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(54) METHOD FOR PRODUCING CAN MANUFACTURING STEEL SHEET

(57) Provided is a method of manufacturing a steel sheet for cans, where excessively high strengthening due to work hardening in cold-rolling is avoided, and thickness variation in the longitudinal direction of a steel sheet coil is inhibited, in a reduction in the steel sheet manufacturing cost by omitting the recrystallization annealing step. The steel compositions contain, in mass%, C: 0.005% or less, Mn: 0.05 to 0.5%, Al: 0.01 to 0.10%, N: 0.0010 to 0.0070%, and B: 0.15xN to 0.75xN (0.20xN to 0.97xN in atomic ratio) and further contain either or both Nb: 4xC to 20×C (0.52xC to 2.58xC in atomic ratio) and Ti: 2xC to 10×C (0.50xC to 2.51×C in atomic ratio), and the balance is Fe and inevitable impurity elements. The steel is continuously cast into a slab, the slab is hot-rolled at a finishing temperature of not higher than Ar_3 transformation point, and the hot-rolled steel sheet is subjected to coiling, pickling, and then cold-rolling at a reduction of 50 to 96%.

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Description

Technical Field

[0001] The present invention relates to a method of manufacturing a steel sheet for cans, being excellent in thickness accuracy, and specifically relates to a method of manufacturing a steel sheet that is suitable for forming cans by drawing so as to have a height similar to the can body diameter or by bending the sheet into a round tube or a rectangular tube and jointing the edges thereof to form a can body and then forming a flange.

Background Art

[0002] Cans, such as beverage cans, food cans, 18-liter cans, and pail cans, are roughly divided into two-piece cans and three-piece cans based on their manufacturing method (process).

[0003] In the two-piece can, a can bottom and a can body are integrally formed by, for example, shallow drawing, drawing and wall ironing (DWI), or drawing and redrawing (DRD) of a surface-treated steel sheet, which is provided with treatment such as tin plating, chromium plating, metal oxide coating, chemical passivation coating, inorganic film coating, organic resin film coating, or oil coating. Then, this is provided with an end to give a can consisting of two parts.

[0004] In the three-piece can, a can body is formed by bending a surface-treated steel sheet into a round tube or a rectangular tube and jointing the edges thereof. Then, this is provided with an upper end and a bottom end to give a can consisting of three parts.

[0005] In these cans, the ratio of material costs to can costs is relatively high. Therefore, in order to reduce the can costs, it is strongly required to reduce the costs of steel sheets. Here, it is needless to say that costs are elevated along with an increase in the number of process steps in manufacturing a steel sheet. In particular, annealing for recrystallizing a steel sheet at high temperature is a step that needs high energy costs for heating and thereby raises the manufacturing costs. Therefore, it is suggested to reduce the costs by omitting this step. However, a steel sheet that is not recrystallized after cold-rolling is in a condition of having excessively high strength due to work hardening and is thereby unsuitable for being used for manufacturing cans. Therefore, methods for obtaining steel sheets provided with appropriate strength by properly controlling steel compositions and hot-rolling conditions have been conventionally investigated.

[0006] For example, Patent Document 1 discloses a method of manufacturing a steel sheet for cans wherein Nb, which is an element forming a carbonitride, is added to an ultra-low carbon steel; hot-rolling is performed at a temperature of Ar_3 point or lower, namely, in an α region; and annealing, after cold-rolling, is not performed. However, the steel sheet obtained by the technique of Patent Document 1 is in the status after the cold-rolling and is therefore poor in ductility and does not have sufficient formability for some purposes.

[0007] As a technique for improving these problems, Patent Document 2 discloses a technique for improving ductility by adding Nb and Ti, which are elements forming carbonitrides, to an ultra-low carbon steel and performing hot-rolling at a temperature of Ar_3 point or less, cold-rolling, and then low-temperature annealing. The term "low-temperature annealing" used herein is annealing that is performed at a temperature not to cause recrystallization, and, therefore, the energy cost for heating is reduced.

