipitates, the strain hardening behavior, that is involved with the interaction between the dislocations and the precipitates, is stabilized.

[0038] If the average interval is 10 nm or more, excessive strengthening of the steel sheet by precipitation is prevented and the ductility is further improved, without its effect being saturated. Accordingly, the average interval of all precipitates is preferably 10 nm or more.

[0039] In the measurement of the average interval of all precipitates, the precipitates are observed using a transmission electron microscope (TEM). An observation sample is produced by an extraction replica method after polishing the surface layer of the steel sheet by electropolishing. The observation is performed on bright field images with 300,000 magnification at an accelerating voltage of 200 kV. Three images are taken for each sample. The taken images are analyzed using image analysis software ("Particle Analysis" available from Nippon Steel Technology Co., Ltd.), and the equivalent circular diameter and the area ratio of the precipitates are calculated. Taking the equivalent circular diameter to be the precipitate size and the area ratio to be the precipitate volume fraction, the precipitate interval d is calculated according to the following formula. The average of the precipitate intervals d calculated for the three images is taken to be the average interval of all precipitates.

$$\mathrm{d} = \left[\left(\sqrt{2}\pi \middle/ 6f\right)^{1/3} - 1\right]a$$

where d is the precipitate interval (nm), f is the precipitate volume fraction, and a is the precipitate size (nm).

[0040] The steel sheet for cans having the above-described chemical composition and microstructure can exhibit the following mechanical properties. Typically, a steel sheet for cans is formed in a can shape and then subjected to paint baking to yield a product can. The mechanical properties of the steel sheet for cans according to one of the disclosed embodiments after heat treatment at 210 °C for 10 min which corresponds to paint baking treatment satisfy the following requirements.

[Upper yield stress: 500 MPa or more and 640 MPa or less]

[0041] To ensure the denting strength of a welded can, the pressure resistance of a two-piece can, and the like, the upper yield stress needs to be 500 MPa or more. Obtaining an upper yield stress of more than 640 MPa requires strengthening elements to be contained in large amount. Containing strengthening elements in large amount can hinder the corrosion resistance, and also can decrease the ductility. Accordingly, the upper yield stress is 640 MPa or less. The upper yield stress is preferably 520 MPa or more and 630 MPa or less.

[Total elongation: 10 % or more]

[0042] The total elongation needs to be 10 % or more. If the total elongation is less than 10 %, for example, there is a possibility that cracking occurs in the production of a can formed by can body forming such as beading or can expansion. If the total elongation is less than 10 %, there is a possibility that cracking occurs during can flanging. The lower limit of the total elongation is therefore 10 %. The total elongation is preferably 11 % or more. The total elongation is preferably 30 % or less, because the dimensional accuracy of the can is further enhanced.

[0043] The yield stress and the total elongation can be measured by the metallic material tensile testing method defined in JIS Z 2241.

[0044] The desired yield stress and total elongation can be achieved by adjusting the chemical composition and adjusting the cooling rate in continuous annealing. The yield stress of 500 MPa or more can be achieved in the following manner: In continuous annealing, a steel sheet having the foregoing chemical composition is soaked, then subjected to primary cooling in a temperature range of 600 °C or more at an average cooling rate of less than 10 °C/s, and then subjected to secondary cooling to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more. The steel sheet is further subjected to secondary cold rolling with a rolling reduction of 3.0 % or less.

[0045] A tensile test is conducted in accordance with the metallic material tensile testing method defined in JIS Z 2241. In detail, a JIS No. 5 tensile test piece (JIS Z 2201) with the direction orthogonal to the rolling direction being the tensile direction is collected, and subjected to paint baking equivalent treatment at 210 °C for 10 min. After this, a parallel portion of the tensile test piece is provided with gauge marks of 50 mm (L) so that the center in the length direction of the parallel portion will be a midpoint on a straight line connecting the gauge marks, and a tensile test conforming to JIS Z 2241 is conducted at a tensile rate of 10 mm/min until the tensile test piece fractures. After the tensile test ends, in the case where the position of the fracture is in a range of -1/2L to 1/2L where the midpoint of L is a zero point, the uniform deformability is evaluated as good (i.e. no local deformation occurs). Although the mechanism by which the proportion of the amount of the Nb-containing precipitates of less than 20 nm in precipitate size to the amount of all Nb-containing precipitates influences the uniform deformability is not clear, it is presumed that, by controlling the particle size distribution of the precipitates which contribute to increased strength of the steel sheet, the strain hardening behavior, that is involved with the interaction between the dislocations and the precipitates, is stabilized.

[0046] The thickness of the steel sheet for cans according to one of the disclosed embodiments is preferably 0.4 mm or less.

[0047] Currently, thinner steel sheets are promoted for the purpose of reducing can production costs. However, making a steel sheet thinner, i.e. reducing the thickness of the steel sheet, may cause a decrease in can strength. With the steel sheet for cans according to one of the disclosed embodiments, such a decrease in can strength is prevented even in the case where the steel sheet is thin. In the case where the steel sheet is thin, high ductility and high strength which are effects according to the present disclosure can be exhibited remarkably. Accordingly, the sheet thickness is preferably 0.4 mm or less. The sheet thickness may be 0.3 mm or less, and may be 0.2 mm or less.

[0048] A method of producing the steel sheet for cans according to one of the disclosed embodiments will be described below.

[0049] The steel sheet according to one of the disclosed embodiments can be produced by: performing a hot rolling process of heating a steel material having the foregoing chemical composition at 1200 °C or more, hot rolling the steel material under conditions of a finish temperature of 850 °C or more and a rolling reduction in a final stand of 8 % or more to obtain a rolled sheet, and coiling the rolled sheet in a temperature range of 640 °C or more and 780 °C or less; performing, after the hot rolling process, a primary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 86 % or more; performing, after the primary cold rolling process, a continuous annealing process of soaking the rolled sheet in a temperature range of 660 °C or more and 800 °C or less, subjecting the rolled sheet to primary cooling to a temperature range of 600 °C or more and 650 °C or less at an average cooling rate of 3 °C/s or more and less than 10 °C/s, and subjecting the rolled sheet to secondary cooling to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more; and then performing a secondary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 0.1 % or more and 3.0 % or less.

