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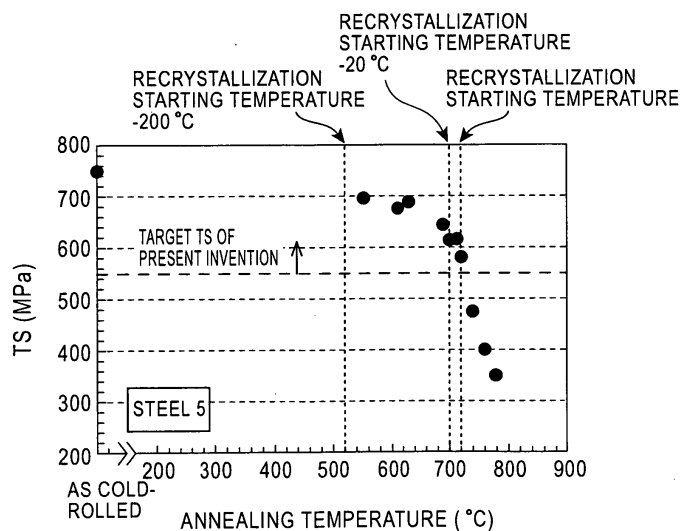
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(54) **PROCESSES FOR PRODUCTION OF STEEL SHEETS FOR CANS**

(57) A high-strength tin mill black plate is manufactured so as to have a tensile strength of 550 to 650 MPa and a total elongation of 5% or more in such a manner that hot rolling is performed at a finishing temperature higher than or equal to an Ar₃ transformation point, cold rolling is performed, and recovery annealing is performed at a temperature 20°C to 200°C lower than a recrystallization

starting temperature. Furthermore, a tin mill black plate is manufactured so as to have a tensile strength of 550 to 700 MPa and a total elongation of 4% or more and be capable of being manufactured by annealing at the same temperature as that of an ordinary tin mill black plate in such a manner that a steel sheet containing at least one of 0.001% to 0.05% Nb and 0.0001% to 0.005% B.

FIG. 2



Description

Technical Field

5 **[0001]** The present invention relates to a process for manufacturing a tin mill black plate used for 2-piece DRD cans (two-piece drawn and redrawn cans) and 3-piece welded cans (three-piece welded cans) used as cans or containers for canned beverages or canned foods.

Background Art

10 **[0002]** In recent years, in order to expand the demand for steel cans manufactured from tin mill black plates, costs for manufacturing the steel cans have been being reduced. One of the methods to reduce the costs for manufacturing the steel cans is reducing material cost. That is, extremely thin high-strength tin mill black plates are used for two-piece cans manufactured by drawing and three-piece cans principally manufactured by forming simple cylinders.

15 **[0003]** In the case where bodies of welded cans are made from steel sheets with a thickness of, for example, 0.16 mm, the steel sheets need to have a Rockwell hardness (HR30T) of about 73 to 77 (at least 73 to 76 and preferably 74 to 77) and high strength, that is, a tensile strength (TS) of about 550 to 620 MPa.

20 **[0004]** Extremely thin, hard tin mill black plates are manufactured by a double reduce process (hereinafter referred to as the DR process) including annealing followed by secondary cold rolling at present. For the DR process, the tin mill black plates are manufactured through a hot rolling step, a cold rolling step, an annealing step, and a secondary cold rolling step. That is, the number of steps in the DR process is one greater than that of steps in an ordinary process ended with an annealing step; hence, the DR process is high in manufacturing cost. This type of tin mill black plate needs to be manufactured at low cost. Therefore, the following processes have been proposed:

25 manufacturing processes which each include a step of adding various strengthening elements (strength-enhancing elements) and which are each ended with an annealing step (herein a recrystallization annealing step) without including secondary cold rolling step.

30 **[0005]** For example, Japanese Unexamined Patent Application Publication No. 2001-107186 (Patent Document 1) and Japanese Unexamined Patent Application Publication No. 2005-336610 (Patent Document 2) disclose high-strength tin mill black plates subjected to recrystallization annealing. The tin mill black plates subjected to recrystallization annealing have low in-plate plastic anisotropy and therefore are suitable for drawn cans in which earing needs to be minimized.

35 **[0006]** A steel sheet that need not have low in-plate plastic anisotropy need not be necessarily subjected to recrystallization annealing after cold rolling. The following technique may be used instead of recrystallization annealing: a technique in which the steel sheet is cold-rolled so as to have increased strength and then heat-treated (called "recovery annealing") at low temperature such that the excessive strain introduced therein by cold-rolling is relieved or the ductility of the material is recovered to a minimum extent. In this technique, no recrystallization annealing is performed and therefore a reduction in hardness due to recrystallization is not caused; hence, it is not necessary to use any element having ability for precipitation hardening or ability for solid solution hardening. Therefore, there is no concern about the influence of such an element on corrosion resistance. The technique called recovery annealing is effective against the steel sheet that need not have low in-plate plastic anisotropy. Techniques below have been proposed.

40 **[0007]** Japanese Examined Patent Application Publication No. 53-20445 (Patent Document 3) discloses a technique in which a steel material is hot-rolled at a finishing temperature lower than or equal to the A_{r3} transformation point thereof and the hot-rolled steel sheet is coiled at high temperature so as to have a grain size of 50 μm or more. According to this technique, the hot-rolled steel sheet is cold-rolled at a reduction rate of 85% to 90% and then subjected to continuous annealing at 450°C to 580°C, whereby a tin mill black plate having a TS of 53 to 57 kgf/mm² and an El (total elongation) of 6% to 8% is obtained. A material used is capped steel containing 0.05% to 0.06% C.

45 **[0008]** Japanese Unexamined Patent Application Publication No. 8-269568 (Patent Document 4) discloses a technique for manufacturing a tin mill black plate having a YS (yield strength) of 640 MPa or more. This tin mill black plate is manufactured in such a manner that a steel material containing REM which is an essential component therefor is hot-rolled at a finishing temperature lower than or equal to the A_{r3} transformation point thereof, the hot-rolled steel sheet is cold-rolled at a reduction rate of 85% or less, and the cold-rolled steel sheet heat-treated at a temperature of 200°C to 500°C for ten minutes or more.

50 **[0009]** Japanese Unexamined Patent Application Publication No. 6-248338 (Patent Document 5) discloses a technique in which a tempered grade T4-T6 tin mill black plate free from stretcher strain is manufactured by annealing a cold-rolled steel sheet at a temperature ranging from 400°C to the recrystallization temperature thereof. The tin mill black plate manufactured by this technique has a Rockwell hardness (HR30T) of up to 72.9.

