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(54) **STEEL SHEET FOR CANS, HOT-ROLLED STEEL SHEET TO BE USED AS THE BASE METAL AND PROCESSES FOR PRODUCTION OF BOTH**

STAHLBLECH FÜR DOSEN, HEISSGEWALZTES STAHLBLECH ZUR VERWENDUNG ALS BASISMETALL UND HERSTELLUNGSVERFAHREN FÜR BEIDE

TÔLE D'ACIER POUR BOÎTES DE CONSERVE, TÔLE D'ACIER LAMINÉ À CHAUD À UTILISER COMME MÉTAL DE BASE ET PROCÉDÉS DE FABRICATION DES DEUX TYPES DE TÔLE

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Description

Technical Field

[0001] The present invention relates to a cold-rolled steel sheet and a hot-rolled steel sheet for use as a base material of the tin mill black sheet. The present invention also relates to processes for manufacturing a cold-rolled steel sheet and a hot-rolled steel sheet used as a base material of the black plate. Specifically, the present invention relates to a cold-rolled steel sheet having high ductility, high strength, and low anisotropy (Δr) (in-plate plastic anisotropy), a hot-rolled steel sheet for use as a base material of the tin mill black sheet and processes for manufacturing the cold-rolled steel sheet and the hot-rolled steel sheet.

Background Art

[0002] In recent years, in order to expand demand for steel cans, there have been taken measures for reducing can manufacturing cost and marketing new can types such as bottle shaped cans and shaped cans.

[0003] As a measure for reducing the can manufacturing cost, the cost of raw materials is reduced. Namely, for both two-piece cans formed by drawing and three-piece cans mainly formed by simple cylinder forming, gauge down of.the steel sheet used is advanced.

[0004] However, since simple gauge down of steel sheets decreases the strength of can bodies, steel sheets simply having undergone gauge down cannot be used, and it is necessary to use a tin mill black plate which is ultrathin and hard.

[0005] Such ultrathin and hard cold-rolled steel sheet are currently manufactured by a double reduce method (referred to as a "DR method" hereinafter) including annealing and subsequent secondary cold rolling. Steel sheets manufactured by the DR method are characterized by high strength and small yield point elongation. In application to DRD cans (drawn and redrawn can) associated with bottom forming, the yield point elongation is preferably as small as possible in order to prevent the occurrence of stretcher strain. From this viewpoint, the DR method is effective. However, DRD cans are desired to have little earing, but earing easily occurs in the DR method because anisotropy tends to increase. There is thus the issue of decreasing the anisotropy (represented by Δr) in order to prevent the occurrence of earing.

[0006] On the other hand, shaped cans which have recently been marketed are associated with body shaping at a high working rate. However, DR materials having low ductility are difficult to apply to shaped cans because of low workability. In addition, the number of manufacturing steps for the DR materials is increased to increase the manufacturing cost as compared with steel sheets undergoing usual temper rolling after annealing.

[0007] In order to remove the disadvantages of the DR materials, there have been proposed, as a single reduce method (SR method) for controlling characteristics by mainly primary cold rolling and annealing steps without secondary cold rolling, various methods, such as a method for manufacturing a high-strength steel sheet using various strengthening methods and a method for manufacturing a steel sheet having a low occurrence rate of earing, as described below.

[0008] For example, Japanese Unexamined Patent Application Publication No. 2001-107186 (Patent Document 1) has proposed a technique of adding large amounts (total of 0.0050% by mass or more) of C and N and bake-hardening a steel sheet to produce a steel sheet for high-strength cans equivalent to DR materials. In this technique, hardness due to aging is controlled by the amount of N added, the prevention of AlN precipitation due to accelerated cooling and low-temperature coiling (600°C or lower) after hot rolling, and heat treatment conditions (e.g., rapid cooling after recrystallization annealing). In addition, yield stress (YS: yield strength, also referred to as "yield point YP") after baking after lacquering is as high as 550 MPa or more.

[0009] Further, Japanese Unexamined Patent Application Publication No. 11-199991 (Patent Document 2) has proposed a technique of increasing strength by baking after lacquering as in Patent Document 1. However, in the technique of this publication, aging is mainly due to solute C (about 5 to 15 ppm) in order to secure non-aging property, and decarbonization is performed by continuous annealing. In addition, N is not used as an aging element but fixed by precipitation as AlN by coiling at 600°C or higher (substantially about 680°C), resulting in an amount of bake hardening of about 40 to 55 MPa.

[0010] Japanese Unexamined Patent Application Publication No. 2005-336610 (Patent Document 3) has proposed that precipitation hardening by a Nb carbide and solution hardening by Mn, P, and N are combined, and a fine grain structure of ferrite having an average crystal grain size of 7 μm or less is formed, thereby obtaining a steel sheet having both high strength (tensile strength TS: 550 MPa or more) and high ductility (elongation: 10% or more). Grain refining of ferrite is achieved by a C content (0.04% by mass or more) and coiling temperature (CT) (630°C or lower). It is also disclosed that YP achieved by this technique is about 480 to 550 MPa.

[0011] Japanese Unexamined Patent Application Publication No. 59-129733 (Patent Document 4) has proposed a manufacturing method in which the C content is suppressed to 0.0030% or less, and temper rolling of 10% or more is performed, thereby producing steel having a yield point elongation of about 1.0% or less, causing no occurrence of stretcher strain, and having a strength level corresponding to T4 to T6 grades.

[0012] Japanese Unexamined Patent Application Publication No. 11-222647 (Patent Document 5) has proposed a ultrathin steel sheet obtained by primary cold rolling of 80 to 88%, having an average crystal grain size of 6 μm or less, causing no occurrence of stretcher strain, and having a low occurrence rate of earing (Δr within ±0.1).

[0013] Japanese Unexamined Patent Application Publication No. 2003-34825 (Patent Document 6) has proposed a technique for obtaining a high-strength steel sheet using grain refining due to transformation. In this technique, low-carbon steel is hot-rolled in an $\alpha + \gamma$ region and then cooled at a high rate, and the heating rate of annealing is specified to refine grains of the steel sheet, thereby producing the steel sheet having a tensile strength of 600 MPa and a total elongation of 30% or more.

Disclosure of Invention

[Problem to be Solved by the Invention]

[0014] In order to gauge down, it is necessary to secure strength. For example, in order to achieve existing can body strength using a steel sheet having the same thickness (about 0.15 to 0.18 mm) as that of DR materials, a yield strength of 500 MPa or more is required. In addition, it is necessary to apply a steel sheet with high ductility to can bodies formed by a high degree of body shaping such as expanding and can bodies formed by a high degree of flanging. Since the trim margin in an ear portion is increased to decrease process yield when steel with a high occurrence rate of earing is applied to a two-piece can such as a DRD can, a steel sheet having a low occurrence rate of earing, i.e., low anisotropy, is desired.

[0015] In consideration of the above-mentioned characteristics, the above-described prior art is capable of manufacturing a steel sheet satisfying any one of strength, ductility, and anisotropy, but a steel sheet satisfying all of the properties cannot be manufactured.

[0016] For example, the method of increasing strength by adding large amounts of C and N and bake hardening as described in Patent Document 1 is effective in increasing strength. However, anisotropy intended in the present invention cannot be achieved by the microstructure obtained in Patent Document 1. This is possibly concerned in the fact that considering in comparison with the technique of the present invention which will be described below, in the technique of Patent Document 1, the crystal grains in a hot-rolled steel sheet are not sufficiently grown because of accelerated cooling started within 0.5 seconds after the finish of hot rolling, coiling at a coiling temperature of 600°C or lower, and water cooling after coiling.

[0017] In Patent Document 2, age hardening is performed by baking, but the tensile strength of steel described in examples is up to about 380 MPa, and a yield strength of 500 MPa or more which is intended in the present invention cannot be achieved.