[0050] In the following description, each temperature is based on the surface temperature of the steel sheet, and the average cooling rate is a value calculated based on the surface temperature. For example, the average cooling rate from the soaking temperature to the temperature range of 600 °C or more is expressed as "(the soaking temperature - the temperature range of 600 °C or more)/(the cooling time from the soaking temperature to the temperature range of 600 °C or more)".

[0051] As the steel material, a slab obtained by adjusting molten steel to the foregoing chemical composition by a publicly known method using a converter or the like and then subjecting the molten steel to, for example, continuous casting is used.

[Heating temperature of steel material: 1200 °C or more]

[0052] The heating temperature of the steel material in the hot rolling process is 1200 °C or more. If the heating temperature is less than 1200 °C, the amount of solute N necessary for ensuring the strength in one of the disclosed embodiments decreases, and the strength decreases. The heating temperature is therefore 1200 °C or more. In the steel composition according to one of the disclosed embodiments, N is expected to mainly exist as AlN in the steel. Hence, (Ntotal - NasAlN) obtained by subtracting the amount of N (NasAlN) existing as AlN from the total amount of N (Ntotal) is regarded as the amount of solute N. To achieve the upper yield stress in the rolling direction of 500 MPa or more, the amount of solute N is preferably 0.0121 % or more. To obtain this amount of solute N, the heating temperature of the steel material is 1200 °C or more. The amount of solute N is more preferably 0.0130 % or more. To obtain this amount of solute N, the heating temperature of the steel material is 1220 °C or more. The heating temperature of the steel material is preferably 1350 °C or less, because the effect is saturated if the heating temperature is more than 1350 °C.

[Finish temperature in hot rolling process: 850 °C or more]

[0053] If the finish temperature in the hot rolling process is less than 850 °C, the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, and local deformation occurs in the tensile test. The finish temperature in the hot rolling process is therefore 850 °C or more. The finish temperature in the hot rolling process is preferably 855 °C or more. Increasing the finish temperature in the hot rolling process more than necessary may hinder the production of a thin steel sheet. For example, if the finish temperature is high, scale formation on the steel sheet surface becomes noticeable, and the surface characteristics are impaired. Specifically, the finish temperature is preferably 950 °C or less. The finish temperature is more preferably 945 °C or less.

[Rolling reduction in final stand: 8 % or more]

[0054] The rolling reduction in the final stand in the hot rolling process is 8 % or more. If the rolling reduction in the final stand is less than 8 %, the average interval of all precipitates is more than 30 nm, and the standard deviation of the height of the curl portion of the can lid is more than 0.07 mm, so that the dimensional accuracy of the height of the curl portion of the can lid decreases. The rolling reduction in the final stand is therefore 8 % or more. To reduce the standard deviation of the height of the curl portion of the can lid, the rolling reduction in the final stand is preferably 10 % or more. The rolling reduction in the final stand is preferably 15 % or less, from the viewpoint of the rolling load.

[Coiling temperature: 640 °C or more and 780 °C or less]

[0055] If the coiling temperature in the hot rolling process is less than 640 °C, the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, and local deformation occurs in the tensile test. The coiling temperature is therefore 640 °C or more. If the coiling temperature is more than 780 °C, part of ferrite in the steel sheet after the continuous annealing coarsens and the steel sheet softens, so that the upper yield stress is less than 500 MPa. The coiling temperature is therefore 780 °C or less. The coiling temperature is preferably 660 °C or more and 760 °C or less.

[Pickling]

[0056] After this, pickling is preferably performed according to need. The conditions of the pickling are not limited as long as surface layer scale of the steel sheet can be removed. Scale may be removed by a method other than pickling.

[0057] Next, cold rolling is performed twice, with annealing being provided therebetween.

[Rolling reduction in primary cold rolling: 86 % or more]

[0058] The rolling reduction in the primary cold rolling process is 86 % or more. If the rolling reduction in the primary cold rolling process is less than 86 %, strain applied to the steel sheet in the cold rolling decreases, making it difficult to achieve an upper yield stress of 500 MPa or more in the steel sheet after the continuous annealing. The rolling reduction in the primary cold rolling process is therefore 86 % or more. The rolling reduction in the primary cold rolling process is preferably 87 % or more and 94 % or less.

[0059] One or more other processes may be performed as appropriate after the hot rolling process and before the primary cold rolling process. The primary cold rolling process may be performed immediately after the hot rolling process, without performing pickling.

[0060] In the annealing process after the primary cold rolling, the steel sheet is soaked in a temperature range of 660 °C or more and 800 °C or less, and subjected to primary cooling that involves cooling to a temperature range of 600 °C or more at an average cooling rate of less than 10 °C/s. The steel sheet is then subjected to secondary cooling that involves cooling to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more.

[Soaking temperature: 660 °C or more and 800 °C or less]

[0061] The soaking treatment in the annealing process is performed at a temperature of 660 °C or more and 800 °C or less. If the soaking temperature is more than 800 °C, sheet passage troubles such as heat buckling are likely to occur in the annealing. Moreover, part of ferrite grains in the steel sheet coarsens and the steel sheet softens, resulting in an upper yield stress of less than 500 MPa. If the annealing temperature is less than 660 °C, the recrystallization of ferrite grains is imperfect, and non-recrystallized microstructure remains. In the case where non-recrystallized microstructure remains, when the steel sheet deforms, strain is non-uniformly applied to the steel sheet, as a result of which local deformation occurs and the total elongation decreases. The soaking temperature is therefore 660 °C or more and 800 °C or less. The soaking temperature is preferably 680 °C or more and 760 °C or less.

[0062] If the holding time at a soaking temperature of 660 °C or more and 800 °C or less is 60 sec or less, the segregation of C contained in the steel sheet to ferrite grain boundaries is further suppressed, and thus the precipitation of carbides in the cooling in the annealing process can be prevented. Consequently, the amount of solute C which contributes to increased strength of the steel sheet can be maintained, and accordingly the upper yield stress can be ensured stably. The holding time at a soaking temperature of 660 °C or more and 800 °C or less is therefore preferably 60 sec or less. If the holding time is 5 sec or more, the soaking temperature is more stable when the steel sheet passes rolls in the soaking zone. Accordingly, the holding time is preferably 5 sec or more.

