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(54) **STEEL PLATE FOR CAP AND METHOD FOR PRODUCING SAME**

(57) Provided is a steel sheet for crown cap that, even when reduced in gauge, has sufficient strength and formability suitable for forming crown caps, and a method for producing the steel sheet for crown cap. The steel sheet for crown cap has a composition including, in terms of % by mass, C: 0.002% or more and 0.010% or less, Si: 0.05% or less, Mn: 0.05% or more and 0.30% or less, P:

0.030% or less, S: 0.020% or less, Al: less than 0.0100%, N: 0.0050% or less, and the balance being Fe and unavoidable impurities. The C content is more than 0.003% when the Al content is 0.005% or more. The yield strength in the rolling direction is 500 MPa or more. The average Lankford value described below is 1.3 or more.

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Description

Technical Field

5 **[0001]** The present invention relates to a steel sheet for crown cap used as a material of crown caps that serve as caps for glass bottles, and to a method for producing the steel sheet for crown cap.

Background Art

10 **[0002]** Glass bottles have been used for many years as bottles for beverages, such as soft drinks and alcoholic drinks. Narrow-mouthed glass bottles have a metal cap called a crown cap. In general, a crown cap is produced by press-forming using a thin steel sheet as a material. Such a crown cap includes a disk-shaped part for closing the mouth of a bottle and a pleated part in the periphery of the disk-shaped part. The pleated part is crimped onto the mouth of the bottle to seal the bottle.

15 **[0003]** The properties of thin steel sheets required for use as materials of crown caps include strength and formability. The bottles to be capped with crown caps are typically filled with, for example, beer or carbonated drinks, which increase the internal pressure of the bottles after the bottles have been filled. Such a crown cap needs to be strong enough to resist an elevated internal pressure resulting from changes in temperature and impacts caused during transportation or the like so as to prevent deformation of the crown cap and subsequent breakage of the seal of the bottle. When the steel sheet has poor formability even with sufficient strength, the shapes of the pleats may be uneven, which may cause inadequate sealing performance even after the steel sheet has been crimped onto the mouth of a bottle.

20 **[0004]** SR (single reduced) steel sheets are mainly used as thin steel sheets that serve as materials of crown caps. Such a SR steel sheet is produced by reducing a steel sheet in gauge by cold rolling, followed by annealing and temper rolling. A crown cap material commonly used in the related art has a thickness of 0.22 to 0.24 mm and is made of mild steel used for, for example, food cans and beverage cans.

25 **[0005]** In recent years, crown cap steel sheets as well as can steel sheets have needed to be reduced in gauge for the purpose of cost reduction. However, when the thickness of crown cap steel sheets that serve as materials of crown caps is less than 0.20 mm, sealing performance is not maintained with SR steel sheets known in the art because of their low strength even though the formability is similar. When the thickness is less than 0.20 mm, the use of a DR (double reduced) steel sheet produced by, after annealing, performing second cold-rolling to ensure strength is conceived easily. However, the use of a DR steel sheet made of low-carbon steel as a crown cap may cause a failure in sealing the bottle because of poor formability.

30 **[0006]** By the way, the following techniques have been proposed in order to obtain steel sheets having both high strength and good formability.

35 **[0007]** Patent Literature 1 discloses an ultra-thin soft steel sheet for containers that achieves high can strength and good can formability. The steel sheet for containers includes, in terms of % by mass, N: 0.0040% to 0.0300% and Al: 0.005% to 0.080% and has 0.2% proof stress: 430 MPa or less, total elongation: 15% to 40%, and internal friction Q^{-1} : 0.0010 or more.

40 **[0008]** Patent Literature 2 discloses a highly processable high-strength steel sheet for cans. The steel sheet for cans includes C: 0.001% to 0.080%, Si: 0.003% to 0.100%, Mn: 0.10% to 0.80%, P: 0.001% to 0.100%, S: 0.001% to 0.020%, Al: 0.005% to 0.100%, N: 0.0050% to 0.0150%, and B: 0.0002% to 0.0050%. In the cross section in the rolling direction, the steel sheet for cans includes, in terms of area ratio, 0.01% to 1.00% of crystal grains having an elongation rate of 5.0 or larger.