55 **[0010]** Japanese Unexamined Patent Application Publication No. 6-248339 (Patent Document 6) discloses a technique

for manufacturing a tin mill black plate having high rigidity (the Rockwell hardness thereof is substantially the same as that disclosed in Patent Document 5). This tin mill black plate is manufactured in such a manner that a steel material having the same composition (specified as follows: C: 0.03% by weight or less, N: 0.005% by weight or less, and so on) as that disclosed in Patent Document 5 is hot-rolled at a finishing temperature lower than or equal to the Ar_3 transformation point thereof at a reduction rate of 50% or more, the hot-rolled steel sheet is cold-rolled at a reduction rate of 50% or more, and the cold-rolled steel sheet is annealed at a temperature ranging from 400°C to the recrystallization temperature thereof. In Patent Documents 5 and 6, the recrystallization temperature is defined as a temperature at which the percentage of recrystallized microstructures is less than 10%.

[0011] Japanese Unexamined Patent Application Publication No. 8-41549 (Patent Document 7) discloses a technique for manufacturing a steel sheet having a YS of 54 to 70 kgf/mm². This steel sheet is manufactured in such a manner that a steel material is finish-rolled such that a total reduction rate at a temperature lower than or equal to the Ar_3 transformation point thereof is 40% or more during hot rolling, the hot-rolled steel sheet is cold-rolled at a reduction rate of 50% or more, and the cold-rolled steel sheet is annealed at a low temperature of 350°C to 650°C for a short time.

Disclosure of Invention

(Problems to be Solved by the Invention)

[0012] The above conventional techniques have problems below.

[0013] For the techniques of Patent Documents 3, 4, 6, and 7, each steel material needs to be finish-rolled at a temperature lower than or equal to the Ar_3 transformation point thereof during hot rolling. The hot-rolled steel sheet prepared by finish rolling at a temperature lower than or equal to the Ar_3 transformation point has a large ferrite grain size and therefore has low strength as shown in Fig. 3 of Patent Document 3. Thus, these techniques are effective in reducing the strength of steel to such an extent that sufficient workability can be achieved. However, if finish rolling is performed at a temperature lower than or equal to the Ar_3 transformation point, widthwise edge portions are cooled at a rate greater than that of a widthwise center portion; hence, the finish-rolling temperature of the widthwise edge portions tends to be lower than that of the widthwise center portion. Therefore, the strain introduced in each edge portion during finish rolling is not sufficiently relieved by recrystallization or recovery directly subsequent to hot rolling and therefore the edge portion tends to have high strength. This results in a large difference in strength between the center and edge portions; hence, it is difficult to obtain a hot-rolled steel sheet that is uniform in the width direction thereof, that is, it is difficult to obtain a uniform one by conventional operation. The expression "lower than or equal to the Ar_3 transformation point" is used herein in accordance with the conventional techniques. However, it is correct to use the expression "less than the Ar_3 transformation point" in a strict sense because the idea of each conventional technique is to perform hot rolling (at least one part thereof) at a temperature at which Ar_3 transformation does not occur yet.

[0014] According to Patent Document 4, the cold-rolled steel sheet is annealed at 200°C to 500°C for ten minutes or more such that the strain of the cold-rolled steel sheet is relieved. If the cold-rolled steel sheet needs to be annealed for ten minutes or more in a continuous annealing furnace, the line speed needs to be low. This leads to a significant reduction in productivity.

[0015] According to Patent Documents 5 and 6, each cold-rolled steel sheet is annealed at a temperature ranging from 400°C to the recrystallization temperature thereof. The obtained steel sheet has a Rockwell hardness of less than 73.0. In order to achieve a steel sheet with a target strength specified herein, the annealing temperature needs to be reduced. This leads to the deviation from an annealing temperature range employed in the manufacture of materials for ordinary cans; hence, a dedicated annealing cycle needs to be used. This leads to a reduction in productivity.

[0016] The present invention has been made in view of the foregoing circumstances. It is an object of the present invention to solve the above problems and to provide a tin mill black plate with high strength.

[0017] That is, the present invention provides a tin mill black plate which is used for applications, not requiring low in-plate plastic anisotropy, such as welded cans and which needs to have high strength and workability. It is another object of the present invention to provide a process for manufacturing a high-strength tin mill black plate which has a sufficient ductility necessary to machine, for example, flanges of welded cans.

(Means for Solving the Problems)

[0018] The inventors have made intensive investigations to solve the above problems and have then obtained findings below.

[0019] In order to achieve a target strength and ductility by recovery annealing, the inventors have investigated components and appropriate manufacturing conditions.

[0020] The inventors have found that target properties can be achieved by meeting the following two requirements as the feature of this invention and major requirements:

- Obtaining a hot-rolled steel sheet in which there is no difference in strength between a center portion and edge portions thereof and which is uniform in the width direction thereof by performing finish rolling at a temperature higher than or equal to the A_{r3} transformation point thereof and
- Reducing the strength of the hot-rolled steel sheet to a target level in a recovery stage in such a manner that the hot-rolled steel sheet is cold-rolled and then annealed at a temperature 20°C to 200°C lower than the recrystallization starting temperature thereof.

[0021] Furthermore, the inventors have found that recovery annealing can be performed in a temperature range (500°C to 700°C) substantially equal to an annealing temperature range used in the manufacture of current tin mill black plates under the above manufacturing conditions adding at least one of 0.001% to 0.05% Nb and 0.0001% to 0.005% B and a tensile strength of 550 to 650 MPa or 550 to 700 MPa can be achieved.

[0022] The present invention has been made on the basis of the above findings. The substance of the present invention is as described below.

1. A process for manufacturing a tin mill black plate with a thickness of 0.18 mm or less includes the steps of hot-rolling a steel material at a finishing temperature higher than or equal to the A_{r3} transformation point thereof, the steel material containing 0.003% or less C, 0.004% or less N, 0.05% to 0.5% Mn, 0.02% or less P, 0.02% or less Si, 0.03% or less S, and 0.1% or less Al on a mass basis, the remainder being iron and unavoidable impurities; coiling the hot-rolled steel sheet at a temperature of 600°C to 750°C; cold-rolling the resulting steel sheet at a reduction rate of 60% to 95%; and annealing the cold-rolled steel sheet at a temperature of (recrystallization starting temperature - 200°C) to (recrystallization starting temperature - 20°C).

2. In the process specified in Item 1 above, the steel material further contains at least one of 0.001% to 0.05% Nb and 0.0001% to 0.005% B on a mass basis.

[0023] The content of a steel component used herein is expressed on a mass basis. For example, the expression "Mn: 0.05% to 0.5%" herein means "Mn: 0.05% or more and 0.5% or less", that is, " $0.05\% \leq \text{Mn} \leq 0.5\%$ ".

[0024] The term "recrystallization starting temperature" is defined as a temperature at which a change in strength greatly varies as shown in Fig. 1 (an example and conditions below). In particular, this term is defined as a temperature at which a microstructure in which recrystallized microstructures occupy 5% of the structure is obtained.