[Primary cooling: cooling to temperature range of 600 °C or more and 650 °C or less at average cooling rate of 3 °C/s or more and less than 10 °C/s]

[0063] After the soaking, the steel sheet is cooled to a temperature range of 600 °C or more and 650 °C or less at an average cooling rate of less than 10 °C/s. If the average cooling rate is 10 °C/s or more, the precipitation of carbides is facilitated during the cooling, and the amount of solute C which contributes to increased strength of the steel sheet decreases, as a result of which the upper yield stress decreases. If the average cooling rate is less than 3 °C/s, the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, and the dimensional accuracy of the height of the curl portion of the can lid decreases. The average cooling rate is therefore 3 °C/s or more. If the cooling stop temperature in the primary cooling after the soaking is less than 600 °C, the precipitation of carbides is facilitated after the primary cooling, and the amount of solute C which contributes to increased strength of the steel sheet decreases, as a result of which the upper yield stress decreases. The cooling stop temperature is therefore 600 °C or more. The cooling stop temperature in the primary cooling after the soaking is more preferably 620 °C or more. If the cooling stop temperature in the primary cooling after the soaking is more than 650 °C, the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, and the dimensional accuracy of the height of the curl portion of the can lid decreases. The cooling stop temperature is therefore 650 °C or less.

[Secondary cooling: cooling to temperature range of 150 °C or less at average cooling rate of 10 °C/s or more]

[0064] In the secondary cooling after the primary cooling, the steel sheet is cooled to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more. If the average cooling rate is less than 10 °C/s, the Nb content fraction of the precipitates of less than 20 nm in size is less than 40 %, and local deformation occurs in the tensile test. The average cooling rate is preferably 12 °C/s or more. If the average cooling rate is more than 30 °C/s, not only the effect is saturated, but also the cooling line takes excessively high costs. The average cooling rate in the secondary cooling is therefore preferably 30 °C/s or less. The average cooling rate is more preferably 25 °C/s or less. In the secondary cooling, the steel sheet is cooled to 150 °C or less. If the cooling stop temperature is more than 150 °C, the amount of solute C which contributes to increased strength of the steel sheet decreases, and the upper yield stress decreases. The cooling stop temperature is preferably 145 °C or less. If the cooling stop temperature is less than 100

°C, not only the effect is saturated, but also the cooling line takes excessively high costs. The cooling stop temperature is therefore preferably 100 °C or more. The cooling stop temperature is more preferably 120 °C or more.

[0065] A continuous annealing device is preferably used in the annealing. One or more other processes may be performed as appropriate after the primary cold rolling process and before the annealing process. The annealing process may be performed immediately after the primary cold rolling process.

[Rolling reduction in secondary cold rolling: 0.1 % or more and 3.0 % or less]

[0066] The steel sheet according to one of the disclosed embodiments needs to have a total elongation of 10 % or more even as an ultra-thin material. In one of the disclosed embodiments, when the secondary cold rolling after the annealing is performed with the same rolling reduction (20 % or more) as typical DR material production conditions, strain introduced during forming increases, as a result of which the total elongation decreases. Moreover, the strain hardening of the steel sheet is non-uniformly introduced in the secondary cold rolling. Hence, if the rolling reduction is excessively high, when deforming the produced steel sheet, local deformation occurs, and the uniform deformability is insufficient. For these reasons, the rolling reduction in the secondary cold rolling is 3.0 % or less. To enhance the uniform deformability of the steel sheet, the secondary cold rolling ratio is desirably low. The rolling reduction in the secondary cold rolling is preferably less than 1.0 %. Meanwhile, the secondary cold rolling has a function of imparting surface roughness to the steel sheet. To uniformly impart surface roughness to the steel sheet, the rolling reduction in the secondary cold rolling needs to be 0.1 % or more. The rolling reduction in the secondary cold rolling is preferably 0.2 % or more and less than 1.0 %.

[0067] The steel sheet for cans according to one of the disclosed embodiments is obtained in the above-described way. In one of the disclosed embodiments, various processes may be further performed after the secondary cold rolling process. For example, a coating layer may be formed on the surface of the steel sheet for cans according to one of the disclosed embodiments. Examples of the coating layer include a Sn coating layer, a Cr coating layer as in tin-free steel, a Ni coating layer, and a Sn-Ni coating layer. Processes such as paint baking treatment and film lamination may also be performed.

[0068] Since the film thickness of the coating, the laminate film, or the like is sufficiently small relative to the sheet thickness, its influence on the mechanical properties of the steel sheet for cans is negligible.

EXAMPLES

[0069] Each steel having the chemical composition indicated in Table 1 with the balance being Fe and inevitable impurities was obtained by steelmaking in a converter, and continuously cast to obtain a steel slab. The obtained steel slab was subjected to hot rolling with the steel material heating temperature, the rolling finish temperature, the final stand rolling reduction, and the coiling temperature indicated in Tables 2 and 3. After the hot rolling, pickling was performed. The steel sheet was then subjected to primary cold rolling with the rolling reduction indicated in Tables 2 and 3, subjected to continuous annealing under the continuous annealing conditions indicated in Tables 2 and 3, and then subjected to secondary cold rolling with the rolling reduction indicated in Tables 2 and 3. The obtained steel sheet was subjected to typical Sn coating to obtain a Sn coated steel sheet (tinned sheet-iron).

[0070] The steel sheet obtained in the above-described manner was subjected to heat treatment equivalent to paint baking treatment at 210 °C for 10 min, and then a tensile test was conducted to measure the upper yield stress and the total elongation. In addition, the corrosion resistance and the precipitates were studied. Further, can lid forming was performed, and the height of the curl portion of the can lid was measured. The measurement methods and the study methods are as follows.