45 Citation List

Patent Literature

[0009]

50

PTL 1: Japanese Unexamined Patent Application Publication No. 2001-49383

PTL 2: Japanese Unexamined Patent Application Publication No. 2013-28842

Summary of Invention

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Technical Problem

[0010] The techniques described in Patent Literature 1 and Patent Literature 2 are intended to produce cans which

are containers and not to produce crown caps. As described below, the steel sheets described in these patent documents are not suitable for forming crown caps.

[0011] The steel sheet described in Patent Literature 1 is flexible. Thus, the anisotropy of the steel sheet increases as the second cold rolling reduction is increased in order to obtain desired strength, which impairs formability.

[0012] It is also difficult to obtain both strength and formability required for crown caps by using the steel sheet described in Patent Literature 2. As such, techniques that have been used for years for obtaining both formability and strength cannot be applied to a steel sheet for crown cap.

[0013] In light of the aforementioned problems, an object of the present invention is to provide a steel sheet for crown that, even when reduced in gauge, has sufficient strength and formability suitable for forming crown caps, and to provide a method for forming the steel sheet for crown cap. Solution to Problem

[0014] The inventors of the present invention have diligently carried out studies to solve the aforementioned problems. As a result, it is found that the aforementioned problems can be solved by optimizing the components and controlling the yield strength in the rolling direction and the average Lankford value in particular ranges, completing the present invention. More specifically, the present invention provides the following.

[1] A steel sheet for crown cap has a composition including, in terms of % by mass, C: 0.002% or more and 0.010% or less, Si: 0.05% or less, Mn: 0.05% or more and 0.30% or less, P: 0.030% or less, S: 0.020% or less, Al: less than 0.0100%, N: 0.0050% or less, and the balance being Fe and unavoidable impurities. The C content is more than 0.003% when the Al content is 0.005% or more. The yield strength in the rolling direction is 500 MPa or more. The average Lankford value described below is 1.3 or more: Average Lankford value = $(r_L + 2 \times r_D + r_C)/4$, where r_L represents a Lankford value in the direction parallel to the rolling direction, r_D represents a Lankford value in the direction at 45° with respect to the rolling direction, and r_C represents a Lankford value in the direction at 90° with respect to the rolling direction.

[2] In the steel sheet for crown cap according to [1], the absolute value of Δr described below is 0.40 or less:

$$\Delta r = (r_L - 2 \times r_D + r_C) / 2,$$

where r_L represents a Lankford value in the direction parallel to the rolling direction, r_D represents a Lankford value in the direction at 45° with respect to the rolling direction, and r_C represents a Lankford value in the direction at 90° with respect to the rolling direction.

[3] A method for producing a steel sheet for crown cap includes a hot-rolling step of rough-rolling a slab having the composition according to [1] and finish-rolling the rough-rolled slab at a finish-rolling temperature of 850°C or higher, a coiling step of coiling the hot-rolled sheet, which is obtained in the hot-rolling step, at 450°C or higher and 750°C or lower, a pickling step of pickling the hot-rolled sheet after the coiling step, a first cold-rolling step of cold-rolling the hot-rolled sheet after the pickling step, an annealing step of annealing the cold-rolled sheet, which is obtained in the first cold-rolling step, at 650°C or higher and 790°C or lower, and a second cold-rolling step of cold-rolling the annealed sheet, which is obtained in the annealing step, at a rolling reduction of 10% or more and 50% or less when the Al content is 0.003% or less or at a rolling reduction of 20% or more and 50% or less when the Al content is more than 0.003%. Advantageous Effects of Invention

[0015] According to the present invention, a steel sheet for crown cap that, even when reduced in gauge, has strength and formability suitable for forming crown caps can be obtained. Description of Embodiments

[0016] Embodiments of the present invention will be described below. The present invention is not limited to the following embodiments.