Brief Description of Drawings

[0025]

Fig. 1 is a graph showing the relationship between annealing temperature (abscissa in °C) and TS (ordinate in MPa), and the recrystallization starting temperature of steel having a composition according to the present invention.

Fig. 2 is a graph showing the relationship between annealing temperature (abscissa in °C) and TS (ordinate in MPa), and the recrystallization starting temperature of steel having another composition according to the present invention.

Best Modes for Carrying Out the Invention

[0026] The present invention will now be described in detail.

[0027] A tin mill black plate manufactured by a process according to the present invention has a tensile strength of 550 to 650 MPa (see Fig. 1) and a total elongation of 5% or more. When the tin mill black plate contains Nb and/or B, the tin mill black plate has a tensile strength of 550 to 700 MPa (see Fig. 2 and conditions below) and a total elongation of 4% or more. The manufacture of the tin mill black plate according to the present invention is characterized in that hot rolling is performed at a finishing temperature higher than or equal to a A_{r3} transformation point and then annealing is performed within a range from a temperature 200°C lower than the recrystallization starting temperature thereof to a temperature 20°C lower than the recrystallization starting temperature thereof.

[0028] Components of the tin mill black plate according to the present invention will now be described.

C: 0.003% or less

[0029] The tin mill black plate according to the present invention has high strength due to the strain introduced therein by cold rolling (primary cold rolling). Therefore, any strengthening element is not essential and the content thereof is minimized in view of ductility. When the tin mill black plate contains greater than 0.003% C, the tin mill black plate has a local ductility insufficient to form cans. An increase in the amount of remaining solute carbon may cause cracks in a can during the stretch-flange forming of a seeming part in the final step of can making. The increase in the amount of

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solute carbon also increases the work hardening coefficient thereof and therefore may cause wrinkles during neck forming or flange forming.. Thus, the content of C is 0.003% or less.

[0030] When the C content is less than 0.0010%, operability is reduced because of a reduction in the annealing temperature necessary to achieve a target strength specified herein and an improvement in ductility is reduced. Thus, the C content is preferably 0.0010% or more.

N: 0.004% or less

[0031] N is an unavoidable impurity in steel. An increase in the content of N may cause slab cracking in an unbending zone during continuous casting. N forms precipitates, which cause a reduction in elongation. The presence of the solute nitrogen causes steel to be hardened. In order to prevent these adverse effects, the content of N is 0.004% or less. When the tin mill black plate is used for applications further requiring workability, the N content is preferably 0.002% or less.

Si: 0.02% or less

[0032] Si is a strengthening element enhancing the strength of steel by solid solution hardening and an increase in the content of Si causes a reduction in corrosion resistance. Thus, the Si content is 0.02% or less.

Mn: 0.05% to 0.5%

[0033] Mn is a strengthening element enhancing the strength of steel by solid solution hardening. Mn reduces the size of crystal grains to increase the strength thereof by grain refining hardening. In order to prevent this adverse effect, the upper limit of the content of Mn is 0.5%. The Mn content is preferably 0.3% or less.

[0034] When the Mn content is less than 0.05%, it is difficult to avoid hot shortness even if the content of S is decreased; hence, problems such as surface cracks are caused during hot rolling. Thus, the lower limit of the Mn content is 0.05%. The Mn content is preferably 0.10% or more.

P: 0.02% or less

[0035] An increase in the content of P significantly increases the strength of steel by solid solution hardening and also deteriorates the corrosion resistance thereof. Thus, the P content is 0.02% or less.

S: 0.03% or less

[0036] S exists as an inclusion in steel and is an element that is unfavorable for the ductility and corrosion resistance of steel; hence, the content of S is 0.03% or less. The S content is preferably 0.01% or less.

Al: 0.1% or less

[0037] Al serves as a deoxidizer to enhance the cleanliness of steel. Al has an effect of reducing the amount of solute N because Al reacts with solute N to form AlN. Therefore, steel preferably contains a certain amount of Al. The content of Al therein is preferably about 0.005% or more. When the Al content exceeds 0.1%, the effect of enhancing the cleanliness of steel is saturated and the following problems arise: an increase in manufacturing cost and an increase in surface defects. Thus, the Al content is 0.1% or less.

[0038] One or two selected from the group consisting of 0.001% to 0.05% Nb and 0.0001% to 0.005% B may be contained in addition to the above components.

Nb: 0.001% to 0.05%

[0039] Nb is an element with a high ability to produce a carbide. The pinning of grain boundaries by the carbide increases the recrystallization temperature of steel. Therefore, the steel recrystallization temperature can be varied by the addition of Nb or the variation of the content of Nb. The annealing temperature can be appropriately increased or decreased, that is, the annealing temperature can be freely adjusted to a target value. This allows the tin mill black plate to be annealed at the same opportunity with another steel sheet and therefore is very efficient in view of productivity.

[0040] When the Nb content exceeds 0.05%, the recrystallization temperature is excessively high. This reduces the processing capability in a CAL (continuous annealing line). Furthermore, the strength exceeds a target value because of the precipitation hardening effect of the carbide. Thus, the Nb content is 0.05% or less.

[0041] No strengthening element is basically used herein; however, Nb is preferably used in view of annealing tem-

perature. A desired strength can be achieved by the precipitation hardening effect of Nb in such a manner that the Nb content is adjusted to 0.05% or less. The addition of Nb prevents recrystallization during welding and therefore is effective in preventing the reduction of weld strength. The upper limit of the Nb content is preferably 0.04%. When the Nb content is less than 0.001%, the above advantages cannot be achieved; hence, the lower limit of the Nb content is 0.001% in the case where Nb is used for the purpose of achieving the above advantages. The Nb content is preferably 0.005% or more and more preferably 0.01% or more.

B: 0.0001% to 0.005%

[0042] B is an element increasing recrystallization temperature. Therefore, B may be used for the same purpose as that of Nb. The use of an excessive amount of B prevents recrystallization of austenite during hot rolling to increase rolling load; hence, the content of B is 0.005% or less. The B content is preferably 0.002% or less.

[0043] When the B content is 0.0001% or less, the effect of enhancing the recrystallization temperature cannot be achieved; hence, the lower limit of the B content is 0.0001% in the case where B is used for the purpose of achieving this effect. The B content is preferably 0.0005% or more and more preferably 0.0008% or more.

[0044] B, as well as Nb, is effective in achieving a desired strength by the precipitation hardening effect of B when the B content is within the above range. B prevents recrystallization during welding and therefore is effective in preventing the reduction of weld strength.

[0045] One or both of Nb and B may be used within the above range.

[0046] The remainder is Fe and unavoidable impurities.