[0071] The tensile test was conducted in accordance with the metallic material tensile testing method defined in JIS Z 2241. In detail, a JIS No. 5 tensile test piece (JIS Z 2201) with the direction orthogonal to the rolling direction being the tensile direction was collected from the Sn coated steel sheet, and subjected to paint baking equivalent treatment at 210 °C for 10 min. After this, a parallel portion of the tensile test piece was provided with gauge marks of 50 mm (L) so that the center in the length direction of the parallel portion would be a midpoint on a straight line connecting the gauge marks, and a tensile test conforming to JIS Z 2241 was conducted at a tensile rate of 10 mm/min until the tensile test piece fractured. The uniform deformability was evaluated as pass (good) in the case where the position of the fracture was in a range of -1/2L to 1/2L where the midpoint of L is a zero point, evaluated as pass (excellent) in the case where the position of the fracture was in a range of -1/4L to 1/4L, and evaluated as fail in the case where the position of the fracture was not between the gauge marks.

Ratio of Nb content in precipitates of less than 20 nm in precipitate size to Nb content in all precipitates

[0072] The Sn coating of the Sn coated steel sheet was peeled away and cut to an appropriate size. The test piece of about 0.2 g was subjected to constant-current electrolysis with a current density of 20 mA/cm^2 in a 10 % AA-based electrolytic solution (10 vol% acetylacetone-1 mass% tetramethylammonium chloride-methanol). The test piece with precipitates adhering to its surface after the electrolysis was taken out of the electrolytic solution, and immersed in a sodium hexametaphosphate aqueous solution (500 mg/l, hereafter "SHMP aqueous solution"). Ultrasonic oscillation was applied to peel the precipitates away from the test piece and extract the precipitates into the SHMP aqueous solution. The precipitates contained in the solution were then filtered using a filter with a pore size of 20 nm. The residue on the filter and the filtrate after the filtering were analyzed using inductively coupled plasma (ICP) emission spectrometry, and the absolute amount of Nb in each of the residue on the filter and the filtrate was measured. The measurement value for the residue on the filter indicates the amount of precipitates of 20 nm or more in size, and the measurement value for the filtrate indicates the amount of precipitates of less than 20 nm in size. Taking the sum of the Nb content in the precipitates of 20 nm or more in size and the Nb content in the precipitates of less than 20 nm in size to be the Nb content in all precipitates, the ratio of the Nb content in the precipitates of less than 20 nm in precipitate size to the Nb content in all precipitates was calculated.

Corrosion resistance

[0073] The coating weight of the Sn coating on the Sn steel sheet per side was set to 11.2 g/m^2, and the number of sites observed as holes as a result of the Sn coating thinning was counted. The observation was performed in a measurement area of 2.7 mm^2 using an optical microscope with 50 magnification. The corrosion resistance was evaluated as pass in the case where the number of sites was 20 or less, and evaluated as fail in the case where the number of sites was 21 or more.

Can lid forming

[0074] A circular blank with a diameter of 67 mm was collected from the Sn coated steel sheet, and sequentially subjected to shell forming and curling to produce a can lid. The height of the curl portion of the produced can lid was measured at eight locations in the circumferential direction using a height gauge, and the standard deviation σH of the height of the curl portion was calculated. The dimensional accuracy of the height of the curl portion was evaluated as pass in the case where σH was 0.07 mm or less, and evaluated as fail in the case where σH was more than 0.07 mm.
[0075] The evaluation results are indicated in Tables 2 and 3.

Table 1

										mass%
Steel No.	C	Si	Mn	P	S	Al	N	Nb	Cr	Remarks
1	0.036	0.01	0.25	0.009	0.012	0.021	0.0153	0.0142	0.027	Ex.
2	0.126	0.02	0.31	0.011	0.009	0.038	0.0151	0.0139	0.032	Ex.
3	0.022	0.01	0.28	0.010	0.016	0.024	0.0156	0.0141	0.029	Ex.
4	0.039	0.01	0.33	0.008	0.013	0.026	0.0152	0.0138	0.014	Ex.
5	0.027	0.04	0.24	0.013	0.010	0.029	0.0149	0.0143	0.018	Ex.
6	0.020	0.02	1.08	0.011	0.014	0.032	0.0155	0.0124	0.026	Ex.
7	0.024	0.01	0.13	0.008	0.011	0.025	0.0167	0.0137	0.034	Ex.
8	0.035	0.01	0.57	0.012	0.015	0.031	0.0147	0.0140	0.025	Ex.
9	0.025	0.01	0.20	0.010	0.009	0.038	0.0172	0.0145	0.019	Ex.
10	0.030	0.02	0.22	0.057	0.011	0.022	0.0148	0.0113	0.023	Ex.
11	0.033	0.01	0.29	0.008	0.015	0.024	0.0147	0.0118	0.003	Ex.
12	0.034	0.02	0.41	0.012	0.028	0.039	0.0171	0.0125	0.024	Ex.
13	0.033	0.02	0.29	0.011	0.010	0.027	0.0153	0.0147	0.039	Ex.
14	0.029	0.01	0.32	0.014	0.019	0.075	0.0172	0.0153	0.035	Ex.
15	0.036	0.01	0.35	0.009	0.016	0.003	0.0146	0.0126	0.031	Ex.
16	0.032	0.02	0.27	0.010	0.018	0.059	0.0164	0.0139	0.026	Ex.

(continued)