<Steel Sheet for Crown Cap>

[0017] A steel sheet for crown cap has a composition including, in terms of % by mass, C: 0.002% or more and 0.010% or less, Si: 0.05% or less, Mn: 0.05% or more and 0.30% or less, P: 0.030% or less, S: 0.020% or less, Al: less than 0.0100%, N: 0.0050% or less, and the balance being Fe and unavoidable impurities. The C content is more than 0.003% when the Al content is 0.005% or more. The yield strength in the rolling direction is 500 MPa or more. The average Lankford value is 1.3 or more. The absolute value of is preferably 0.40 or less. The steel sheet for crown cap of the present invention will be described below for its composition and physical properties in this order.

[0018] In the description of the composition below, "%" expressing the amount of each component contained in the steel sheet for crown cap of the present invention denotes "% by mass".

C: 0.002% or more and 0.010% or less

[0019] When the C content is more than 0.010%, the average Lankford value after second cold-rolling is low, which impairs formability as described below and makes the steel sheet unsuitable for forming crown caps. When the C content is more than 0.010%, the formed crown cap has uneven pleats, that is, a shape defect. When the C content is less than 0.002%, it is difficult to obtain desired strength even by second cold-rolling. Therefore, the C content is set to 0.002% or more and 0.010% or less. The C content is preferably 0.002% or more and 0.006% or less, and more preferably 0.003% or more and 0.005% or less.

Si: 0.05% or less

[0020] A Si content of more than 0.05% is undesirable because Si affects formability because of the same reason as for C. Therefore, the Si content is set to 0.05% or less. The Si content is more preferably 0.03% or less. The Si content is still more preferably 0.01% or less.

Mn: 0.05% or more and 0.30% or less

[0021] When the Mn content is less than 0.05%, it is difficult to avoid hot brittleness even at a low S content, which causes problems associated with, for example, surface cracks in continuous casting. A Mn content of more than 0.30% is also undesirable because of the same reason as for C. Therefore, the Mn content is set to 0.05% or more and 0.30% or less. The Mn content is more preferably 0.10% or more and 0.30% or less. The Mn content is still more preferably 0.15% or more and 0.25% or less.

P: 0.030% or less

[0022] A P content of more than 0.030% results in steel being hard or low corrosion resistance. Therefore, the upper limit of the P content is set to 0.030%. The upper limit of the P content is more preferably 0.020%.

S: 0.020% or less

[0023] Sulfur bonds to Mn in steel to form MnS. A large amount of MnS precipitation reduces the hot ductility of the steel. This effect becomes notable when the sulfur content is more than 0.020%. Therefore, the upper limit of the S content is set to 0.020%. The upper limit of the S content is more preferably 0.011%. The S content is still more preferably 0.007% or less.

Al: less than 0.0100%

[0024] Aluminum is an element to be added as a deoxidizer. Aluminum has an effect of reducing the amount of oxygen (O) in molten steel and thus suppressing generation of solidification defects in a steel ingot. In order to obtain this effect, the Al content is preferably 0.0005% or more. However, a large amount of Al results in reduced formability. Specifically, when the Al content is 0.0100% or more, the average Lankford value is low, which makes the shapes of the pleats uneven in forming crown caps and causes a shape defect. Therefore, the Al content is set to less than 0.0100%.

[0025] Furthermore, when the Al content is 0.003% or less, an improvement in the solid-solution strengthening ability attributed to C and N is achieved, which eliminates a need to increase the rolling reduction in the second cold-rolling. Specifically, even when a steel sheet for crown cap having a thickness of less than 0.20 mm is produced, desired properties can be achieved by setting the rolling reduction in the second cold-rolling to 10% to 40%. Therefore, the Al content is preferably set to 0.003% or less. The Al content is more preferably 0.002% or less. When the strength is improved by setting the Al content to 0.003% or less as described above, degradation of formability due to C can be avoided by setting the C content to 0.002% to 0.006%.

N: 0.0050% or less

[0026] When the N content is more than 0.0050%, the average Lankford value after the second cold-rolling is low, which results in degraded formability. Therefore, the N content is set to 0.0050% or less. The N content is preferably less than 0.0040%.

[0027] The C content is more than 0.003% when the Al content is 0.005% or more. When the Al content is 0.005% or more, N in the steel bonds to Al to reduce yield strength. Therefore, when the Al content is 0.005% or more, the yield strength is ensured by setting the C content to more than 0.003%.