Plate thickness: 0.18 mm or less

[0047] The thickness of the tin mill black plate is an important factor in the present invention. When the thickness thereof is 0.18 mm or less, it is meaningful to gauge down the tin mill black plate such that the tin mill black plate has a tensile strength of 550 MPa or more. Further, although steel sheets having a thickness exceeding 0.18 mm can be continuously annealed at high temperatures exceeding 750°C with ease, steel sheets having a thickness of 0.18 mm or less may be broken or deteriorated in shape during continuous annealing, which leads to a reduction in productivity. In a process according to the present invention, an annealing temperature is set to be 20°C or more lower than a recrystallization starting temperature (usually to about 700°C or less as described in an example below); hence, a steel sheet having a thickness of 0.18 mm can be readily manufactured.

[0048] In the present invention, the thickness of the tin mill black plate is therefore limited to 0.18 mm or less because a tensile strength of 550 MPa or more is effective and annealing at low temperatures is remarkably effective in enhancing productivity.

[0049] Target properties of the tin mill black plate and reasons for setting such target properties will now be described.

Tensile strength: 550 to 700 MPa

[0050] An object of the tin mill black plate, which is manufactured by a process according to the present invention, is that the tin mill black plate is used in a field where ultra-thin high-strength steel sheets such as DR materials are presently used and, in particular, is used for bodies of welded cans such as DRD cans. In such a field, a steel sheet having a thickness of 0.18 mm or less and a tensile strength of 550 MPa or less is used, the steel sheet may be buckled because its strength is insufficient. In order to avoid this problem, the target tensile strength of the tin mill black plate is set to 550 MPa or more. In order to achieve a tensile strength exceeding 700 MPa (a tensile strength exceeding 650 MPa in the case where no Nb or B is used), a large amount of a strengthening element needs to be used. This may deteriorate the corrosion resistance of the tin mill black plate.

[0051] The tensile strength thereof is controlled to a target value mainly by adjusting the composition, cold rolling reduction rate, and/or annealing temperature of the tin mill black plate.

[0052] In particular, the tensile strength thereof is controlled to 550 to 650 MPa in such a manner that the tin mill black plate is prepared to so as to have a C content of 0.003% or less, a N content of 0.004% or less, a Mn content of 0.05% to 0.5%, a P content of 0.02% or less, a Si content of 0.02% or less, a S content of 0.03% or less, and an Al content of 0.1% or less; the cold rolling reduction rate thereof is adjusted to 60% or more; and annealing is performed at a soaking temperature 20°C to 200°C lower than the recrystallization starting temperature thereof (see Fig. 1).

[0053] Alternatively, the tensile strength thereof is controlled to 550 to 700 MPa in such a manner that the tin mill black plate is prepared to so as to have a C content of 0.003% or less, a N content of 0.004% or less, a Mn content of 0.05% to 0.5%, a P content of 0.02% or less, a Si content of 0.02% or less, a S content of 0.03% or less, an Al content of 0.1% or less, and at least one of a Nb content of 0.001% to 0.05% and a B content of 0.0001% to 0.005%; the cold-rolling reduction rate thereof is adjusted to 60% or more; and annealing is performed at a soaking temperature 20°C to 200°C

lower than the recrystallization starting temperature thereof (see Fig. 2).

[0054] The Rockwell hardness (HR30T) of the tin mill black plate is about 74 to 77 when the tin mill black plate contains no Nb or B. The Rockwell hardness (HR30T) thereof is about 74 to 80 when the tin mill black plate contains at least one of Nb and B.

Total elongation: 4% or more

[0055] When the total elongation of the tin mill black plate is less than 4%, the flange workability of a welded can is deteriorated and the incidence of cracks is increased, that is, workability is affected. In order to avoid this problem, the target total elongation thereof is 4% or more. In order to achieve extremely high workability, the total elongation thereof is preferably 5% or more.

[0056] The total elongation thereof is controlled to a target value mainly by adjusting the composition of the tin mill black plate or the cooling rate of the finish-rolled tin mill black plate in hot rolling.

[0057] A process for manufacturing the tin mill black plate according to the present invention will now be described.

[0058] A molten steel containing the above chemical components is produced by a known steel-making method using a converter and the like and then cast into a rolling material (a steel ingot or slab in particular) by an ordinary casting method such as a continuous casting method.

[0059] The obtained rolling material is hot-rolled into a hot-rolled steel sheet. Before being hot-rolled, the rolling material is preferably heated to 1250°C or more. This is because precipitates in steel are completely converted into solid solutions such that segregation is eliminated and thereby the rolling material is homogenized.

[0060] The finishing temperature of the hot-rolled steel sheet is higher than or equal to the Ar_3 transformation point thereof. Then, the hot-rolled steel sheet is coiled at 600°C to 750°C. The hot-rolled steel sheet is then usually pickled, whereby scales are removed therefrom. The resulting hot-rolled steel sheet is cold-rolled at a reduction rate of 60% to 95% and the cold-rolled steel sheet is annealed at a temperature of (recrystallization starting temperature - 200°C) to (recrystallization starting temperature - 20°C).

(1) Hot rolling conditions

[0061] Finishing temperature: Ar_3 transformation point or more

[0062] The finishing temperature during hot rolling needs to be higher than or equal to the Ar_3 transformation point of the steel sheet. As described above, the finish rolling of the steel sheet at a temperature lower than the Ar_3 transformation point thereof has an advantage in reducing the strength of the steel sheet during recovery annealing. If, however, a slab is finish-rolled such that a center portion thereof has a temperature lower than its Ar_3 transformation point, widthwise edge portions thereof are cooled at a rate greater than that of the center portion; hence, it is difficult to relieve the strain introduced into each widthwise edge portion during finish rolling by recrystallization or recovery. This results in a large difference in strength between the widthwise center and edge portions because the widthwise edge portion is hardened; further, a hot-rolled steel sheet having a nonuniform microstructure is likely to be obtained. Thus, in order to obtain a hot-rolled steel sheet having a uniform microstructure, the finishing temperature needs to be higher than or equal to the Ar_3 transformation point.

[0063] In order to enhance properties (ductility and the like), the finishing temperature is preferably 5°C or more higher than the Ar_3 transformation point (i.e. (Ar_3 transformation point + 5°C) or higher).

[0064] In order to avoid defects due to scales, the finishing temperature is preferably 950°C or less.

[0065] According to the composition and hot rolling conditions of the tin mill black plate of the present invention, the Ar_3 transformation point thereof is within a range from 840°C to 910°C.