[0018] In Patent Document 3, strength is increased by composite hardening including precipitation hardening and solution hardening. However, steel having undergone precipitation hardening generally has low anisotropy, and, in particular, the anisotropy intended in the present invention cannot be achieved under the hot-rolling conditions proposed in Patent Document 3.

[0019] Patent Document 4 discloses steel at the T6 level where yield point elongation becomes substantially zero, but temper rolling with a rolling rate of 10% or more is required. Therefore, the manufacturing method is substantially the same as that for DR materials and costs much, and manufacture of steel over the T6 level is not described. Further, ductility is not described in the specification of Patent Document 4, but it is assumed that rolling at a reduction ratio of 10% or more degrades ductility.

[0020] Patent Document 5 describes the method for manufacturing a steel sheet in which the occurrence of earing is suppressed by controlling chemical components and manufacturing conditions such as hot rolling conditions. However, the yield point strength of steel described in examples is up to about 420 MPa and thus does not reach 500 MPa or more which is a target of the present invention.

[0021] Hardening by rapid cooling proposed in Patent Document 6 increases the operation cost. In addition, anisotropy intended in the present invention cannot be achieved by the structure obtained in Patent Document 6. This is possibly concerned in the fact that considering in comparison with the technique of the present invention which will be described below, in the technique of Patent Document 6, the crystal grains in a hot-rolled steel sheet are not sufficiently grown because of cooling started at a cooling rate of 100 °C/s or more in a temperature range of 80°C or higher within 1 second after the finish of hot rolling, and coiling at 650°C or lower.

[0022] The present invention has been achieved in consideration of the above-mentioned situation, and provides a cold-rolled steel sheet which can have a yield point strength of 500 MPa or more, a yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0 each after baking after lacquering, a hot-rolled steel sheet for use as a base material of the tin mill black sheet, and processes for manufacturing the tin mill black plate and the hot-rolled steel sheet.

[Means for Solving the Problem]

[0023] In order to solve the above-described problems, the inventors have studied extensively. As a result, the following findings were obtained.

[0024] The inventors paid attention to a composite combination of solution hardening, precipitation hardening, crystal grain refining hardening, and age hardening. Namely, strength is increased with elongation kept high by solution hardening using a solution hardening element, and by composite hardening using Nb, P, and Mn including solution hardening, precipitation hardening and grain refining hardening. Further, strength is increased by age hardening after baking after lacquering using solute C and solute N in steel. In addition, the microstructure is substantially a ferrite single phase structure, and the ferrite average crystal grain size is defined to maintain both high strength and high ductility, thereby achieving a yield point strength of 500 MPa or more and a total elongation of 10% or more. In particular, in the present invention, consideration is given to deterioration in anisotropy which is the problem of use of precipitation hardening, and hot rolling conditions are properly controlled to improve (i.e. remedy) anisotropy, thereby achieving Δr of -0.50 to 0.

[0025] In the present invention, on the basis of the above-mentioned finding, a cold-rolled steel sheet with high strength and high ductility and a process for manufacturing thereof can be completed by comprehensively controlling components and the manufacturing process.

[1] A cold-rolled steel sheet (tin mill black plate) for cans, the cold-rolled steel sheet having a composition containing, by mass, 0.04 to 0.12% of C, 0.005 to 0.5% of Si, 0.3 to 1.5% of Mn, 0.005 to 0.2% of P, 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb, the balance comprising iron and inevitable impurities, and a microstructure substantially composed of a ferrite single phase, the ferrite average crystal grain size being 7 μm or less, wherein properties, that is, a yield point strength of 500 MPa or more, a yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0, can be achieved by baking after lacquering.

[2] A process for manufacturing the cold-rolled steel sheet (tin mill black plate) for cans described above in [1], the process including hot-rolling, at a finishing temperature (FT) of 870°C or higher, steel consisting of, by mass, 0.04 to 0.12% of C, 0.005 to 0.5% of Si, 0.3 to 1.5% of Mn, 0.005 to 0.2% of P, 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb, the balance comprising iron and inevitable impurities, then cooling the steel at an average cooling rate of 40 °C/s or less until coiling, coiling the steel at a coiling temperature of 620°C or higher, cold-rolling the steel at a reduction ratio of 80% or more, continuously annealing the steel under conditions of a soaking temperature of 650°C to 750°C and a soaking time of 40 seconds or less, and then temper-rolling the steel at a temper elongation of 1.5% or less.

[3] A hot-rolled steel sheet suitable for use as a base material of a tin mill black plate, the steel sheet having a composition consisting of, by mass, 0.04 to 0.12% of C, 0.005 to 0.5% of Si, 0.3 to 1.1 % of Mn, 0.005 to 0.2% of P, more than 0.02% and 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb, the balance comprising iron and inevitable impurities, and a microstructure substantially composed of a ferrite single phase, the ferrite average crystal grain size being 6 μm or more.

[4] A process for manufacturing a hot-rolled steel sheet comprising hot-rolling, at a finishing temperature (FT) of 870°C or higher, steel consisting of, by mass, 0.04 to 0.12% of C, 0.005 to 0.5% of Si, 0.3 to 1.5% of Mn, 0.005 to 0.2% of P, 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb, the balance comprising iron and inevitable impurities, then cooling the steel at an average cooling rate of 40 °C/s or less until coiling, and coiling the steel at a coiling temperature of 620°C or higher.

[0026] In the specification, "%" of each component of the steel is "% by mass". For example, the expression "0.005 to 0.5% of Si" means that Si is 0.005% or more and 0.5% or less, or $0.005\% \leq Si \leq 0.5\%$.

[0027] In addition, in the present invention, "baking after lacquering" means a heat treatment at 210°C for 20 minutes corresponding to baking after lacquering, and differs from so-called bake hardening in which pre-strain is applied for aging.

Brief Description of Drawings

[0028] Fig. 1 is a diagram showing a relation between anisotropy (Δr) (ordinate) of a tin mill black plate (cold-rolled steel sheet) and a ferrite average crystal grain size (abscissa: μm) of a hot-rolled steel sheet used as a base material for a tin mill black plate.

Best Mode for Carrying Out the Invention

[0029] The present invention will be described in detail below.

[0030] A cold-rolled steel sheet of the present invention is a high-strength, high-ductility cold-rolled steel sheet which can have steel sheet properties obtained by baking after lacquering, such as a yield point strength of 500 MPa or more, a yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0. Although the baking after lacquering is based on a treatment at 210°C for 20 minutes, substantially the similar effect can be obtained by a heat treatment at 180°C to 265°C for 2 to 30 minutes. In addition, as a heat treatment for age hardening, heat laminating may be performed instead of baking after lacquering. Hereinafter, the baking after lacquering includes similar heat treatments such as heat laminating and the like.

[0031] The present invention also includes a cold-rolled steel sheet having the above-described plate properties and having undergone baking after lacquering. In this case, the conditions for baking after lacquering preferably meet the . above-described references, but are not particularly limited as long as the plate properties can be achieved under the conditions.

[0032] A steel sheet in which strength is increased by the DR method generally exhibits an elongation of several %. On the other hand, the present invention is characterized in that a steel sheet undergoing solution hardening using Nb, P, and Mn, precipitation hardening, and grain refining hardening is manufactured by continuous annealing, thereby increasing strength while maintaining high elongation. Further, proper amounts of solute C and solute N are left in steel so that age hardening of 30 MPa or more is caused by a heat treatment necessary for a can making process such as baking after lacquering. Namely, YP is increased by age hardening, thereby enabling increased in pressure capacity at the bottom of a drawn can and the dent strength of a welded can.

[0033] Further, when the finishing temperature in hot rolling is 870°C or higher, the cooling rate is 40 °C/s or less, and the coiling temperature is 620 °C or higher, a Δr value in the range of -0.50 to 0 can be obtained.