[0028] The balance, excluding the above-described components, is Fe and unavoidable impurities. The unavoidable impurities include components that are unavoidably mixed in the production process and components that are unavoidably added in order to impart desired properties unless the advantageous effects of the present invention are impaired. Examples of the unavoidable impurities include at least one of V, B, Ca, Zn, Co, and As in a total amount of 0.02% or less, Cu: 0.10% or less, Ni: 0.10% or less, Cr: 0.09% or less, and O: 0.0150% or less.

[0029] Next, the mechanical properties of the steel sheet for crown cap according to the present invention will be described.

Yield strength: 500 MPa or more

[0030] The steel sheet for crown cap needs to have sufficient strength to avoid detachment of a crown cap from the bottle against the internal pressure of the bottle. A typical steel sheet for crown cap has a thickness of about 0.22 to 0.24 mm. If the steel sheet for crown cap is reduced in gauge below this range, the strength of the steel sheet for crown cap needs to be further increased. When the yield strength of the steel sheet for crown cap in the rolling direction is less than 500 MPa, it is impossible to impart sufficient strength to such a crown cap that has been reduced in gauge, which results in low pressure resistance. Therefore, the yield strength in the rolling direction is set to 500 MPa or more. The yield strength is preferably set to 550 MPa or more. When the yield strength in the rolling direction is more than 650 MPa, it may be difficult to control the press conditions in forming crown caps. The yield strength in the rolling direction is thus preferably set to 650 MPa or less. The yield strength can be determined by Metallic materials--tensile testing--method described in "JIS Z 2241".

Average Lankford value: 1.3 or more

[0031] The steel sheet for crown cap is punched into a circular blank, which is then pressed to form a crown cap. The shape of the crown cap after forming is evaluated mainly based on the evenness of the shapes of the pleats. If the shapes of the pleats are uneven, the sealing performance after capping is impaired, which may cause the content of the bottle to be leaked. The formability of the steel sheet for crown cap is associated with the composition and the yield strength and more closely associated with the average Lankford value. Specifically, when the average Lankford value is less than 1.3, the shapes of the pleats after forming are uneven. Consequently, the average Lankford value is set to 1.3 or more. The average Lankford value is preferably 1.4 or more. A larger average Lankford value is more preferred. The average Lankford value can be evaluated by determining the r values by the method described in the attached document JA in "JIS Z 2254". The average Lankford value is obtained by determining r_L : the r value in the direction parallel to the rolling direction, r_D : the r value in the direction at 45° with respect to the rolling direction, and r_C : the r value in the direction at 90° with respect to the rolling direction by the method described above, and performing calculation in accordance with $(r_L + 2 \times r_D + r_C)/4$.

Absolute value of Δr : 0.40 or less

[0032] In the present invention, the absolute value of is preferably 0.40 or less. The steel sheet for crown cap is punched into a circular blank, which is then pressed to form a crown cap. The shape of the crown cap after forming is evaluated mainly based on the evenness of the shapes of the pleats. If the shapes of the pleats are uneven, the sealing performance after capping is impaired, which may cause the content of the bottle to be leaked. The formability of the steel sheet for crown cap is associated with the composition and the yield strength and also closely associated with the absolute value of (Lankford value (r value) for in-plane anisotropy). Specifically, when the absolute value of is more than 0.40, the shapes of the pleats after forming are uneven. Therefore, the absolute value of Δr is set to 0.40 or less. A smaller absolute value of is more preferred. The absolute value of is preferably 0.20 or less. The absolute value of is obtained by determining r_L : the r value in the direction parallel to the rolling direction, r_D : the r value in the direction at 45° with respect to the rolling direction, and r_C : the r value in the direction at 90° with respect to the rolling direction by the method described above, and performing calculation in accordance with $(r_L - 2 \times r_D + r_C)/2$.

Thickness: less than 0.20 mm

[0033] The thickness of the steel sheet for crown cap of the present invention is not limited, but the steel sheet for crown cap of the present invention has both good formability and high strength even if it is thin. The term "thin" means that the thickness is less than 0.20 mm, and more specifically 0.13 to 0.19 mm.