[0066] Unlike a conventional technique using recovery annealing, the process according to the present invention allows the total elongation of steel to be adjusted by performing only hot rolling at a temperature higher than or equal to the Ar_3 transformation point. This is because as described below. When the finishing temperature of a hot-rolled steel sheet is higher than or equal to its Ar_3 transformation point (this is a condition of the process according to the present invention), the hot-rolled steel sheet has a relatively small ferrite grain size. However, when the finishing temperature of a hot-rolled steel sheet is lower than its Ar_3 transformation point (this is a condition of the conventional technique using recovery annealing), this hot-rolled steel sheet has a relatively large ferrite grain size. After these hot-rolled steel sheets are cold-rolled, the cold-rolled steel sheet prepared from the hot-rolled steel sheet with a small ferrite grain size has higher strain energy. This is because this cold-rolled steel sheet has a large number of grain boundaries keeping strain. Since the driving force for a recovery phenomenon is the strain energy stored in this cold-rolled steel sheet, a condition of the present invention promotes the progress of the recovery phenomenon. This cold-rolled steel sheet is reduced in strength because of the recovery phenomenon. Since the condition thereof allows the strain energy to be maintained high, the strength of this cold-rolled steel sheet can be maintained at a high target value after recovery. The recovery phenomenon improves the ductility of this cold-rolled steel sheet; hence, the ductility thereof can be maintained

at an appropriate target value. High-temperature finish hot rolling and high purity composition are preferably avoided because the grain size becomes large due to the above mechanism.

(2) Coiling temperature: 600°C to 750°C

[0067] The coiling temperature of a hot rolling step needs to be 600°C to 750°C. When the coiling temperature is lower than 600°C, the hot-rolled steel sheet has excessively high strength because the heat retention of the coiled hot-rolled steel sheet is insufficient and therefore the hot-rolled steel sheet has an excessively small ferrite grain size. Furthermore, a microstructure having a mixed grain size is likely to be formed, which is not preferable.

[0068] On the other hand, when the coiling temperature exceeds 750°C, scales on the hot-rolled steel sheet have a significantly large thickness and therefore the descalability of a subsequent pickling step can be low. In order to further remedy such a problem, the coiling temperature is preferably 700°C or less.

(3) Cold rolling condition (reduction rate): 60% to 95%

[0069] Cold rolling is performed at a reduction rate of 60% to 95%. When the reduction rate is less than 60%, the cold-rolled steel sheet heat-treated (subjected to recovery annealing) cannot reach target strength. Furthermore, the cold-rolled steel sheet has defects probably caused by the non-uniformity, especially by the thickness-wise non-uniformity of the cold-rolled steel sheet. On the other hand, when the reduction rate exceeds 95%, it is difficult to avoid the deterioration of local ductility. The reduction rate is preferably 80% or more.

(4) Condition of heat treatment (annealing) subsequent to cold rolling

[0070] Temperature: (recrystallization starting temperature - 200°C) or more, (recrystallization starting temperature - 20°C) or less

[0071] Heat treatment (annealing) is performed in a temperature range of (recrystallization starting temperature - 200°C) or more and (recrystallization starting temperature - 20°C) or less. The recrystallization temperature of steel is variable due to the use of, for example, Nb and/or B, the temperature range (soaking temperature range) of the steel is set to be 20°C to 200°C lower than the recrystallization starting temperature thereof.

[0072] In the present invention, an object of annealing (recovery annealing) is to reduce the increased strength of the cold-rolled steel sheet strained by cold rolling to a target value by strain relief annealing. When the annealing temperature is below a temperature 200°C lower than the recrystallization starting temperature, the strain of the cold-rolled steel sheet is not sufficiently relieved and the annealed steel sheet has a strength greater than a target value and a ductility smaller than a target value. Hence, the lower limit of the annealing temperature is a temperature 200°C lower than the recrystallization starting temperature. In view of ductility, the lower limit of the annealing temperature is preferably a temperature 150°C lower than the recrystallization starting temperature.

[0073] When the annealing temperature is excessively high, a target strength cannot be achieved because of excessive softening due to the onset of recrystallization or a uniform structure cannot be achieved because of local recrystallization. Hence, the upper limit of the annealing temperature is a temperature 20°C lower than the recrystallization starting temperature. Recrystallized grains and as-recovered grains can be identified from each other by optical or electronic microscopy. In view of strength, the upper limit thereof is a temperature 30°C lower than the recrystallization starting temperature.

[0074] The recrystallization starting temperature of the steel sheet, cold-rolled under the above conditions, having the above composition is within a range from about 560°C to 650°C (in the case of the absence of both Nb and B) or a range from about 620°C to 780°C (in the case of the presence of at least one of Nb and B).

[0075] According to the present invention, in view of productivity, annealing is preferably performed using a continuous annealing furnace. In order to avoid a reduction in productivity, the soaking time during annealing is preferably 10s or more and 90s or less.

Examples

Example 1

[0076] Steels containing components shown in Table 1 were produced, the remainder being unavoidable impurities and Fe. Slabs of the steels were then manufactured. The steel slabs were reheated at temperatures shown in Table 2 and then hot-rolled. In hot rolling, the finishing temperature and coiling temperature of the steel slabs were varied within a range from 800°C to 950°C and a range from 550°C to 700°C, respectively (as shown in Table 2). The obtained hot-rolled steel sheets were pickled and then cold-rolled at reduction rates shown in Table 2, whereby thin steel sheets with

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a thickness of 0.15 mm were manufactured (the hot-rolled steel sheets were adjusted in thickness depending on the reduction rates). The thin steel sheets were annealed (recovery-annealed) at 350°C to 620°C for 30 s in a continuous annealing furnace, temper-rolled so as to have an elongation rate of 1.5% or less, and then continuously plated (electroplated) with chromium by an ordinary technique, whereby plated steel sheets (tin-free steel sheets) were obtained.

Detailed manufacturing conditions are summarized in Table 2.

[0077] Effects of an annealing temperature were investigated from the recrystallization behavior of a steel sheet (manufactured under substantially the same conditions as those of Steel Sheet 1 shown in Table 2 except the annealing temperature thereof) manufactured from Steel 1 shown in Table 1. The investigation results were illustrated in Fig. 1. Since it was confirmed that the recrystallization of Steel 1 started at 590°C, the annealing temperature of each steel sheet manufactured from Steel 1 (90% cold rolling) was set to be within a range from 390°C to 570°C. The recrystallization of the steel sheet was substantially completed by annealing the steel sheet at 600°C.