[0034] These properties are characteristics of the present invention and important factors. Therefore, the cold-rolled steel sheet having a yield point strength of 500 MPa or more, a yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0 can be obtained by optimizing the components mainly including a solution hardening element, a precipitation hardening element, and a grain refining hardening element, the microstructure, and the manufacturing conditions.

[0035] Next, the composition of the cold-rolled steel sheets of the present invention will be described.

• C: 0.04 to 0.12%

[0036] It is essential for the cold-rolled steel sheet of the present invention to achieve predetermined strength or more (yield point strength of 500 MPa or more) and have a total elongation of 10% or more after continuous annealing and temper rolling. Therefore, it is necessary that the ferrite average crystal grain size is 7 μm or less. In order to manufacture the cold-rolled steel sheet satisfying these properties, the C content is important. In particular, the amount and density of a carbide are greatly concerned in the strength and ferrite average crystal grain size of the cold-rolled steel sheet, and thus it is necessary to secure a carbon amount which can be used for precipitation. Further, precipitation of a carbide at grain boundaries suppresses grain boundary segregation of P and thus has the effect of maximizing solution hardening by P.

[0037] In order to achieve the above effect, the lower limit of the amount of C added is limited to 0.04%. On the other hand, the upper limit is limited to 0.12% because when the C content exceeds 0.12%, sub-peritectic cracking occurs in a cooling step for steel making. The upper limit is preferably 0.10% or less.

• Si: 0.005 to 0.5%

[0038] Si is an element which increases strength of steel by solution hardening, but a high Si content significantly impairs corrosion resistance. Therefore, the upper limit of the Si content is limited to 0.5%. The upper limit is preferably 0.05% or less. On the other hand, in applications required to have high corrosion resistance, the Si content must be minimized, but the lower limit is limited to 0.005% in view of reduction cost.

• Mn: 0.3 to 1.5%

[0039] Mn increases steel strength by solution hardening and also decreases a crystal gain size. When the Mn content is 0.3% or more, the effect of decreasing a crystal grain size significantly occurs, and a Mn content of at least 0.3% is required for securing the intended strength. Therefore, the lower limit of the Mn content is limited to 0.3%. On the other hand, when the Mn content is high, corrosion resistance is degraded. Therefore, the upper limit of the Mn content is limited to 1.5%. Preferably, the upper limit is 1.1% or less.

• P: 0.005% to 0.2%

[0040] P is an element having a high ability of solution hardening, but corrosion resistance is significantly degraded when a large amount of P is added. Therefore, the upper limit is limited to 0.2% and preferably 0.1% or less. On the other hand, in application required to have high corrosion resistance, it is necessary to minimize the amount of P added. However, in view of reduction cost, the lower limit is limited to 0.005%.

• Al: 0.10% or less

[0041] When the Al content is increased, the recrystallization temperature is increased, thereby causing the need to increase the annealing temperature. In the present invention, the recrystallization temperature is also increased by another element added for increasing strength, and thus the annealing temperature is increased. Therefore, it is preferred to avoid an increase in the recrystallization temperature due to Al. Therefore, the upper limit of the Al content is limited to 0.10%. From the viewpoint that deoxidization is sufficiently performed for suppressing the occurrence of bubbles in steel due to oxygen residue, the Al content preferably exceeds 0.02%.

• N: 0.012% or less

[0042] N is an element having the effect of increasing age hardening. In order to exhibit the age hardening effect, it is preferred to add 0.005% or more and preferably 0.0060% or more of N. On the other hand, when a large amount is added, hot-rolling ductility is degraded, and slab cracking easily occurs in an unbending zone during continuous casting. Therefore, the upper limit of the N content is limited to 0.012%. When age hardening by N is not positively utilized, the N content may be about 0.001 to 0.004%. In this case, YS grows lower unless a larger amount of another hardening element is added.

• Nb: 0.005 to 0.10%

[0043] Nb is an important element to be added in the present invention. Nb is an element having a high ability of forming a carbide and precipitates a fine carbide to increase strength. Also, strength is increased by grain refining of ferrite. Further, the grain size influences not only strength but also surface properties in drawing. When the ferrite average crystal grain size of a final product exceeds 7 μm, surface roughness phenomenon occurs in a portion after drawing, thereby losing the beauty of the surface appearance. As described above, strength and surface properties can be controlled by the amount of Nb added, and this effect occurs when the Nb content exceeds 0.005%. Therefore, the lower limit of the Nb content is limited to 0.005%. The Nb content is preferably 0.01% or more.

[0044] On the other hand, Nb increases the recrystallization temperature. Therefore, when over 0.10% of Nb is added, an unrecrystallized portion remains in continuous annealing performed at a soaking temperature of 650 to 750°C for a soaking time of 40 seconds or less, which are specified in the present invention, thereby causing difficulty in annealing. When the annealing temperature is increased as a countermeasure against this, a recrystallized structure is obtained, but the elements in steel are concentrated in a surface layer, thereby degrading surface properties. Therefore, the upper limit of the Nb content is limited to 0.10%. The Nb content is preferably 0.06% or less.

[0045] The balance in the composition of the steel sheet comprises Fe and inevitable impurities. Examples of the inevitable impurities include S.

[0046] Next, the microstructure and characteristics of the cold-rolled steel sheet of the present invention will be described. Ferrite single phase microstructure, ferrite average crystal grain size: 7 μm or less

[0047] In the present invention, the cold-rolled steel sheet substantially has a ferrite single phage microstructure. The term "substantially" means being equivalent to a ferrite single phase microstructure from the viewpoint of the function and advantage of the present invention. For example, even when about 1% of cementite or the like is contained, the structure is substantially a ferrite single phase microstructure as long as the function and advantage of the present invention are exhibited.

[0048] In addition, when the ferrite average crystal gain size exceeds 7 μm, the beauty of the surface appearance after can making is lost. This possibly corresponds to an extreme change in surface roughness, such as a surface roughness phenomenon. In particular, this phenomenon is recognized in bodies of two-piece welded cans, and in three-piece welded cans formed by expanding. Therefore, the ferrite average crystal gain size is 7 μm or less. The lower limit of the ferrite average crystal gain size is not particularly limited but is generally about 4 μm or more.

[0049] The ferrite crystal gain size is measured using an intercept method defined in JIS G0551.

[0050] In addition, the ferrite average crystal gain size is controlled to the target value by adjusting mainly the steel sheet composition, the cold reduction, and the annealing temperature. Specifically, the composition consists of 0.04 to 0.12% of C, 0. 005 to 0.5% of Si, 0.3 to 1.5% of Mn, 0.005 to 0.2% of P, 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb (or these elements in preferred ranges) (the balance comprising iron and inevitable impurities), and a crystal grain size of 7 μm or less can be obtained by hot-rolling at a finishing temperature of 870°C or higher, cooling at a rate of 40 °C/s or less until coiling, coiling at a temperature of 620°C, cold-rolling at a reduction ratio of 80% or more, and then continuous annealing under conditions of a soaking temperature of 650 to 750°C and a soaking time of 40 seconds or less.

- Yield point strength (YP): 500 MPa or more (after baking after lacquering)

[0051] The yield point strength is an important factor for securing dent-resistance strength of a welded can. The dent resistance strength is generally represented by a relational expression between thickness and yield point strength. When the present invention is applied to applications generally using a DR material, the yield point strength is 500 MPa or more in order to secure dent strength with the thickness (usually 0.15 to 0.17 mm) of a DR material. The upper limit of YP is need not be limited but generally about 700 MPa or less.

- Yield ratio (YR): 0.9 or more (after baking after lacquering)

[0052] When tensile strength is increased, deformation resistance in hot rolling and cold rolling is increased, and the workability of rolling is decreased. On the other hand, from the viewpoint of body strength, it is necessary to secure a yield point strength of 500 MPa or more. Namely, it is necessary to increase the yield point strength and decrease the tensile strength, and the yield ratio is set to 0.9 or more as a condition for achieving the above-described properties with no trouble in an operation. The upper limit of YR is not particularly specified, and the upper limit may be the maximum value (= 1).