mass%										
Steel No.	C	Si	Mn	P	S	Al	N	Nb	Cr	Remarks
17	0.024	0.01	0.31	0.013	0.015	0.013	0.0158	0.0146	0.017	Ex.
18	0.033	0.01	0.24	0.012	0.010	0.027	0.0193	0.0142	0.033	Ex.
19	0.028	0.01	0.34	0.015	0.014	0.019	0.0124	0.0160	0.029	Ex.
20	0.023	0.02	0.30	0.008	0.011	0.024	0.0182	0.0124	0.009	Ex.
21	0.035	0.02	0.32	0.011	0.017	0.036	0.0133	0.0171	0.021	Ex.
22	0.032	0.03	0.23	0.015	0.008	0.016	0.0146	0.0287	0.024	Ex.
23	0.027	0.02	0.26	0.011	0.015	0.022	0.0157	0.0074	0.005	Ex.
24	0.031	0.01	0.29	0.013	0.012	0.025	0.0154	0.0198	0.009	Ex.
25	0.026	0.02	0.31	0.009	0.017	0.029	0.0150	0.0082	0.016	Ex.
26	0.193	0.02	0.24	0.014	0.020	0.031	0.0147	0.0135	0.025	Comp. Ex.
27	0.166	0.01	0.36	0.010	0.014	0.027	0.0153	0.0141	0.032	Comp. Ex.
28	0.141	0.01	0.28	0.009	0.009	0.034	0.0160	0.0157	0.018	Comp. Ex.
29	0.025	0.01	0.33	0.012	0.015	0.028	0.0149	0.0114	0.053	Comp. Ex.
30	0.014	0.02	0.19	0.015	0.011	0.034	0.0152	0.0136	0.027	Comp. Ex.
31	0.018	0.02	0.41	0.017	0.024	0.040	0.0165	0.0183	0.034	Comp. Ex.
32	0.029	0.05	0.27	0.014	0.016	0.037	0.0151	0.0145	0.023	Comp. Ex.
33	0.037	0.02	1.46	0.009	0.021	0.024	0.0147	0.0172	0.028	Comp. Ex.
34	0.026	0.01	0.04	0.011	0.018	0.036	0.0154	0.0150	0.022	Comp. Ex.
35	0.028	0.02	0.35	0.016	0.014	0.022	0.0156	0.0141	0.130	Comp. Ex.
36	0.033	0.01	0.30	0.014	0.010	0.124	0.1690	0.0168	0.035	Comp. Ex.
37	0.025	0.01	0.28	0.012	0.017	0.029	0.0242	0.0134	0.012	Comp. Ex.
38	0.034	0.02	0.42	0.009	0.013	0.045	0.0225	0.0146	0.024	Comp. Ex.
39	0.030	0.02	0.24	0.018	0.011	0.038	0.0114	0.0172	0.018	Comp. Ex.
40	0.027	0.02	0.37	0.016	0.015	0.031	0.0019	0.0149	0.025	Comp. Ex.
41	0.033	0.02	0.23	0.011	0.019	0.024	0.0137	0.0336	0.031	Comp. Ex.
42	0.029	0.01	0.41	0.017	0.022	0.037	0.0171	0.0542	0.033	Comp. Ex.
43	0.034	0.02	0.38	0.010	0.014	0.025	0.0164	0.0035	0.027	Comp. Ex.
44	0.026	0.01	0.45	0.014	0.017	0.030	0.0152	0.0056	0.019	Comp. Ex.
45	0.028	0.01	0.37	0.125	0.013	0.026	0.1520	0.0056	0.019	Comp. Ex.
Note: Underlines indicate outside range according to present disclosure,										

Table 2

Steel sheet No.	Steel No.	Steel material heating temperature (°C)	Rolling finish temperature (°C)	Rolling reduction in final stand (%)	Coiling temperature (°C)	Hot-rolled sheet thickness (mm)	Rolling reduction in primary cold rolling (%)	Soaking temperature (°C)	Soaking holding time (s)	Primary cooling average rate (°C/s)	Primary cooling stop temperature (°C)	Secondary cooling average rate (°C/s)	Secondary cooling stop temperature (°C)	Rolling reduction in secondary cold rolling (%)	Finish sheet thickness (mm)	Ratio of Nb content in precipitates of less than 20 nm in size (%)	Average precipitate interval (nm)	Upper yield stress in rolling direction (MPa)	Total elongation (%)	Corrosion resistance	Uniform deformability	Curl height	Remarks
1	1	1220	890	10	665	2.0	91	695	28	8	635	21	130	0.9	0.18	47	17	546	18	Pass	Pass (excellent)	Pass	Ex.
2	2	1235	905	11	690	1.9	90	685	42	7	610	23	135	0.8	0.19	46	23	631	12	Pass	Pass (good)	Pass	Ex.
3	3	1210	920	12	645	1.8	90	720	12	7	630	30	140	0.9	0.18	40	21	535	16	Pass	Pass (excellent)	Pass	Ex.
4	4	1225	875	10	705	2.0	92	690	35	9	625	12	125	0.7	0.16	54	19	557	15	Pass	Pass (excellent)	Pass	Ex.
5	5	1240	900	10	720	1.8	89	705	24	7	630	24	140	1.0	0.20	51	20	543	15	Pass	Pass (good)	Pass	Ex.
6	6	1215	935	8	710	2.0	89	715	37	7	630	11	105	0.5	0.22	52	18	628	10	Pass	Pass (good)	Pass	Ex.
7	7	1270	925	11	690	2.0	90	700	23	8	620	28	130	2.8	0.19	49	23	527	14	Pass	Pass (excellent)	Pass	Ex.
8	8	1260	920	9	680	1.9	91	695	41	8	605	15	115	0.7	0.17	53	21	591	17	Pass	Pass (excellent)	Pass	Ex.
9	9	1255	865	10	705	1.8	90	710	16	8	630	26	135	2.1	0.18	47	18	554	15	Pass	Pass (excellent)	Pass	Ex.
10	10	1240	880	9	715	1.9	91	770	57	5	640	19	140	1.2	0.17	55	16	570	16	Pass	Pass (good)	Pass	Ex.
11	11	1250	875	10	695	2.1	92	715	30	7	610	22	135	0.9	0.17	51	26	552	15	Pass	Pass (excellent)	Pass	Ex.
12	12	1230	910	11	650	2.0	86	730	28	8	650	14	140	1.3	0.28	43	19	549	16	Pass	Pass (good)	Pass	Ex.
13	13	1235	925	11	680	2.4	92	710	43	6	640	18	145	0.8	0.19	50	27	564	18	Pass	Pass (good)	Pass	Ex.
14	14	1305	945	10	725	2.2	91	775	55	9	655	21	120	0.9	0.20	58	25	557	16	Pass	Pass (good)	Pass	Ex.
15	15	1200	950	10	650	1.9	91	660	18	3	625	25	135	1.0	0.17	46	22	532	14	Pass	Pass (excellent)	Pass	Ex.
16	16	1285	885	9	750	1.9	91	675	23	5	615	17	115	0.7	0.17	63	20	568	16	Pass	Pass (excellent)	Pass	Ex.
17	17	1270	870	10	735	2.0	90	670	36	6	635	20	130	0.6	0.20	59	21	551	16	Pass	Pass (excellent)	Pass	Ex.
18	18	1280	930	9	640	2.0	91	735	21	7	625	16	135	0.9	0.18	43	18	586	14	Pass	Pass (good)	Pass	Ex.
19	19	1220	860	9	695	2.6	93	720	39	4	615	22	125	1.0	0.18	56	17	535	17	Pass	Pass (excellent)	Pass	Ex.
20	20	1295	925	10	645	2.3	92	705	45	8	620	18	135	0.9	0.18	42	22	581	16	Pass	Pass (excellent)	Pass	Ex.
21	21	1240	905	10	685	2.0	89	740	28	7	610	16	140	0.8	0.22	47	19	553	16	Pass	Pass (excellent)	Pass	Ex.
22	22	1265	890	10	760	2.0	88	725	42	7	640	24	140	0.9	0.24	61	18	606	14	Pass	Pass (good)	Pass	Ex.
23	23	1210	875	10	680	1.9	91	690	44	9	650	15	130	1.6	0.17	51	24	568	15	Pass	Pass (excellent)	Pass	Ex.