Table 1

Steels	C	Si	Mn	P	S	N	Al	Nb	B	Remarks
1	0.0017	0.01	0.15	0.01	0.003	0.0025	0.05	0	0	Compliant
4	0.0031	0.01	0.28	0.01	0.004	0.0025	0.05	0.022	0.002	Compliant
* Unit: mass percent										

Table 2

Steel sheets	Steels	Heating temperature (°C)	Finishing temperature (°C)	Ar ₃ transformation point (°C)	Coiling temperature (°C)	Cold reduction (%)	Annealing temperature (°C)	Recrystallization starting temperature (°C)	Remarks
1	1	1250	890	880	620	90	550	590	Example
2	1	1150	890	880	620	90	570	590	Example
3	1	1250	890	880	700	90	350	590	Comparative Example
4	1	1250	800	880	620	90	620	590	Comparative Example
20	1	1250	890	880	620	90	550	590	Example
21	1	1250	850	880	620	90	550	590	Comparative Example
22	1	1250	920	880	620	90	550	590	Example
23	1	1250	890	880	700	90	550	590	Example
24	1	1250	890	880	620	80	550	590	Example
25	1	1250	890	880	620	70	550	590	Comparative Example
26	1	1300	890	880	620	90	550	590	Example
27	1	1150	890	880	620	90	550	590	Example
28	4	1250	890	870	620	90	700	720	Example
29	4	1250	840	870	620	90	700	720	Comparative Example
30	4	1250	950	870	620	90	700	720	Example
31	4	1250	890	870	700	90	700	720	Example
32	4	1250	890	870	550	90	700	720	Comparative Example
33	4	1300	890	870	620	90	700	720	Example
34	4	1150	890	870	620	90	700	720	Example

[0078] The plated steel sheets manufactured as described above were subjected to a tensile test and r-value measurement. In the tensile test, tensile test specimens (rolling direction) of JIS No. 5 size were used to measure tensile strength and elongation (total elongation) and then evaluated for strength and ductility. The average r-value of each specimen was determined by the natural frequency method specified in JIS Z2254.

[0079] The obtained results are summarized in Table 3. Properties of the steel sheets were investigated using samples taken from widthwise center portions of the steel sheets. Properties of specially-noted widthwise edge portions of the steel sheets were investigated using samples taken from portions 50 mm apart from widthwise edges of the steel sheets.

Table 3

Steel sheets	Steels	TS (MPa)	El (%)	Average r value	Final sheet thickness (mm)	Remarks
1	1	575	6	1.1	0.15	Example
2	1	564	5	1	0.15	Example
3	1	630	1	1	0.15	Comparative Example
4	1	500	9	1	0.15	Comparative Example
20*	1	575 (575)	6 (6)	1 (1)	0.15	Example
21*	1	560 (600)	7 (5)	1 (0.9)	0.15	Comparative Example
22*	1	570 (570)	6 (6)	1.2 (1.2)	0.15	Example
23	1	555	7	1	0.15	Example
24	1	555	6	1	0.15	Example
25	1	550	6	0.9	0.15	Example
26*	1	570 (570)	6 (6)	1.1 (1.1)	0.15	Example
27*	1	564 (570)	5 (5)	1 (1)	0.15	Example
28*	4	580 (580)	6 (6)	1.1 (1.1)	0.15	Example
29*	4	570 (610)	6 (5)	1.1 (1)	0.15	Comparative Example
30*	4	560 (560)	7 (7)	1.1 (1.1)	0.15	Example
31	4	550	8	1.1	0.15	Example
32	4	710	1	0.9	0.15	Comparative Example
33*	4	575 (575)	6 (6)	1 (1)	0.15	Example
34*	4	570 (585)	5 (4)	1 (0.9)	0.15	Example
* Bracketed numbers represent values of edge portions in the width direction of each sheet.						

[0080] Table 3 shows that examples (Steel Sheets 1, 2, and so on) of the present invention have a tensile strength of 550 to 600 MPa and a total elongation of 5% or more.

[0081] On the other hand, a comparative example (Steel Sheet 3) have low ductility because the annealing temperature thereof is lower than the temperature range specified herein and therefore the strain stored therein is only slightly relieved. The annealing temperature of a comparative example (Steel Sheet 4) is higher than the temperature range specified herein and therefore the strength thereof is insufficient because of local recrystallization.

[0082] These results are the same as those illustrated in Fig. 1. That is, the steel sheets annealed at a temperature 20°C to 200°C lower than the recrystallization starting temperature thereof have a TS of 550 to 650 MPa. Here, followings are further understood. The steel sheets annealed at a temperature 40°C or more lower than the recrystallization starting temperature thereof have a TS of 600 to 650 MPa. In order to obtain a steel sheet having a TS of 550 to 600 MPa, annealing is preferably performed at a temperature about 20°C to 50°C (preferably 20°C to 40°C) lower than the recrystallization starting temperature thereof.

[0083] It is shown that when the finishing temperature is less than the Ar_3 transformation point, the edge portions have higher hardness and lower properties and therefore the steel sheet has different hardness grades of steel sheet (Steel Sheets 21 and 29). The comparison between Steel Sheets 20 and 25 shows that an excessive decrease in cold reduction rate leads to a reduction in strength without any improvement in ductility.

Comparative Example 2

[0084] Steels containing components shown in Table 4 were produced with an existing converter, the remainder being unavoidable impurities and Fe. Slabs of the steels were then manufactured. The steel slabs were reheated at 1150°C to 1250°C and then hot-rolled. During hot rolling, the finishing temperature of the steel slabs was varied within a range from 880°C to 900°C and the coiling temperature thereof was 620°C. The obtained hot-rolled steel sheets were pickled and then cold-rolled at a reduction rate of 80% to 90%, whereby thin steel sheets with a thickness of 0.15 to 0.18 mm were manufactured. Thus obtained thin steel sheets were annealed (recovery-annealed) at 300°C to 700°C for 30 s in a continuous annealing furnace, temper-rolled so as to have an elongation rate of 1.5% or less, and then continuously plated with chromium by an ordinary technique, whereby tin-free steel sheets were obtained. Detailed manufacturing conditions are summarized in Table 5.

[0085] The recrystallization behavior of Steels 2 to 18 was investigated, whereby it was confirmed that the recrystallization thereof was completed at an annealing temperature of 620°C to 720°C as shown in Table 5. Fig. 2 shows the results obtained by investigating the recrystallization behavior of Steel 5 (manufactured under substantially the same conditions as those for manufacturing Steel Sheet 13 shown in Table 5 except the annealing temperature thereof) shown in Table 4.

Table 4

Steels	C	Si	Mn	P	S	N	Al	Nb	B	Remarks
2	0.0016	0.01	0.15	0.01	0.004	0.002	0.045	0.015	0	Compliant
3	0.0011	0.01	0.32	0.016	0.003	0.0021	0.05	0	0.002	Compliant
4	0.0031	0.01	0.28	0.01	0.004	0.0025	0.05	0.022	0.0024	Compliant
5	0.0028	0.01	0.29	0.01	0.004	0.0023	0.05	0.023	0.0032	Compliant
6	0.05	0.01	1.00	0.017	0.003	0.01	0.04	0.025	0.002	Not compliant
7	0.005	0.01	0.3	0.01	0.004	0.0025	0.05	0.02	0.0024	Not compliant
8	0.003	0.01	0.3	0.01	0.004	0.007	0.05	0.02	0.0024	Nor compliant
9	0.003	0.01	0.7	0.01	0.004	0.0025	0.05	0.02	0.0024	Not compliant
10	0.003	0.01	0.3	0.01	0.004	0.0025	0.02	0.02	0.0024	Compliant
11	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0.005	0	Compliant
12	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0.04	0	Compliant
13	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0.07	0	Not compliant
14	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0	0.0005	Compliant
15	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0	0.004	Compliant
16	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0	0.007	Not compliant
17	0.003	0.01	0.3	0.01	0.004	0.0025	0.05	0.04	0.004	Compliant
18	0.002	0.01	0.05	0.01	0.003	0.0025	0.05	0	0	Compliant