[0053] The YP and TS are mainly controlled to target values by adjusting the steel sheet composition, the cold reduction, and the annealing temperature. Specifically, the composition consists of 0.02 to 0.12% of C, 0.005 to 0.5% of Si, 0.3 to 1.5% of Mn, 0.005 to 0.2% of P, 0.10% or less of Al, 0.012% or less of N, and 0.005 to 0.10% of Nb (or these elements in preferred ranges) (the balance including iron and inevitable impurities), and YP and TS can be controlled to target values by hot-rolling at a finishing temperature of 870°C or higher, cooling at a rate of 40 °C/s or less until coiling, coiling at a temperature of 620°C, cold-rolling at a reduction ratio of 80% or more, and continuous annealing under conditions of a soaking temperature of 650 to 750°C and a soaking time of 40 seconds or less.

[0054] The YP and YR before baking after lacquering are not particularly limited but are about 460 to 550 MPa and about 85 to 95, respectively.

- Total elongation (El): 10% or more (after baking after lacquering)

[0055] When elongation (total elongation) is lower than 10%, the steel sheet is difficult to apply to cans associated with a high degree of body forming, e.g., expanding. Therefore, the total elongation is 10% or more. Although the upper limit of the total elongation need not be particularly limited but is generally about 50%. The ferrite single phase fine microstructure is particularly effective as means for securing a total elongation of 10% or more.

[0056] The El before baking after lacquering is not particularly limited but is about 15 to 50%.

- Δr: -0.50 to 0 (after baking after lacquering)

[0057] Δr represented by the expression below is used as an index for anisotropy in the present invention.

$$\Delta r = (r_0 + r_{90} - 2 \times r_{45})/4$$

r_0, r_{45}, and r_{90} represent r values (Lankford value) in a tensile test in the rolling direction, a tensile test in a direction at 45° with the rolling direction, and a tensile test in a direction at 90° with the rolling direction, respectively.

[0058] In the steel sheet having a Δr of less than -0.50, for example, in forming into a DRD can, the trim margin is increased due to the high occurrence of earing, thereby decreasing the process yield of the steel sheet. Namely, from the viewpoint of process yield, Δr is required in the rage of -0.50 to 0 in order to suppress the occurrence of earing. Also, when Δr is large in absolute value, flange wrinkling occurs in a flange portion of a DRD can or welded can due to a thickness distribution (deviation in thickness) in the circumferential direction, and thus steel having Δr of -0.45 to 0 is preferably used. Further, in application in which the circularity of a can is considered important, it is necessary to suppress as much as possible a thickness distribution in the circumferential direction, and thus Δr is preferably -0.30 to 0.

[0059] The Δr is mainly controlled to the target value by adjusting the finishing temperature in hot rolling, the cooling rate after finishing, and the coiling temperature. Specifically, Δr can be controlled to the target value by hot-rolling at a finishing temperature of 870°C or higher, cooling at a rate of 40 °C/s or less until coiling, and coiling at a temperature of 620 °C or higher.

[0060] The Δr before baking after lacquering is not particularly limited but takes a value close to a value after baking.

[0061] Next, the microstructure of the hot-rolled steel sheet for a base material for the tin mill black plate will be described.

• Microstructure of hot-rolled steel sheet: ferrite single phase microstructure, average crystal grain size 6 μm or more

[0062] In the present invention, the microstructure of the hot-rolled steel sheet is substantially a ferrite single phase microstructure. Like for a cold-rolled steel sheet (subjected to cold rolling, annealing, and temper rolling), the term "substantially" means that even when about 1% of cementite or the like is contained, the microstructure is decided as substantially a ferrite single phase microstructure as long as the function and advantage of the present invention are exhibited.

[0063] The anisotropy of the steel sheet after cold rolling, continuous annealing, and temper rolling is greatly affected by the ferrite grain size in the stage of the hot-rolled steel sheet. For example, Fig. 1 shows a relation between anisotropy of a cold-rolled steel sheet obtained by continuous annealing at a cold rolling reduction ratio of 90%, a soaking temperature of 710°C, and a soaking time of 30 seconds and the ferrite average crystal grain size in the stage of a hot-rolled steel sheet (hot-rolled material) using steel 1 shown in examples which will be described below. Fig. 1 indicates that when the ferrite average crystal grain size of the hot-rolled material is less than 6 μm, Δr is less than -0.50, and a desired anisotropy value cannot be obtained. Therefore, the ferrite average crystal grain size of the hot-rolled material is preferably 6 μm or more. When steel having a Δr of -0.45 to 0 is preferred to be used, the ferrite average crystal grain size of the hot-rolled material is more preferably 7 μm or more. When steel having a Δr of -0.30 to 0 is preferred to be used, the ferrite average crystal grain size of the hot-rolled material is more preferably 8 μm or more. Although the upper limit is not particularly specified, the ferrite average crystal grain size of the material obtained by hot rolling is normally about 15 μm or less. The method for measuring the ferrite crystal grain size is the same as that for the cold-rolled steel sheet.

[0064] The crystal grain size of the hot-rolled material is controlled to the target value by controlling mainly the components, FT in hot rolling, the cooling rate until CT, and CT.

[0065] The sheet thickness and ageing index are not particularly limited in the claims, but preferred conditions for carrying out the invention fall in the following respective ranges. • Preferred thickness of tin mill black plate: 0.2 mm or less, preferred thickness of hot-rolled steel sheet: 2 mm or less

[0066] The present invention is mainly aimed at application to gauge down of drawn cans and welded cans, and is thus mainly applied to a thickness of 0.2 mm or less.

[0067] In order to adjust the thickness of steel to 0.2 mm or less at the strength level which is proposed in the present invention, rolling at a reduction ratio of in the vicinity of 94% or less is preferred. Therefore, the thickness of the hot-rolled material is preferably 2 mm or less.

• Ageing index: 30 MPa or more

[0068] In order to securely obtain a yield point strength of 500 MPa after baking after lacquering or after heat laminating, the ageing index is preferably 30 MPa or more. In the present invention, the term "ageing index" indicates the amount of age hardening performed by a heat treatment at 100°C for 60 minutes after pre-strain of 8% is applied.

[0069] Next, the process for manufacturing the cold-rolled steel sheet and the hot-rolled steel sheet for the base material thereof will be described below.

[0070] Molten steel prepared to have the above-described chemical components is produced by a known steel making method using a converter or the like, and then cast by a usual casting method, such as continuous casting, to form a rolling material (ingot, particularly a slab).

[0071] Next, the rolling material obtained as described above is hot-rolled to form a hot-rolled steel sheet. Before hot rolling, the rolling material is preferably heated to 1250°C or higher (SRT ≥ 1250°C). The purpose of this is to completely dissolve N in the steel. The start temperature of rough rolling is preferably 1350°C or lower.

[0072] The finishing temperature is 870°C or higher. In addition, the material is cooled at a cooling rate of 40 °C/s or less until coiling and then coiled at a coiling temperature of 620 °C or higher. From the viewpoint of anisotropy, the ferrite average crystal grain size of the resultant hot-rolled material is 6 μm or more. The hot-rolled steel sheet as the base material is manufactured by the above-described process, but pickling or the like, which will be described below, may be performed.

[0073] In order to manufacture the cold-rolled steel sheet for cans, cold rolling is further performed, but scales which cover the surface of the steel sheet are generally removed by pickling before cold rolling. Then, cold rolling is performed at a reduction ratio of 80% or more, and continuous annealing is then performed under the conditions including a soaking temperature of 650 to 750°C and a soaking time of 40 seconds or less, followed by temper rolling at a temper elongation of 1.5% or less. Each of the factors will be described in detail below.