<Method for Producing Steel Sheet for Crown Cap>

[0034] An exemplary method for producing the steel sheet for crown cap of the present invention will be described below.

[0035] The steel sheet for crown cap of the present invention can be produced by a DR method including a hot-rolling step, a coiling step, a pickling step, a first cold-rolling step, an annealing step, and a second cold-rolling step. Each step will be described below.

Hot-Rolling Step

[0036] The hot-rolling step is a step of rough-rolling a slab having the composition described above and finish-rolling the rough-rolled slab. The slab is produced, for example, by controlling the molten steel so as to have the above-mentioned chemical components (composition) by a publicly known method using a converter or the like, followed by continuous casting. Since the composition of the slab is equivalent to the composition of the steel sheet for crown cap, the composition of the steel sheet for crown cap is controlled when the slab is produced.

[0037] The rough-rolling conditions are not limited, but the slab is preferably heated to 1200°C or higher in rough rolling. The upper limit of the heating temperature is not limited, but application of significantly high heating temperature causes excess scale formation, which results in defects on the product surface. Therefore, the heating temperature is preferably set to 1300°C or lower.

[0038] The finish-rolling temperature is set to 850°C or higher from the viewpoint of the stability of the rolling load. The finish-rolling temperature is preferably 880°C or higher, and more preferably 900°C or higher. Since it is difficult to produce a thin steel sheet at a finish-rolling temperature higher than needed, the finish-rolling temperature is preferably set to 960°C or lower.

Coiling Step

[0039] The coiling step is a step of coiling the hot-rolled sheet obtained in the hot-rolling step. When the coiling temperature is higher than 750°C, crystal grains are coarsened to reduce the strength and, as a result, the mechanical properties defined in the present invention are not obtained. Therefore, the coiling temperature in the hot-rolling step is set to 750°C or lower. The coiling temperature is preferably 740°C or lower and more preferably 700°C or lower. The coiling temperature is still more preferably 650°C or lower. In order to lower the coiling temperature to less than 450°C and operate without impairing efficiency, the finish-rolling temperature needs to be lowered accordingly. Since it is difficult to control the shape of the sheet at a low finish-rolling temperature, the coiling temperature is set to 450°C or higher. The coiling temperature is more preferably 500°C or higher. The coiling temperature is still more preferably 550°C or higher.

Pickling Step

[0040] The pickling step is a step of pickling the hot-rolled sheet after the coiling step. The pickling step involves removing surface scale. The pickling conditions are not limited as long as surface scale can be removed.

First cold-rolling step

[0041] The first cold-rolling step is a step of cold-rolling the hot-rolled sheet after the pickling step. The rolling reduction in the first cold-rolling step is not limited, but the rolling reduction is preferably set to 85% to 94% in order to produce an ultra-thin material.

Annealing step

[0042] The annealing step is a step of annealing the cold-rolled sheet obtained in the first cold-rolling step. When the annealing temperature is higher than 790°C, troubles, such as heat buckling, that occur during the passage of the sheet tend to occur in continuous annealing. When the annealing temperature is lower than 650°C, the recrystallization is incomplete, which leads to an uneven material. Therefore, the annealing temperature is set to 650°C to 790°C.

Second cold-rolling step

[0043] The second cold-rolling step is a step of cold-rolling the annealed sheet obtained in the annealing step. This second cold-rolling imparts desired strength. In the production method of the present invention, the condition of the rolling reduction to be selected differs with the Al content. Specifically, the rolling reduction is 10% or more and 50% or

less when the Al content is 0.003% or less. The rolling reduction is 20% or more and 50% or less when the Al content is more than 0.003%. If the rolling reduction is less than 10% when the Al content is 0.003% or less and if the rolling reduction is less than 20% when the Al content is more than 0.003%, the strength sufficient to ensure the pressure resistance of the crown cap is not obtained. When the rolling reduction in the second cold-rolling is more than 50%, the excess anisotropy is induced and thus the formability is impaired. Consequently, the rolling reduction in the second cold-rolling is set in the above-mentioned range in accordance with the Al content. The preferred upper limit of the rolling reduction is 40% at any Al content. However, one of the characteristics is that the rolling reduction can be low when the Al content is 0.003% or less. The rolling reduction is preferably 40% or less as described below when the Al content is 0.003% or less.