Table 2(cont'd)

Steel sheet No.	Steel No.	Steel material heating temperature (°C)	Rolling finish temperature (°C)	Rolling reduction in final stand (%)	Coiling temperature (°C)	Hot-rolled sheet thickness (mm)	Rolling reduction in primary cold rolling (%)	Soaking temperature (°C)	Soaking holding time (s)	Primary cooling average rate (°C/s)	Primary cooling stop temperature (°C)	Secondary cooling average rate (°C/s)	Secondary cooling stop temperature (°C)	Rolling reduction in secondary cold rolling (%)	Finish sheet thickness (mm)	Ratio of Nb content in precipitates of less than 20 nm in size (%)	Average precipitate interval (nm)	Upper yield stress in rolling direction (MPa)	Total elongation (%)	Corrosion resistance	Uniform deformability	Curl height	Remarks
24	24	1275	935	9	700	1.9	91	680	31	8	635	23	130	0.9	0.17	55	23	592	17	Pass	Pass (excellent)	Pass	Ex.
25	25	1240	900	9	690	1.7	89	715	22	8	615	18	125	0.8	0.19	54	21	554	17	Pass	Pass (excellent)	Pass	Ex.
26	26	1230	875	8	665	1.8	90	720	58	8	625	21	135	0.7	0.18	37	29	648	6	Pass	Fail	Pass	Comp. Ex.
27	27	1220	855	9	710	1.8	91	725	24	8	620	14	100	0.3	0.16	33	26	656	8	Pass	Fail	Pass	Comp. Ex.
28	28	1210	915	9	725	2.0	90	750	17	7	615	23	120	0.5	0.20	35	28	645	7	Pass	Fail	Pass	Comp. Ex.
29	29	1235	925	10	670	2.0	89	715	29	7	620	22	135	0.8	0.22	32	42	541	15	Pass	Fail	Fail	Comp. Ex.
30	30	1265	900	11	740	2.1	91	665	13	4	605	30	105	2.8	0.18	36	27	474	27	Pass	Fail	Pass	Comp. Ex.
31	31	1240	885	11	715	2.6	93	700	27	8	625	27	110	1.6	0.18	28	27	482	25	Pass	Fail	Pass	Comp. Ex.
32	32	1220	890	8	750	2.2	91	715	42	6	610	29	130	0.5	0.20	41	26	529	15	Fail	Pass (good)	Pass	Comp. Ex.
33	33	1205	905	8	650	2.0	92	730	51	8	665	10	140	0.9	0.16	35	24	632	10	Fail	Fail	Pass	Comp. Ex.
34	34	1235	910	10	685	2.0	90	695	46	8	625	24	150	0.8	0.20	41	28	457	16	Pass	Pass (good)	Pass	Comp. Ex.
35	35	1260	930	10	645	1.9	91	700	24	9	670	15	140	1.0	0.17	33	49	563	14	Fail	Fail	Fail	Comp. Ex.
36	36	1335	870	11	705	2.4	90	790	19	9	640	21	135	0.6	0.24	42	21	472	18	Pass	Pass (good)	Pass	Comp. Ex.
37	37	1275	860	10	670	1.8	89	735	52	6	630	17	120	0.7	0.20	31	23	540	14	Pass	Fail	Pass	Comp. Ex.
38	38	1255	915	10	775	2.0	91	680	27	6	645	24	115	1.9	0.18	34	22	551	13	Pass	Fail	Pass	Comp. Ex.
39	39	1215	930	9	730	2.1	91	675	50	7	625	20	140	1.4	0.19	42	28	486	19	Pass	Pass (good)	Pass	Comp. Ex.
40	40	1220	925	10	670	2.1	87	690	41	9	635	18	135	2.1	0.27	41	29	455	18	Pass	Pass (good)	Pass	Comp. Ex.
41	41	1265	895	10	650	1.9	90	740	33	6	610	22	130	0.9	0.19	32	17	548	8	Pass	Fail	Pass	Comp. Ex.
42	42	1285	905	9	765	2.4	91	725	18	6	615	19	140	1.5	0.21	35	21	552	8	Pass	Fail	Pass	Comp. Ex.
43	43	1230	880	9	690	2.4	92	690	26	8	620	16	125	0.9	0.19	41	26	464	16	Pass	Pass (good)	Pass	Comp. Ex.
44	44	1210	865	9	720	1.9	89	705	28	8	625	23	135	0.8	0.21	41	28	477	18	Pass	Pass (good)	Pass	Comp. Ex.
45	45	1230	870	9	675	2.0	90	700	31	7	620	18	140	0.7	0.20	33	27	623	10	Fail	Fail	Pass	Comp. Ex.

Note: Underlines indicate outside range according to present disclosure.