• Hot rolling finishing temperature (FT): 870°C or higher

[0074] The finishing temperature in hot rolling is an important item for controlling anisotropy. In order to secure Δr of -0.50 or more (0 or less) using Nb-added steel, it is necessary to control the ferrite average crystal grain size of the hot-rolled material to 6 μm or more and control a texture. In order to achieve this control, the hot-rolling finishing temperature is 870°C or higher. In addition, FT is preferably 950°C or lower from the viewpoint of suppressing defects due to scales.

• Average cooling rate until coiling after finishing rolling: 40 °C/s or less

[0075] The anisotropy of the cold-rolled steel sheet is significantly influenced by the ferrite average crystal grain size of the hot-rolled material. As described above (refer to Fig. 1), in order to control Δr in the range of -0.50 to 0, it is necessary to control the ferrite average crystal grain size of the hot-rolled material to 6 μm or more. In order to control the ferrite average crystal grain size of the hot-rolled material to 6 μm or more, it is necessary to keep the cooling rate low after hot rolling. As a condition for this, the average cooling rate after finishing is 40 °C/s or less. The average cooling rate is determined by dividing a temperature drop from the finish of hot rolling to coiling by the elapsed time.
[0076] In order to securely obtain steel having a Δr of -0.45 to 0 over the entire width direction, the ferrite average crystal grain size of the hot-rolled material is preferably 7 μm or more. For this purpose, it is necessary to control the average cooling rate to 30 °C/s or less.
[0077] Further, in order to securely obtain steel having a Δr of -0.30 to 0 over the entire width direction, the ferrite average crystal grain size of the hot-rolled material is preferably 8 μm or more. For this purpose, it is necessary to control the average cooling rate to 20 °C/s or less.
[0078] From the viewpoint of productivity, the average cooling rate is preferably 10 °C/s or more.
[0079] The cooling rate is controlled by, for example, the amount of the cooling water supplied. In cooling at the maximum strength by a hot rolling equipment according to the general industrial standards, the cooling rate is about 80 to 100 °C/s. In usual hot rolling, the steel sheet is cooled with water at a rate near the upper limit, from the viewpoint of economy, or at least 50 °C/s of more. On the other hand, when no accelerated cooling means is used, the cooling rate is about several °C/s, but this is impractical as industrial production means because the coiling temperature is increased to cause defects due to scales.

• Coiling temperature (CT): 620°C or higher

[0080] In order to control the ferrite average crystal grain size of the hot-rolled material to 6 μm or more, it is necessary to keep the coiling temperature high. As a condition for this, the coiling temperature is 620 °C or higher. From the viewpoint of a Δr of -0.45 to 0, the coiling temperature is preferably 640°C or higher. In order to obtain steel having a Δr of -0.30 to 0, the coiling temperature is preferably 700°C or higher.
[0081] From the viewpoint of descaling properties, the coiling temperature is preferably 750°C or lower.

• Cold reduction (reduction ratio): 80% or more

[0082] The reduction rate of cold rolling is an important. condition in the present invention. When the reduction ratio of cold rolling is less than 80%, it is difficult to manufacture a steel sheet having a yield point strength of 500 MPa or more. Further, in order to obtain a thickness (0.2 mm or less, usually about 0.17 mm) corresponding to a DR material, when the reduction ratio is less than 80%, the hot-rolled steel sheet is required to have a thickness of at least 1 mm or less, causing to difficulty in operation. Therefore, the reduction ratio is 80% or more.' In addition, the upper limit of the cold rolling reduction ratio is preferably about 96% because when the cold rolling reduction ratio is excessively high, the rolling load is increased to disenable rolling by the ability of a general rolling equipment.

• Annealing condition: soaking temperature 650°C to 750°C, soaking time 40 seconds or less

[0083] Annealing is performed by a continuous annealing method. In order to secure good formability, it is necessary for the soaking temperature in continuous annealing to be higher than the recrystallization temperature of the steel sheet. Also, in order to form a more uniform microstructure, it is necessary for the soaking temperature to be 650°C or higher. On the other hand, for continuous annealing at over 750°C, it is necessary to minimize the speed (steel strip speed) in order to prevent breakage of the steel sheet, thereby decreasing productivity. As a condition for preventing a reduction in productivity, the temperature is 750°C or lower. With respect to the soaking time, the soaking time is 40 seconds or less because productivity cannot be secured at a speed corresponding to a soaking time of 40 seconds or more. The lower limit of the soaking time is not particularly specified, and for example, there is no problem in processing with a soaking time of zero, in which cooling is started immediately after the soaking temperature (maximum temperature) is attained.

• Temper elongation: 1.5% or more

[0084] When the temper elongation (reduction ratio of temper rolling) is increased, like in a DR material, stain introduced in processing is increased, thereby decreasing ductility. In the present invention, since it is necessary to secure a total elongation of 10% or more by an ultrathin material, the temperature elongation is 1.5% or less.

[EXAMPLES]

(EXAMPLE 1)

[0085] Steel having each of the compositions shown in Table 1 and containing the balance composed of Fe and inevitable impurities was molten by a converter to form a steel slab. The resultant steel slab was re-heated to 1250°C, and then hot rolling was started. The steel slab was hot-rolled at a finishing rolling temperature in the range of 880°C to 900°C, cooled at an average cooling rate of 20 to 40 °C/s, and then coiled at a coiling temperature in the range of 620 °C to 700°C. Then, after pickling, the resultant steel sheet was cold-rolled at a reduction ratio of about 90 to 94% to manufacture a thin steel sheet having a thickness of 0.17 to 0.2 mm. The resultant thin steel sheet was heated to 690°C to 750°C at a heating rate of 15 °C/sec and subjected to continuous annealing at 690°C to 750°C for 20 seconds. Then, after cooling, temper rolling was performed so that the reduction ratio (measured by elongation) was 1.5% or less, followed by continuous usual chromium plating (electroplating) to produce tin-free steel. The soaking temperature was controlled within the range of 690°C to 750°C according to the amount of Nb added.

Table 1

	C	Si	Mn	P	S	N	Nb	Al	Remarks
1	0.05	0.010	0.6	0.070	0.005	0.009	0.035	0.05	This invention example
2	0.07	0.010	0.8	0.070	0.005	0.010	0.035	0.05	This invention example
3	0.12	0.010	0.5	0.100	0.005	0.005	0.050	0.05	This invention example
4	0.12	0.010	1.1	0.050	0.005	0.010	0.020	0.05	This invention example
5	0.02	0.010	0.6	0.070	0.005	0.011	0.050	0.05	Comparative example
6	0.12	0.005	0.6	0.005	0.010	0.010	0.050	0.06	This invention example
7	0.12	0.010	0.6	0.100	0.010	0.010	0.120	0.05	Comparative Example
8	0.01	0.010	0.1	0.010	0.005	0.002	0.003	0.04	Comparative Example
20	0.05	0.010	0.6	0.070	0.005	0.007	0.035	0.05	This invention example
21	0.05	0.010	0.6	0.070	0.005	0.003	0.035	0.05	This invention example
22	0.05	0.010	0.6	0.070	0.005	0.015	0.035	0.05	Comparative Example
23	0.0047	0.010	0.6	0.070	0.005	0.009	0.035	0.05	Comparative Example
24	0.05	0.010	0.1	0.070	0.005	0.009	0.035	0.05	Comparative Example
*** Unit: % by mass**									

[0086] Each of the thus-obtained plated steel sheets (tin-free steel) was subjected to baking-after-lacquering treatment at 210°C for 20 minutes and then subjected to a tensile test. In addition, the crystal microstructure and average crystal grain size were examined (the crystal microstructure and average crystal grain size are not particularly changed before and after baking-after-lacquering treatment). Similarly, the crystal microstructure and average crystal grain size of each of the hot-rolled steel sheets were measured. The examination methods were as follows.