[0044] When the Al content is 0.003% or less in the present invention, an improvement in the solid-solution strengthening ability attributed C and N is achieved, which eliminates a need to increase the rolling reduction in the second cold-rolling. Specifically, even when a steel sheet for crown cap having a thickness of less than 0.20 mm is produced, desired properties can be achieved by setting the rolling reduction in the second cold-rolling to 10% to 40%.

[0045] After the second cold-rolling, a process such as a plating process (electrolytic tin plating, electrolytic chromium plating) is performed by an ordinary method to produce a steel sheet for crown cap.

[0046] As described above, according to the embodiments, the steel sheet has both high strength and good crown cap formability, which enables gauge reduction of crown caps.

EXAMPLES

[0047] In Examples, a steel having the composition described in Table 1 with the balance being Fe and unavoidable impurities was first smelted in an actual converter and continuously cast to obtain a steel slab. The steel slab thus obtained was reheated to 1250°C and then hot-rolled in the conditions at a rolling start temperature of 1150°C and at the finish-rolling temperature described in Table 2. The resulting sheet was coiled at the coiling temperature described in Table 2 and then pickled after coiling. Next, the sheet was subjected to first cold-rolling at the first cold rolling reduction described in Table 2, continuously annealed at the annealing temperature described in Table 2, and subsequently subjected to second cold-rolling at the second cold rolling reduction described in Table 2. The obtained steel sheet was continuously subjected to ordinary chromium plating to produce a tin-free steel.

[0048] The steel sheet thus obtained was subjected to a heat treatment corresponding to coating baking at 210°C for 15 minutes. The steel sheet was then subjected to tensile testing and measured for its average Lankford value and Δr value.

[0049] Tensile testing was performed by using a JIS No. 5 tensile test piece in accordance with JIS Z 2241 to determine the yield strength in the rolling direction.

[0050] The average Lankford value was determined by using the natural-vibration method described in the attached document JA in "JIS Z 2254." In this test, r_L was determined by preforming tensile testing in the rolling direction, r_D was determined by performing tensile testing in the direction at 45° with respect to the rolling direction, and r_C was determined by performing tensile testing in the direction at 90° with respect to the rolling direction. The absolute value of Δr was obtained by calculating $(r_L - 2 \times r_D + r_C)/2$ from the measured results.

[0051] The obtained steel sheet was used to form a crown cap and evaluated for crown cap formability. A circular blank having a diameter of 37 mm was pressed in the size of the third type of crown cap (outer diameter: 32.1 mm, height: 6.5 mm, number of pleats: 21) described in "JIS S 9017" (withdrawn standard). The crown cap formability was evaluated by visual observation and rated "A" for the case where the sizes of the pleats were even and "B" for the case where the sizes of the pleats were uneven.

[0052] Pressure testing was performed by using the formed crown cap. A polyvinyl chloride liner was formed on the inner side of the crown cap, and a commercial beer bottle was capped with the crown cap. The internal pressure at which the crown cap was detached was determined by using Secure Seal Tester available from Secure Pak. The pressure resistance was rated "A" for the case where the pressure resistance was higher than or equal to that of crown caps known in the art and "B" for the case where the pressure resistance was lower than that of crown caps known in the art. The obtained results are shown in Table 3.