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(continued)

Steels	C	Si	Mn	P	S	N	Al	Nb	B	Remarks
19	0.0007	0.01	0.15	0.01	0.003	0.0025	0.05	0	0	Compliant
* Unit: mass percent										

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Table 5									
Steel sheets	Steels	Heating temperature (°C)	Finishing temperature (°C)	Ar ₃ transformation point (°C)	Coiling temperature (°C)	Cold reduction (%)	Annealing temperature (°C)	Recrystallization starting temperature (°C)	Remarks
5	2	1150	890	880	620	90	610	700	Example
6	2	1150	890	880	620	90	480	700	Comparative Example
7	3	1150	890	880	620	90	550	620	Example
8	3	1150	890	880	620	90	300	620	Comparative Example
9	4	1150	890	870	620	90	700	720	Example
10	4	1250	890	870	620	80	680	700	Example
11	4	1250	890	870	620	90	750	720	Comparative Example
12	5	1250	890	870	620	80	680	700	Example
13	5	1150	890	870	620	90	700	720	Example
14	6	1150	890	830	620	90	670	690	Comparative Example
40	7	1250	890	870	620	90	680	710	Comparative Example
41	8	1250	900	880	620	90	680	710	Comparative Example
42	9	1250	880	860	620	90	690	720	Comparative Example
43	10	1250	900	880	620	90	690	720	Example
44	11	1250	900	880	620	90	660	690	Example
45	12	1250	900	880	620	90	690	720	Example
46	13	1250	900	880	620	90	700	730	Comparative Example
47	14	1250	900	880	620	90	590	620	Example

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(continued)

Steel sheets	Steels	Heating temperature (°C)	Finishing temperature (°C)	Ar ₃ transformation point (°C)	Coiling temperature (°C)	Cold reduction (%)	Annealing temperature (°C)	Recrystallization starting temperature (°C)	Remarks
48	15	1250	890	870	620	90	620	650	Example
49	16	1250	880	860	620	90	670	700	Comparative Example
50	17	1250	900	880	620	90	690	720	Example
51	18	1250	900	880	620	90	590	620	Example
52	19	1250	900	880	620	90	590	620	Example

[0086] The plated steel sheets (tin-free steel sheets) manufactured as described above were subjected to a tensile test and r-value measurement. Properties of the plated steel sheets were measured in the same manner as that described in Example 1. The obtained results are summarized in Table 6.

Table 6

Steel sheets	Steels	TS (MPa)	El (%)	Average r value	Sheet thickness (mm)	Remarks
5	2	600	5.5	0.9	0.15	Example
6	2	680	1.5	0.7	0.16	Comparative Example
7	3	615	4	0.8	0.16	Example
8	3	660	1	0.7	0.16	Comparative Example
9	4	614	6	0.9	0.16	Example
10	4	576	7	1	0.18	Example
11	4	360	30	1.6	0.16	Comparative Example
12	5	646	5	1	0.18	Example
13	5	595	7	1	0.15	Example
14	6	740	1	0.8	0.16	Comparative Example
40	7	710	2	1	0.17	Comparative Example
41	8	710	1	0.9	0.17	Comparative Example
42	9	730	1	0.8	0.17	Comparative Example
43	10	560	7	1.1	0.16	Example
44	11	580	5	1.2	0.16	Example
45	12	560	6	1.1	0.15	Example
46	13	710	2	1.1	0.15	Comparative Example
47	14	670	4	1	0.18	Example
48	15	600	5	1	0.15	Example
49	16	720	2	0.9	0.16	Comparative Example
50	17	650	4	1	0.17	Example
51	18	550	5	0.9	0.15	Example
52	19	550	5	1	0.18	Example

[0087] Table 6 shows that examples (Steel Sheets 5, 7, 9, 10, 12, 13, and so on) have a tensile strength of 550 to 700 MPa and a total elongation of 4% or more.

[0088] On the other hand, comparative examples (Steel Sheets 6 and 8) have high strength and low ductility because the annealing temperature thereof is lower than the temperature range specified herein and therefore the strain stored therein is only slightly relieved. The annealing temperature of a comparative example (Steel Sheet 11) is higher than the temperature range specified herein and therefore the strength thereof is insufficient because of local recrystallization.

[0089] These results are the same as those illustrated in Fig. 2. That is, the steel sheets annealed at a temperature 20°C to 200°C lower than the recrystallization starting temperature thereof have a TS of 550 to 700 MPa. The steel sheets annealed at a temperature 40°C or more lower than the recrystallization starting temperature have a TS of 650 to 700 MPa. In order to obtain a steel sheet having a TS of 550 to 650 MPa, annealing is preferably performed at a temperature 20°C to 50°C (preferably 20°C to 40°C) lower than the recrystallization starting temperature thereof.

[0090] Comparative examples (Steel Sheets 14 and so on) have high strength and low ductility because the content of a component therein exceeds the range specified herein.

[0091] The annealing temperature of a steel sheet according to the present invention can be varied because the recrystallization behavior thereof varies depending on the content of Nb or B. The strength therefore can be also varied by controlling the Nb or B content. Therefore, a process according to the present invention is extremely efficient in manufacturing a tin mill black plate with an existing plant because a steel sheet for manufacturing the tin mill black plate

can be annealed in the same cycle as that of other tin mill black plates so as to have a desired strength.

Industrial Applicability

[0092] According to the present invention, a tin mill black plate having a tensile strength of 550 to 650 MPa and a total elongation of 5% or more can be obtained. When the tin mill black plate contains Nb and/or B, the tin mill black plate can be manufactured even by a process including no DR step or recrystallization annealing step so as to have a tensile strength of 550 to 700 MPa and a total elongation of 4% or more.

[0093] Therefore, a high-strength tin mill black plate which is used to manufacture cans and therefore need not have low in-plate plastic anisotropy can be manufactured at low cost by a process according to the present invention without impairing the corrosion resistance thereof.

[0094] The process according to the present invention includes annealing performed at a lower temperature as compared to a process for manufacturing an ordinary tin mill black plate and therefore is effective in reducing energy cost. The addition of Nb and/or B allows annealing to be performed at the same temperature as that at which ordinary tin mill black plates are annealed. In this case, no separate annealing chances are necessary. Therefore, a steel sheet having a TS of 550 to 700 MPa can be manufactured without a reduction in productivity.

[0095] Furthermore, according to the present invention, as is clear from Figs. 1 and 2, annealing can be performed within a temperature range where a change in strength is small; hence, a steel sheet that is uniform in the width direction thereof can be obtained even if the annealing temperature thereof is varied.