[0087] In the tensile test, a tensile specimen of JIS No 5 size (described in JIS Z 2201) was used for measuring yield elongation, tensile strength, and elongation (total elongation) and evaluating strength and ductility. The r value was measured using a tensile specimen of JIS No. 5 half size (width: 12.5 mm, parallel portion: 35 mm, gauge length: 20 mm) to measure Δr according to the following method:

$$\Delta r = (r_0 + r_{90} - 2 \times r_{45})/4$$

r_0, r_{45}, and r_{90} represent r values in a tensile test in the rolling direction, a tensile test in a direction at 45° with the rolling direction, and a tensile test in a direction at 90° with the rolling direction, respectively.

[0088] With respect to the crystal microstructure (both the hot-rolled steel sheet and the cold-rolled steel sheet), a sample (cross section in the rolling direction) was polished, and crystal grain boundaries were etched with nital (alcohol-based solution of nitric acid) and then observed through an optical microscope. The average crystal grain size was measured by the intercept method defined in JIS G0551 on the basis of the crystal microstructure observed as described above.

[0089] The obtained results are shown in Table 2.

Table 2

No	Hot-rolled material	Annealed material (after baking-after-lacquering treatment)					Remarks
	Average crystal grain size (μm)	YP (MPa)	YR	El (%)	Δr	Average crystal grain size (μm)	
1	7.1	510	0.94	20	-0.41	5.0	This invention example
2	7.8	530	0.96	15	-0.44	5.0	This Invention example
3	6.9	550	0.95	22	-0.43	5.0	This invention example
4	8.9	540	0.93	18	-0.30	5.0	This invention example
5	7.1	500	0.93	22	-0.43	5.0	Comparative example
6	6.8	500	0.94	22	-0.48	5.5	This invention example
7	5.4	580	0.94	19	-0.60	5.5	Comparative Example
8	9.3	320	0.91	20	-0.20	5.0	Comparative Example
20	7.3	505	0.95	21	-0.40	5.5	This invention example
21	7.6	500	0.95	22	-0.43	5.5	This invention example
22	7.6	500	0.88	22	-0.43	5.5	Comparative Example
23	12.2	330	0.92	28	-0.18	8.5	Comparative Example
24	8.0	490	0.92	21	-0.35	5.5	Comparative Example

[0090] It is confirmed from Table 2 that in each of the examples (Nos. 1 to 4, 6, 20, 21) of the present invention, the ferrite average crystal grain size of the annealed material (plated steel sheet) microstructure is 7 μm or less. Also, a uniform and fine ferrite single-phase microstructure not containing a duplex grain microstructure was confirmed by microstructure observation. Table 2 also indicates that the examples of the present invention are excellent in both strength and ductility. In addition, in each of the examples of the present invention (Nos. 1 to 4, 6, 20) each containing 0.005% or more of N, the ageing index reaches 30 MPa, and in the examples of the present invention (Nos. 1, 2, 4, 6, 20) each containing 0.0060% or more of N, the ageing index reaches 40 MPa.

[0091] On the other hand, the comparative example (No. 7) having an excessively high Nb content is lack of anisotropy and the comparative example (No. 8) having an insufficient Nb content is lack of strength.

[0092] In each of the examples of the present invention, the hot-rolled steel microstructure was substantially a ferrite single-phase microstructure having an average grain size of 6 μm or more.

(EXAMPLE 2)

[0093] Steel having the composition (the same as No. 1 of. Example 1) shown in Table 3 and containing the balance composed of Fe and inevitable impurities was molten by a converter to form a steel slab. The resultant steel slab was re-heated to 1250°C, and then hot rolling was started. The steel slab was hot-rolled at a finishing rolling temperature of 830°C to 900°C, cooled at an average cooling rate of 16 to 45 °C/s until coiling, and then coiled at a coiling temperature in the range of 580°C to 720°C. Next, the steel sheet was cold-rolled at a reduction ratio of 75 to 94% to manufacture a thin steel sheet having a thickness of 0.15 to 0.18 mm. The resultant thin steel sheet was heated to 630°C to 740°C at a heating rate of 20 °C/sec and subjected to continuous annealing at 630°C to 740°C for 20 to 30 seconds. Then, after cooling, temper rolling was performed so that the reduction ratio was 1.5% or less, and usual chromium plating was continuously performed to produce tin-free steel. The detailed manufacture conditions are shown in Table 4.

Table 3

Steel	C	Si	Mn	P	S	N	Nb	Al	Remarks
1	0.05	0.010	0.6	0.070	0.005	0.009	0.035	0.05	This invention example
* Unit: % by mass									

Table 4

No	Finishing rolling temperature (°C)	Cooling rate after finishing (°C/s)	Coiling temperature (°C)	Cold reduction (%)	Annealing temperature (°C)	Soaking time (s)	Remarks
9	900	18	700	91	710	20	This invention example
10	880	25	660	91	710	20	This invention example
11	880	35	620	90	710	20	This invention example
12	880	25	660	91	730	20	This invention example
13	880	42	620	90	710	20	Comparative Example
14	880	45	580	90	710	20	Comparative Example
15	830	40	580	90	710	20	Comparative Example
16	880	18	700	91	630	30	Comparative Example

(continued)

No	Finishing rolling temperature (°C)	Cooling rate after finishing (°C/s)	Coiling temperature (°C)	Cold reduction (%)	Annealing temperature (°C)	Soaking time (s)	Remarks
30	880	18	660	91	710	20	This invention example
31	880	25	700	91	710	20	This invention example
32	880	35	660	91	710	20	This invention example
33	880	42	660	91	710	20	Comparative Example
34	880	25	620	91	710	20	This invention example
35	880	18	700	91	710	20	This invention example
36	880	16	720	91	710	20	This invention example
37	880	18	640	91	710	20	This invention example
38	880	18	620	91	710	20	This invention example
39	880	18	600	91	710	20	Comparative Example
40	930	18	700	91	710	20	This invention example
41	830	18	700	91	710	20	Comparative Example
42	880	18	700	94	710	20	This invention example
43	880	18	700	85	710	20	This invention example
44	880	18	700	75	710	20	Comparative Example
45	880	18	700	91	740	20	This invention example

[0094] The thus-obtained plated steel sheet (tin-free steel) was subjected to baking-after-lacquering treatment at 210°C for 20 minutes and then subjected to a tensile test. In addition, the crystal microstructure and average crystal grain size were measured. In addition, the crystal microstructure and average crystal grain size of the hot-rolled steel sheet were examined. The test and examination methods were the same as in Example 1.

[0095] The obtained results are shown in Table 5.

Table 5

No	Hot-rolled material	Annealed material (after baking-after-lacquering treatment)					Remarks
	Average crystal grain size (μm)	YP (MPa)	YR	El (%)	Δr	Average crystal grain size (μm)	
9	8.5	510	0.93	19	-0.28	5.0	This invention example
10	7.5	510	0.93	18	-0.39	6.0	This invention example
11	6.9	520	0.90	18	-0.49	5.0	This invention example
12	7.5	500	0.93	18	-0.35	5.0	This invention example
13	5.4	520	0.90	18	-0.58	5.0	Comparative Example
14	5.9	530	0.91	17	-0.55	5.0	Comparative Example
15	5.0	530	0.91	17	-0.70	5.0	Comparative Example
16	8.5	600	0.92	8	-0.28	Unable to measure due to unrecrystallized structure	Comparative Example
30	7.9	515	0.93	18	-0.32	5.0	This invention example
31	7.8	510	0.93	20	-0.40	5.0	This invention example
32	6.8	520	0.95	17	-0.46	5.0	This invention example
33	5.8	515	0.94	18	-0.65	5.5	Comparative Example
34	6.9	520	0.94	17	-0.46	5.0	This invention example
35	8.5	510	0.93	19	-0.30	5.0	This invention example
36	8.8	505	0.93	22	-0.26	6.0	This invention example

(continued)

No	Hot-rolled material	Annealed material (after baking-after-lacquering treatment)					Remarks
	Average crystal grain size (μm)	YP (MPa)	YR	El (%)	Δr	Average crystal grain size (μm)	
37	7.9	515	0.92	17	-0.35	6.0	This invention example
38	7.8	530	0.93	17	-0.38	5.0	This invention example
39	5.6	515	0.93	18	-0.60	5.5	Comparative Example
40	8.5	520	0.95	17	-0.28	5.0	This invention example
41	5.8	520	0.95	18	-0.70	5.0	Comparative Example
42	8.0	535	0.94	16	-0.29	5.0	This invention example
433	8.0	505	0.97	20	-0.15	5.5	This invention example
44	8.5	480	0.96	22	0.25	7.5	Comparative Example
45	8.0	520	0.91	19	-0.27	5.0	This invention example

[0096] Table 5 indicates that in each of the examples of the present invention (Nos. 9 to 12, etc.), when the cooling rate after finishing rolling is small and the coiling temperature is high, a high-strength steel sheet with low anisotropy and high ductility can be obtained.