[0053] In Table 3, the steel sheets of Samples 1 to 5, 13, and 14 which are Invention Examples have a yield strength in the rolling direction of 500 MPa or more, an average Lankford value of 1.3 or more, and an absolute value of Δr of 0.40 or less, which shows both good crown cap formability and high pressure resistance. In contrast, the steel sheet of Sample 6 which is Comparative Example has a yield strength in the rolling direction of less than 500 MPa, namely, low pressure resistance because the Al content is more than 0.005% but the C content is less than 0.003%. In Comparative Examples, the steel sheet of Sample 7 has an excessively high C content, the steel sheet of Sample 8 has an excessively high Mn content, the steel sheet of Sample 9 has an excessively high Al content, the steel sheet of Sample 10 has an excessively high N content, and the coiling temperature after hot rolling was too high for the steel sheet of Sample 11. Because of these reasons, all of these steel sheets have an average Lankford value of less than 1.3, namely, poor crown

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cap formability. With regard to the steel sheet of Sample 12 which is Comparative Example, the second cold rolling reduction was too low, and thus the yield strength in the rolling direction is less than 500 MPa, which shows low pressure resistance.

[Table 1]

	(% by mass)						
	C	Si	Mn	P	S	Al	N
Sample 1	0.005	0.03	0.10	0.011	0.013	0.0045	0.0028
Sample 2	0.004	0.03	0.25	0.014	0.011	0.0056	0.0022
Sample 3	0.008	0.04	0.08	0.020	0.009	0.0032	0.0038
Sample 4	0.010	0.02	0.09	0.013	0.014	0.0060	0.0031
Sample 5	0.005	0.03	0.15	0.016	0.010	0.0089	0.0019
Sample 6	0.002	0.05	0.16	0.022	0.015	0.0052	0.0027
Sample 7	0.012	0.02	0.13	0.012	0.013	0.0073	0.0016
Sample 8	0.004	0.01	0.41	0.013	0.008	0.0046	0.0030
Sample 9	0.005	0.03	0.21	0.020	0.014	0.0132	0.0024
Sample 10	0.006	0.04	0.07	0.013	0.013	0.0057	0.0056
Sample 11	0.010	0.02	0.14	0.016	0.008	0.0061	0.0024
Sample 12	0.006	0.03	0.09	0.011	0.013	0.0058	0.0035
Sample 13	0.003	0.001	0.22	0.009	0.005	0.0010	0.0025
Sample 14	0.004	0.001	0.21	0.011	0.003	0.0020	0.0018

[Table 2]

[Table 2]

	Finish-rolling temperature (°C) in hot rolling	Coiling temperature (°C) after hot rolling	Thickness (mm) of hot-rolled sheet	First cold rolling reduction (%)	Annealing temperature (°C)	Second cold rolling reduction (%)	Thickness (mm) of finished sheet	Note
1	880	630	2.5	89	663	35	0.18	Invention Example
2	880	590	2.3	90	680	20	0.18	Invention Example
3	880	725	2.0	88	691	30	0.17	Invention Example
4	880	565	2.5	92	655	25	0.15	Invention Example
5	880	610	2.5	90	683	40	0.15	Invention Example
6	880	595	2.3	90	679	25	0.17	Comparative Example
7	880	720	2.0	88	667	20	0.19	Comparative Example
8	880	630	2.3	90	690	30	0.16	Comparative Example
9	880	680	2.3	90	657	20	0.18	Comparative Example
10	880	700	2.5	92	682	25	0.15	Comparative Example
11	880	760	2.5	90	680	40	0.15	Comparative Example
12	880	705	2.5	92	695	15	0.17	Comparative Example
13	930	690	2.3	89	685	35	0.17	Invention Example

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(continued)

	Finish-rolling temperature (°C) in hot rolling	Coiling temperature (°C) after hot rolling	Thickness (mm) of hot-rolled sheet	First cold rolling reduction (%)	Annealing temperature (°C)	Second cold rolling reduction (%)	Thickness (mm) of finished sheet	Note
14	920	640	2.3	90	692	24	0.17	Invention Example

[Table 3]

[Table 3]