[0096] A tin mill black plate manufactured by the process according to the present invention is suitable for cans, especially two-piece DRD cans and three-piece welded cans used as containers for canned beverages or canned foods.

Claims

1. A process for manufacturing a tin mill black plate with a thickness of 0.18 mm or less, comprising the steps of:

hot-rolling a steel material at a finishing temperature higher than or equal to the A_{r3} transformation point thereof, the steel material containing 0.003% or less C, 0.004% or less N, 0.05% to 0.5% Mn, 0.02% or less P, 0.02% or less Si, 0.03% or less S, and 0.1% or less Al on a mass basis, the remainder being iron and unavoidable impurities;

coiling the hot-rolled steel sheet at a temperature of 600°C to 750°C;

cold-rolling the resulting steel sheet at a reduction rate of 60% to 95%; and

annealing the cold-rolled steel sheet at a temperature of (recrystallization starting temperature - 200°C) to (recrystallization starting temperature - 20°C).

2. The process according to Claim 1, wherein the steel material further contains at least one of 0.001% to 0.05% Nb and 0.0001% to 0.005% B on a mass basis.

FIG. 1

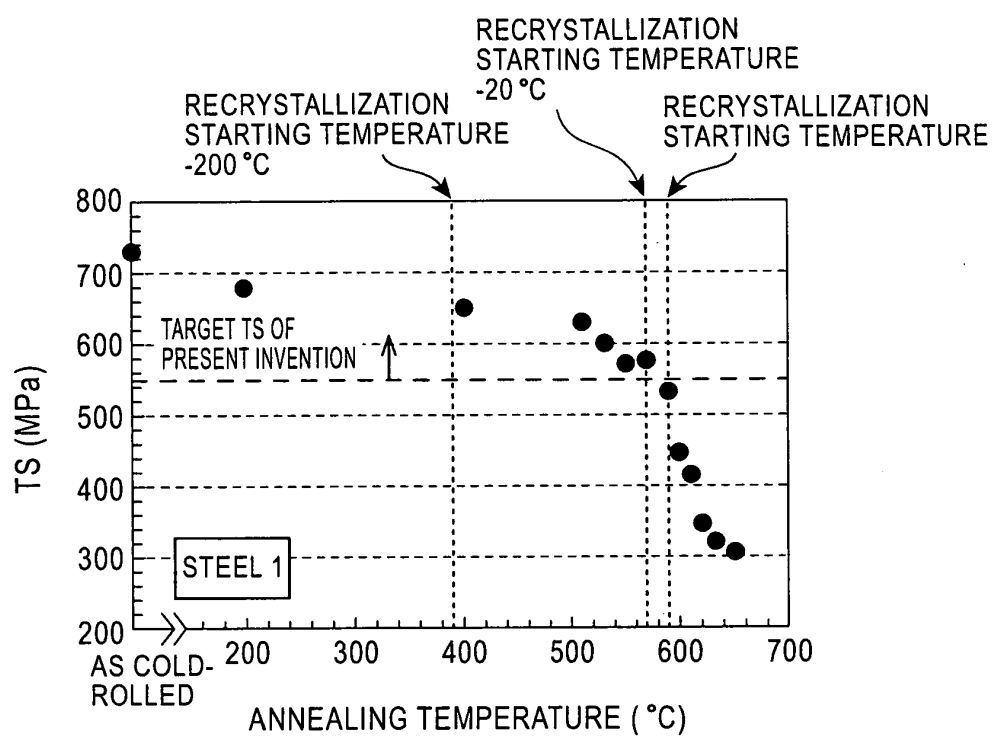
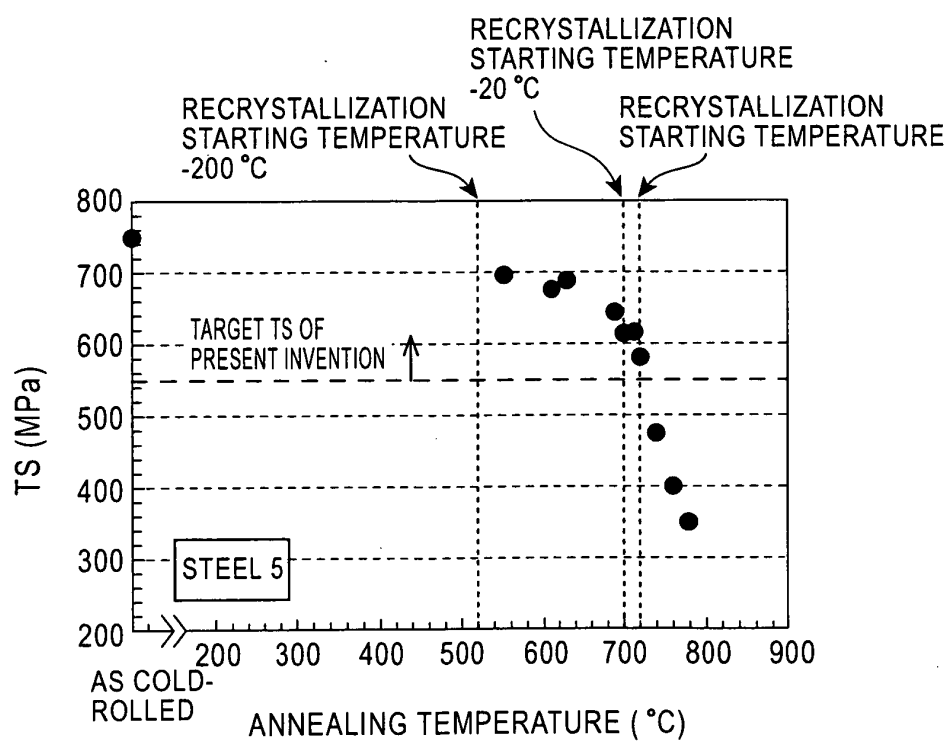


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/053125

A. CLASSIFICATION OF SUBJECT MATTER

C21D9/46(2006.01)i, C21D8/02(2006.01)i, C22C38/12(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)

C21D9/46-9/48, C21D8/00-8/04, C22C38/00-38/60

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 62-161938 A (Kawasaki Steel Corp.), 17 July, 1987 (17.07.87), Claims (Family: none)	1, 2
A	JP 2004-285418 A (Nippon Steel Corp.), 14 October, 2004 (14.10.04), Claims; Figs. 1, 2 (Family: none)	1, 2

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

* Special categories of cited documents:	"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
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Date of the actual completion of the international search
19 May, 2008 (19.05.08)Date of mailing of the international search report
27 May, 2008 (27.05.08)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/053125

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2-118026 A (Kawasaki Steel Corp.), 02 May, 1990 (02.05.90), Claims; Fig. 6 (Family: none)	1, 2
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Form PCT/ISA/210 (continuation of second sheet) (April 2007)

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