[0097] On the other hand, in each the comparative examples (Nos. 13 to 15, etc.) in each of which the finishing rolling temperature is low, the coiling temperature is low or the cooling rate after finishing rolling is high, the strength and ductility reach the respective target values, while the steel sheet has large anisotropy because of the low coiling temperature. In the comparative examples (No. 16, etc.) in each of which the soaking temperature is low, strength and anisotropy reach the respective target values, while the steel sheet shows low ductility because an unrecrystallized portion remains due to incomplete recrystallization.

[0098] Further, as a result of drawing of these steel sheets, in each of the examples of the present invention (Nos. 9 to 12, etc.), the steel sheet shows good surface properties without surface roughness phenomenon and shows the low occurrence of earing. On the other hand, in the comparative examples in each of which Δr is -0.50 or less, the steel sheets show the large occurrence of earing.

[0099] In each of the examples of the present invention, the hot-rolled microstructure is substantially a ferrite single-phase micrstructure having an average grain size of 6 μm or more.

Industrial Applicability

[0100] According to the present invention, it is possible to obtain a high-strength, high-ductility cold-rolled steel sheet having a yield point strength of 500 MPa or more, a yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0.

[0101] In detail, in the present invention, strength is increased while maintaining high elongation by solution hardening using a solution hardening element and composite hardening (solution hardening, precipitation hardening, and grain refining hardening) using Nb, P, and Mn, and thus a steel sheet having a yield point strength of 500 MPa or more can be securely manufactured even when the reduction ratio of temper rolling after annealing is as low as 1.5% or less.

[0102] As a result, since the strength of the raw plate (steel sheet) is increased, high body strength of a welded can can be secured even when gauge down is performed. In addition, in application to a pressured can required to have pressure capacity at the bottom thereof, high pressure capacity can be achieved with the existing thickness. Further, a high degree of body forming such as expanding can be enabled by increasing ductility.

[0103] In addition, in application to a drawn can, it is necessary to prevent the occurrence of earing in order to decrease the trim margin and increase the process yield. In the present invention, Δr is suppressed to the range of - 0.50 to 0 by controlling the finishing temperature to 870°C or higher, controlling the cooling rate to 40 °C/s or less until coiling, and controlling the coiling temperature to 620 °C or higher, thereby preventing the occurrence of earing.

[0104] Namely, in the present invention, a steel sheet excellent in all properties such as strength, ductility, and anisotropy can be obtained, and thus the steel sheet is optimum for a cold-rolled steel sheet mainly for three-piece cans associated with a high degree of body forming and two-piece cans requiring pressure capacity, such as pressured cans.

Claims

1. A cold-rolled steel sheet for cans, the cold-rolled steel sheet having a composition containing, by mass:

C:	0.04 to 0.12%,	Si:	0.005 to 0.5%,
Mn:	0.3 to 1.5%,	P:	0.005 to 0.2%,
Al:	0.10% or less,	N:	0.012% or less,
Nb:	0.005 to 0.10%,		

the balance comprising iron and inevitable impurities, and a microstructure substantially composed of a ferrite single phase, the ferrite average crystal grain size being 7 μm or less,
wherein properties, that is, a yield point strength of 500 MPa or more, yield ratio of 0.9 or more, a total elongation of 10% or more, and Δr of -0.50 to 0, can be achieved by baking after lacquering.

2. A process for manufacturing a cold-rolled steel sheet for cans, the process comprising:

hot-rolling, at a finishing temperature of 870°C or higher, steel containing, by mass:

C:	0.04 to 0.12%,	Si:	0.005 to 0.5%,
Mn:	0.3 to 1.5%,	P:	0.005 to 0.2%,
Al:	0.10% or less,	N:	0.012% or less,
Nb:	0.005 to 0.10%,		

the balance comprising iron and inevitable impurities;
cooling the steel at an average cooling rate of 40 °C/s or less until coiling;
coiling the steel at a coiling temperature of 620°C or higher;
cold-rolling the steel at a reduction ratio of 80% or more;
continuously annealing the steel under conditions of a soaking temperature of 650°C to 750°C and a soaking time of 40 seconds or less; and
temper-rolling the steel at a temper elongation of 1.5% or less.

3. A hot-rolled steel sheet having a composition containing, by mass:

C:	0.04 to 0.12%,	Si:	0.005 to 0.5%,
Mn:	0.3 to 1.1%,	P:	0.005 to 0.2%,
Al:	more than 0.02% and 0.10% or less,	N:	0.012% or less,
Nb:	0.005 to 0.10%,		

the balance comprising iron and inevitable impurities, and a microstructure substantially composed of a ferrite single phase, the ferrite average crystal grain size being 6 μm or more.

4. A process for manufacturing a hot-rolled steel sheet comprising:

hot-rolling, at a finishing temperature of 870°C or higher, steel containing, by mass:

C: 0.04 to 0.12%,	Si: 0.005 to 0.5%,
Mn: 0.3 to 1.5%,	P: 0.005 to 0.2%,
A1: 0.10% or less,	N: 0.012% or less,
Nb: 0.005 to 0.10%,	

the balance comprising iron and inevitable impurities;
cooling the steel at an average cooling rate of 40 °C/s or less until coiling; and
coiling the steel at a coiling temperature of 620°C or higher.

Patentansprüche

1. Kaltgewalztes Stahlblech für Dosen, wobei das kaltgewalzte Stahlblech eine Zusammensetzung aufweist, die in Massenprozent enthält:

C: 0,04 bis 0,12%,	Si: 0,005 bis 0,5%,
Mn: 0,3 bis 1,5%,	P: 0,005 bis 0,2%,
Al: 0,10% oder weniger,	N: 0,012% oder weniger,
Nb: 0,005 bis 0,10%,	

wobei der Rest Eisen und unausweichliche Verunreinigungen umfasst, und eine Mikrostruktur im Wesentlichen aus einer einzelnen Ferritphase besteht, wobei die durchschnittliche Kristallkorngröße des Ferrits 7 μm oder weniger beträgt,
wobei Eigenschaften, die eine Streckgrenze von 500 MPa oder mehr, ein Streckgrenzenverhältnis von 0,9 oder mehr, eine Gesamtdehnung von 10% oder mehr und ein Δr von -0,50 bis 0 sind, durch Einbrennen nach einem Lackieren erreicht werden können.

2. Verfahren zum Herstellen eines kaltgewalzten Stahlblechs für Dosen, wobei das Verfahren umfasst:

Warmwalzen bei einer Fertigungstemperatur von 870°C oder höher von Stahl, der in Massenprozent enthält:

C: 0,04 bis 0,12%,	Si: 0,005 bis 0,5%,
Mn: 0,3 bis 1,5%,	P: 0,005 bis 0,2%,
Al: 0,10% oder weniger,	N: 0,012% oder weniger,
Nb: 0,005 bis 0,10%,	

wobei der Rest Eisen und unausweichliche Verunreinigungen umfasst;
Kühlen des Stahls bei einer durchschnittlichen Kühlrate von 40°C/s oder weniger bis zum Aufrollen;
Aufrollen des Stahls bei einer Aufrolltemperatur von 620°C oder höher;
Kaltwalzen des Stahls bei einem Reduktionsverhältnis von 80% oder mehr;
Kontinuierliches Glühen des Stahls bei einer Haltetemperatur von 650°C bis 750°C und einer Haltezeit von 40 Sekunden oder weniger; und
Nachwalzen des Stahls bei einer Nachdehnung von 1,5% oder weniger.