Table 3

Steel sheet No.	Steel No.	Steel material heating temperature (°C)	Rolling finish temperature (°C)	Rolling reduction in final stand (%)	Coiling temperature (°C)	Hot-rolled sheet thickness (mm)	Rolling reduction in primary cold rolling (%)	Soaking temperature (°C)	Soaking holding time (s)	Primary cooling average rate (°C/s)	Primary cooling stop temperature (°C)	Secondary cooling average rate (°C/s)	Secondary cooling stop temperature (°C)	Rolling reduction in secondary cold rolling (%)	Finish sheet thickness (mm)	Ratio of Nb content in precipitates of less than 20 nm in size (%)	Average precipitate interval (nm)	Upper yield stress in rolling direction (MPa)	Total elongation (%)	Corrosion resistance	Uniform deformability	Curl height	Remarks
46	3	1230	915	11	640	1.9	90	715	32	9	620	16	140	1.0	0.19	42	21	561	17	Pass	Pass (excellent)	Pass	Ex.
47	3	1140	890	10	720	1.9	90	665	29	9	605	24	120	2.3	0.19	53	15	483	19	Pass	Pass (good)	Pass	Comp. Ex.
48	3	1215	810	10	680	1.9	89	730	11	9	615	21	145	0.6	0.21	37	27	535	12	Pass	Fail	Pass	Comp. Ex.
49	3	1245	910	6	655	1.8	90	705	24	7	630	17	135	0.9	0.18	44	38	572	18	Pass	Pass (excellent)	Fail	Comp. Ex.
50	3	1210	865	8	660	2.0	91	690	58	7	575	16	120	1.5	0.18	47	25	479	22	Pass	Pass (good)	Pass	Comp. Ex.
51	3	1240	930	9	690	2.5	89	720	25	8	640	15	135	0.7	0.27	52	17	544	19	Pass	Pass (excellent)	Pass	Ex.
52	3	1290	905	9	805	2.3	91	710	41	8	610	15	110	1.2	0.20	42	28	491	13	Pass	Pass (good)	Pass	Comp. Ex.
53	13	1235	870	9	645	1.8	91	695	19	8	605	23	120	1.4	0.16	41	26	586	20	Pass	Pass (excellent)	Pass	Ex.
54	13	1225	935	7	735	1.8	90	710	30	8	650	23	130	2.0	0.18	55	35	550	16	Pass	Pass (excellent)	Fail	Comp. Ex.
55	16	1205	855	9	685	1.9	91	745	104	9	620	18	140	0.8	0.17	48	24	487	17	Pass	Pass (good)	Pass	Comp. Ex.
56	16	1220	870	9	705	2.0	91	715	52	12	635	22	135	0.9	0.18	51	22	470	21	Pass	Pass (good)	Pass	Comp. Ex.
57	16	1250	910	10	715	1.7	84	685	33	7	615	25	130	1.9	0.27	53	19	483	18	Pass	Pass (good)	Pass	Comp. Ex.
58	16	1230	890	10	650	2.3	93	705	11	7	625	10	105	0.3	0.16	44	26	547	22	Pass	Pass (excellent)	Pass	Ex.
59	16	1295	945	11	695	1.9	91	690	29	7	645	27	140	1.1	0.17	50	20	573	19	Pass	Pass (excellent)	Pass	Ex.
60	16	1255	915	9	660	1.9	88	720	42	8	630	16	120	0.4	0.23	46	27	565	21	Pass	Pass (excellent)	Pass	Ex.
61	16	1270	880	10	725	2.0	90	670	35	8	615	17	135	0.9	0.20	57	18	581	20	Pass	Pass (excellent)	Pass	Ex.
62	21	1240	925	10	680	2.0	89	680	18	8	630	22	120	4.8	0.21	52	24	558	14	Pass	Fail	Pass	Comp. Ex.
63	21	1260	890	10	560	2.0	89	725	37	8	610	26	140	1.2	0.22	36	26	526	13	Pass	Fail	Pass	Comp. Ex.
64	21	1225	875	10	730	1.8	90	730	44	3	640	18	120	1.4	0.18	59	17	582	18	Pass	Pass (excellent)	Pass	Ex.
65	21	1245	890	8	690	1.8	90	675	24	9	620	30	130	0.8	0.18	53	22	554	23	Pass	Pass (excellent)	Pass	Ex.

Note: Underlines indicate outside range according to present disclosure.

Table 3(cont'd)