	Yield strength (MPa) in rolling direction	Average Lankford value	Δr	Crown cap formability	Pressure resistance	Note
Sample 1	605	1.5	0.3	A	A	Invention Example
Sample 2	532	1.6	0.1	A	A	Invention Example
Sample 3	587	1.5	0.2	A	A	Invention Example
Sample 4	564	1.4	0.3	A	A	Invention Example
Sample 5	623	1.6	0.3	A	A	Invention Example
Sample 6	487	1.5	0.3	A	B	Comparative Example
Sample 7	525	1.1	0.4	B	B	Comparative Example
Sample 8	592	1.0	0.4	B	B	Comparative Example
Sample 9	523	1.0	0.4	B	B	Comparative Example
Sample 10	553	1.2	0.3	B	B	Comparative Example
Sample 11	514	1.2	0.4	B	B	Comparative Example
Sample 12	465	1.5	0.3	A	B	Comparative Example
Sample 13	577	1.4	0.1	A	A	Invention Example
Sample 14	605	1.5	0.2	A	A	Invention Example

Claims

1. A steel sheet for crown cap having a composition comprising, in terms of % by mass, C: 0.002% or more and 0.010% or less, Si: 0.05% or less, Mn: 0.05% or more and 0.30% or less, P: 0.030% or less, S: 0.020% or less, Al: less than 0.0100%, N: 0.0050% or less, and the balance being Fe and unavoidable impurities, the C content being more than 0.003% when the Al content is 0.005% or more, a yield strength in a rolling direction being 500 MPa or more, and an average Lankford value described below being 1.3 or more:

$$\text{Average Lankford value} = (r_L + 2 \times r_D + r_C) / 4,$$

where r_L represents a Lankford value in a direction parallel to the rolling direction, r_D represents a Lankford value in a direction at 45° with respect to the rolling direction, and r_C represents a Lankford value in a direction at 90° with respect to the rolling direction.

2. The steel sheet for crown cap according to Claim 1, wherein an absolute value of described below is 0.40 or less:

$$\Delta r = (r_L - 2 \times r_D + r_C) / 2,$$

where r_L represents a Lankford value in a direction parallel to the rolling direction, r_D represents a Lankford value in a direction at 45° with respect to the rolling direction, and r_C represents a Lankford value in a direction at 90° with respect to the rolling direction.

3. A method for producing a steel sheet for crown cap, the method comprising:

a hot-rolling step of rough-rolling a slab having the composition according to Claim 1 and finish-rolling the rough-rolled slab at a finish-rolling temperature of 850°C or higher;

a coiling step of coiling the hot-rolled sheet, which is obtained in the hot-rolling step, at 450°C or higher and 750°C or lower;

a pickling step of pickling the hot-rolled sheet after the coiling step;

a first cold-rolling step of cold-rolling the hot-rolled sheet after the pickling step;

an annealing step of annealing the cold-rolled sheet, which is obtained in the first cold-rolling step, at 650°C or higher and 790°C or lower; and

a second cold-rolling step of cold-rolling the annealed sheet, which is obtained in the annealing step, at a rolling reduction of 10% or more and 50% or less when the Al content is 0.003% or less or at a rolling reduction of 20% or more and 50% or less when the Al content is more than 0.003%.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/005115

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, C21D9/46(2006.01)i, C22C38/06(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C38/00, C21D9/46, C22C38/06

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 1996-2015

Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-263789 A (JFE Steel Corp.), 12 November 2009 (12.11.2009), claims; paragraph [0031]; tables 1 to 3 & WO 2010/113333 A1 & CN 102388156 A & KR 10-2011-0130478 A & TW 201037091 A1	1-3
A	JP 2013-19027 A (JFE Steel Corp.), 31 January 2013 (31.01.2013), claims; paragraph [0042]; tables 1 to 3 & WO 2013/008457 A1 & CN 103649353 A & KR 10-2014-0030334 A & TW 201311912 A1	1-3
A	JP 9-118928 A (Kawasaki Steel Corp.), 06 May 1997 (06.05.1997), claims; tables 1 to 2 (Family: none)	1-3



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document member of the same patent family

Date of the actual completion of the international search

14 December 2015 (14.12.15)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/005115

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 5-247669 A (Toyo Kohan Co., Ltd.), 24 September 1993 (24.09.1993), claims; paragraph [0033] (Family: none)	1-3
A	JP 55-48574 B2 (Nippon Steel Corp.), 06 December 1980 (06.12.1980), column 2, lines 19 to 22 & JP 50-121118 A	1-3

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2001049383 A [0009]
- JP 2013028842 A [0009]