3. Warmgewalztes Stahlblech, das eine Zusammensetzung aufweist, die in Massenprozent enthält:

C: 0,04 bis 0,12%,	Si: 0,005 bis 0,5%,
Mn: 0,3 bis 1,1%,	P: 0,005 bis 0,2%,
A1: mehr als 0,02% und 0,10% oder weniger,	
N: 0,012% oder weniger,	
Nb: 0,005 bis 0,10%,	

wobei der Rest Eisen und unausweichliche Verunreinigungen umfasst, und eine Mikrostruktur, die im Wesentlichen aus einer einzelnen Ferritphase besteht, wobei die durchschnittliche Kristallkorngröße des Ferrits 6 pm oder mehr beträgt.

4. Verfahren zum Herstellen eines warmgewalzten Stahlblechs, umfassend:

Warmwalzen bei einer Fertigungstemperatur von 870°C oder höher, von Stahl, der in Massenprozent enthält:

C: 0,04 bis 0,12%,	Si: 0,005 bis 0,5%,
Mn: 0,3 bis 1,5%,	P: 0,005 bis 0,2%,
A1: 0,10% oder weniger,	N: 0,012% oder weniger,
Nb: 0,005 bis 0,10%,	

wobei der Rest Eisen und unausweichliche Verunreinigungen umfasst;
Kühlen des Stahls bei einer durchschnittlichen Kühlrate von 40°C/s oder weniger bis zum Aufrollen; und
Aufrollen des Stahls bei einer Aufrolltemperatur von 620°C oder höher.

Revendications

1. Tôle d'acier laminée à froid pour boîtes de conserve, la tôle d'acier laminée à froid ayant une composition constituée en masse de :

C : 0,04 à 0,12 %,	Si : 0,005 à 0,5 %,
Mn : 0,3 à 1,5 %,	P : 0,005 à 0,2 %,
Al : 0,10 % ou moins,	N : 0,012 % ou moins,
Nb: 0,005 à 0,10%,	

le reste étant du fer et des impuretés inévitables, et une microstructure sensiblement composée d'une phase unique de ferrite, la grosseur de grain moyenne des cristaux de ferrite étant de 7 μm ou moins,
dans laquelle des propriétés, à savoir, une limite apparente d'élasticité de 500 MPa ou plus, un rapport d'élasticité de 0,9 ou plus, un allongement total de 10 % ou plus et un Δr de -0,50 à 0, peuvent être obtenues par cuisson après laquage.

2. Procédé de fabrication d'une tôle d'acier laminée à froid pour boîtes de conserve, le procédé comprenant :

le laminage à chaud, à une température de finition de 870°C ou plus, d'un acier constitué en masse de :

C : 0,04 à 0,12 %,	Si : 0,005 à 0,5 %,
Mn : 0,3 à 1,5 %,	P : 0,005 à 0,2 %,
Al : 0,10 % ou moins,	N : 0,012 % ou moins,
Nb: 0,005 à 0,10%,	

le reste étant du fer et des impuretés inévitables ;
le refroidissement de l'acier à une vitesse de refroidissement moyenne de 40 °C/s ou moins jusqu'au bobinage;
le bobinage de l'acier à une température de bobinage de 620 °C ou plus ;
le laminage à froid de l'acier à un taux de réduction de 80 % ou plus ;
le recuit en continu de l'acier dans des conditions de température de trempe de 650 à 750 °C et de durée de trempe de 40 secondes ou moins ; et
le dressage par laminage à froid de l'acier avec un allongement de correction de 1,5 % ou moins.

3. Tôle d'acier laminée à chaud ayant une composition constituée en masse de :

C : 0,04 à 0,12 %,	Si : 0,005 à 0,5 %,
Mn : 0,3 à 1,1 %,	P : 0,005 à 0,2 %,

(suite)

Al : plus de 0,02 % et 0,10 % ou moins,	N : 0,012 % ou moins,
Nb: 0,005 à 0,10%,	

le reste étant du fer et des impuretés inévitables, et une microstructure sensiblement composée d'une phase unique de ferrite, la grosseur de grain moyenne des cristaux de ferrite étant de 6 μm ou plus.

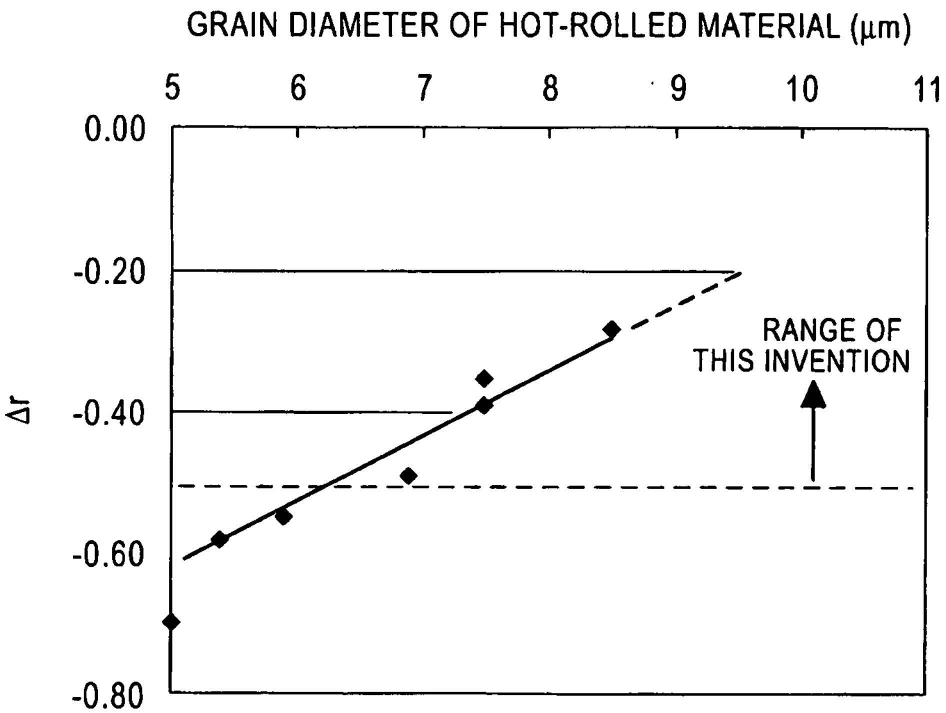
4. Procédé de fabrication d'une tôle d'acier laminée à chaud comprenant :

le laminage à chaud à une température de finition de 870°C ou plus d'un acier constitué en masse de :

C : 0,04 à 0,12 %,	Si : 0,005 à 0,5 %,
Mn : 0,3 à 1,5 %,	P : 0,005 à 0,2 %,
Al : 0,10 % ou moins,	N : 0,012 % ou moins,
Nb: 0,005 à 0,10%,	

le reste étant du fer et des impuretés inévitables ;
le refroidissement de l'acier à une vitesse de refroidissement moyenne de 40 °C/s ou moins jusqu'au bobinage ; et
le bobinage de l'acier à une température de bobinage de 620 °C ou plus.

FIG. 1


GRAIN DIAMETER OF HOT-ROLLED MATERIAL (μm)
5
6
7
8
9
10
11
0.00
-0.20
-0.40
-0.60
-0.80
Δr
RANGE OF
THIS INVENTION

REFERENCES CITED IN THE DESCRIPTION

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