Steel sheet No.	Steel No.	Steel material heating temperature (°C)	Rolling finish temperature (°C)	Rolling reduction in final stand (%)	Coiling temperature (°C)	Hot-rolled sheet thickness (mm)	Rolling reduction in primary cold rolling (%)	Soaking temperature (°C)	Soaking holding time (s)	Primary cooling average rate (°C/s)	Primary cooling stop temperature (°C)	Secondary cooling average rate (°C/s)	Secondary cooling stop temperature (°C)	Rolling reduction in secondary cold rolling (%)	Finish sheet thickness (mm)	Ratio of Nb content in precipitates of less than 20 nm in size (%)	Average precipitate interval (nm)	Upper yield stress in rolling direction (MPa)	Total elongation (%)	Corrosion resistance	Uniform deformability	Curl height	Remarks
66	21	1205	865	8	740	1.8	90	615	53	9	615	12	120	0.5	0.18	62	19	512	7	Pass	Pass (good)	Pass	Comp. Ex.
67	21	1230	920	11	680	1.6	86	725	21	9	630	8	120	2.9	0.22	37	23	547	13	Pass	Fail	Pass	Comp. Ex.
68	21	1250	935	11	655	2.7	92	735	29	6	605	14	140	11.0	0.19	45	26	585	11	Pass	Fail	Pass	Comp. Ex.
69	21	1240	915	10	690	2.0	90	840	34	6	610	12	130	1.5	0.20	42	28	487	13	Pass	Pass (good)	Pass	Comp. Ex.
70	21	1225	890	9	685	2.0	91	715	25	1	620	13	135	1.6	0.18	37	26	546	13	Pass	Pass (good)	Fail	Comp. Ex.
71	21	1260	905	9	710	1.9	90	685	38	7	635	16	110	1.3	0.19	54	21	569	18	Pass	Pass (excellent)	Pass	Ex.
72	24	1275	900	10	695	1.9	91	700	49	7	650	21	130	0.7	0.17	52	22	604	16	Pass	Pass (excellent)	Pass	Ex.
73	24	1230	880	10	600	1.9	91	710	30	5	620	15	140	1.1	0.17	35	28	523	12	Pass	Fail	Pass	Comp. Ex.
74	24	1300	900	9	690	1.8	90	725	27	5	630	19	140	1.1	0.18	53	20	548	19	Pass	Pass (excellent)	Pass	Ex.
75	24	1255	920	9	540	1.8	86	750	41	9	630	11	130	1.1	0.25	34	25	517	12	Pass	Fail	Pass	Comp. Ex.
76	24	1225	890	8	700	2.7	94	695	56	8	675	20	120	0.9	0.16	38	28	545	14	Pass	Pass (good)	Fail	Comp. Ex.
77	24	1250	880	8	675	2.3	92	715	23	8	625	16	120	0.9	0.18	46	26	541	20	Pass	Pass (excellent)	Pass	Ex.
78	24	1230	905	10	720	2.0	91	720	49	9	615	30	145	2.4	0.18	54	19	539	21	Pass	Pass (excellent)	Pass	Ex.
79	27	1205	860	10	680	2.3	92	675	18	9	630	24	170	0.7	0.18	34	22	656	5	-	Fail	Pass	Comp. Ex.
80	27	1290	875	9	715	2.3	93	690	30	8	655	6	140	0.4	0.16	36	20	649	7	-	Fail	Pass	Comp. Ex.
81	35	1275	935	6	665	1.9	90	720	25	8	640	13	100	1.8	0.19	31	41	662	4	Pass	Fail	Fail	Comp. Ex.
82	37	1250	885	11	715	2.1	90	720	19	8	625	17	135	7.7	0.19	33	21	613	11	Pass	Fail	Pass	Comp. Ex.
83	37	1265	930	10	735	2.1	92	715	37	8	630	7	125	1.3	0.17	35	19	540	12	Pass	Fail	Pass	Comp. Ex.
84	42	1210	945	10	575	1.9	89	680	44	8	645	21	120	1.0	0.21	33	27	554	7	-	Fail	Pass	Comp. Ex.
85	42	1225	920	10	705	1.9	89	685	31	8	615	26	200	1.0	0.21	34	24	496	8	-	Fail	Pass	Comp. Ex.

Note: Underlines indicate outside range according to present disclosure.

[0076] As can be seen from Tables 2 and 3, in each Example (Ex.), a high-ductility and high-strength steel sheet for cans having superior uniform deformability was obtained. Further, the corrosion resistance and the dimensional accuracy of the height of the curl portion of the can lid were superior.

INDUSTRIAL APPLICABILITY

[0077] It is thus possible to obtain a steel sheet for cans having high strength, excellent ductility, and excellent uniform deformability. The steel sheet for cans also has favorable corrosion resistance even against highly corrosive contents. Such a steel sheet for cans is optimal mainly for use in a three-piece can produced using can body forming with a large amount of deformation, a two-piece can produced by forming a bottom portion in several %, and a can lid.

Claims

1. A steel sheet for cans, comprising
a chemical composition containing, in mass%,
C: 0.020 % or more and 0.130 % or less,
Si: 0.04 % or less,
Mn: 0.10 % or more and 1.20 % or less,
P: 0.007 % or more and 0.100 % or less,
S: 0.030 % or less,
Al: 0.001 % or more and 0.100 % or less,
N: more than 0.0120 % and 0.0200 % or less,
Nb: 0.0060 % or more and 0.0300 % or less, and
Cr: 0.040 % or less,
with a balance being Fe and inevitable impurities,
wherein a ratio of Nb content in precipitates of less than 20 nm in size to Nb content in all precipitates is 40 % or more,
an average interval of all precipitates is 30 nm or less,
an upper yield stress after heat treatment at 210 °C for 10 min is 500 MPa or more and 640 MPa or less, and
a total elongation after the heat treatment is 10 % or more.

2. A method of producing a steel sheet for cans, comprising:

performing a hot rolling process of heating a steel material at 1200 °C or more, hot rolling the steel material under conditions of a finish temperature of 850 °C or more and a rolling reduction in a final stand of 8 % or more to obtain a rolled sheet, and coiling the rolled sheet in a temperature range of 640 °C or more and 780 °C or less, the steel material having a chemical composition containing, in mass%, C: 0.020 % or more and 0.130 % or less, Si: 0.04 % or less, Mn: 0.10 % or more and 1.20 % or less, P: 0.007 % or more and 0.100 % or less, S: 0.030 % or less, Al: 0.001 % or more and 0.100 % or less, N: more than 0.0120 % and 0.0200 % or less, Nb: 0.0060 % or more and 0.0300 % or less, and Cr: 0.040 % or less, with a balance being Fe and inevitable impurities;
performing, after the hot rolling process, a primary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 86 % or more;
performing, after the primary cold rolling process, an annealing process of soaking the rolled sheet in a temperature range of 660 °C or more and 800 °C or less, subjecting the rolled sheet to primary cooling to a temperature range of 600 °C or more and 650 °C or less at an average cooling rate of 3 °C/s or more and less than 10 °C/s, and subjecting the rolled sheet to secondary cooling to a temperature range of 150 °C or less at an average cooling rate of 10 °C/s or more; and
performing a secondary cold rolling process of cold rolling the rolled sheet with a rolling reduction of 0.1 % or more and 3.0 % or less.

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/033548

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C22C38/00(2006.01)i, B21B1/00(2006.01)i, C21D9/46(2006.01)i, C22C38/26(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. C22C38/00-38/60, B21B1/00, C21D9/46, C21D9/48

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2018-59196 A (JFE STEEL CORPORATION) 12 April 2018 (Family: none)	1-2
A	JP 2017-155267 A (JFE STEEL CORPORATION) 07 September 2017 (Family: none)	1-2
A	WO 2016/031234 A1 (JFE STEEL CORPORATION) 03 March 2016 & KR 10-2017-0029635 A & CN 106605006 A & TW 201610180 A	1-2

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
08 November 2019 (08.11.2019)	19 November 2019 (19.11.2019)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP H8325670 A **[0006] [0007]**
- JP 2004183074 A **[0006] [0007]**
- JP 2001089828 A **[0006] [0007]**
- JP 5858208 B **[0006] [0007]**