[0008] In addition, Patent Document 3 discloses a technique involving adding Nb, Ti, Zr, V, and B, which are elements forming carbonitrides, to an ultra-low carbon steel and performing hot-rolling at a temperature of Ar_3 point or less, cold-rolling, and then annealing at a temperature of not higher than the recrystallization temperature.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 4-280926
Patent Document 2: Japanese Unexamined Patent Application Publication No. 8-41549
Patent Document 3: Japanese Unexamined Patent Application Publication No. 6-248339

Disclosure of Invention

[0009] The characteristics common in the background art of Patent Documents 1 to 3 are that an ultra-low carbon steel is used as the steel; elements forming carbonitrides are added; and the hot-rolling is performed at a temperature of not higher than Ar_3 point. However, the steel sheets manufactured under.these conditions have a problem that thickness uniformity in the longitudinal direction of a steel sheet coil is insufficient. In addition, according to Examples in Patent Documents 2 and 3, the annealing after cold-rolling is performed at a temperature higher than 400˚C. The temperature is relatively low compared to that of conventional recrystallization annealing, but it is still high and is insufficient for sufficiently reducing energy costs for heating.

[0010] The present invention has been accomplished under these circumstances. In reduction of the steel sheet manufacturing cost by omitting the recrystallization annealing step, it is therefore an object of the present invention to provide a method of manufacturing a steel sheet for cans, where excessively high strengthening due to work hardening in cold-rolling is avoided, thickness variation in the longitudinal direction of a steel sheet coil is inhibited, and also the effect of reducing the cost due to omission of the recrystallization annealing step is maximized.

[0011] Aspects of the present invention are as follows;

(1) a method of manufacturing a steel sheet for cans, the method including providing a slab by continuous casting of a steel consisting of steel compositions containing, in mass%, C: 0.005% or less, Mn: 0.05 to 0.5%, Al: 0.01 to 0.12%, N: 0.0010 to 0.0070%, and B: 0.15xN to 0.75xN (0.20xN to 0.97xN in atomic ratio) and further containing either or both Nb: 4xC to 20xC (0.52xC to 2.58xC in atomic ratio) and Ti: 2xC to 10×C (0.50×C to 2.51×C in atomic ratio) and the balance of Fe and inevitable impurity elements; hot-rolling the slab at a finishing temperature of not higher than Ar_3 transformation point; and subjecting the hot-rolled steel sheet to coiling, pickling, and then cold-rolling at a reduction of 50 to 96%,

(2) the method of manufacturing a steel sheet for cans according to the above (1), wherein the coiling is performed at a temperature of 640 to 750˚C, and

(3) the method of manufacturing a steel sheet for cans according to the above (1) or (2), the method further including heat treatment at a temperature of 150 to 400˚C after the cold-rolling.

[0012] Incidentally, in the present invention, % showing steel compositions all means mass%.

[0013] According to the present invention, a reduction in the steel sheet manufacturing cost can be achieved by omitting the recrystallization annealing step. Furthermore, in the resulting steel sheet, thickness variation in the longitudinal direction of a steel sheet coil is inhibited.

[0014] Since the steel sheet having reduced thickness variation in the longitudinal direction of the steel sheet coil is thus obtained by omitting recrystallization annealing, it is possible to manufacture the steel sheet at costs lower than conventional methods, which contributes to a reduction in costs of a can body itself.

Best Modes for Carrying Out the Invention

[0015] The present invention will be described in detail below.

[0016] The present inventors have accomplished the present invention by investigating thickness variation in the longitudinal direction of a steel sheet coil when an ultra-low carbon steel containing carbonitride-forming element(s) is hot-rolled at a temperature of Ar_3 point or less and is further cold-rolled. The present invention will be described in detail below.

[0017] First, the reasons for limiting steel compositions will be described.

C: 0.005% or less

[0018] The present invention is a method of manufacturing a steel sheet for cans where the cost is reduced by omitting the recrystallization annealing step. However, since a steel sheet that is not recrystallized after cold-rolling is in a condition of having excessively high strength due to work hardening and has insufficient ductility, the steel sheet is unsuitable for being used for manufacturing cans. Therefore, it is necessary to use a steel primarily having low strength by itself. For this, it is necessary to use an ultra-low carbon steel containing carbon, which has a high sold-solution strengthening ability, in a reduced amount as a steel composition. When the amount of C is higher than 0.005%, the steel after cold-rolling is in a condition of having excessively high strength and insufficient ductility and is therefore unsuitable for being used for manufacturing cans. Consequently, the C content is determined to be 0.005% or less, preferably, 0.003% or less. Incidentally, from the viewpoint of using a steel having low strength by itself, a lower C content is desirable, but decarburization for reducing C content takes a long time, resulting in an increase in the manufacturing cost. Therefore, the lower limit of the C content is preferably 0.0005% or more, more preferably, 0.0015% or more.

Mn: 0.05 to 0.5%

[0019] When the Mn content is lower than 0.05%, it is difficult to avoid so-called high-temperature brittleness, even if the S content is decreased, which may cause problems such as surface cracking. On the other hand, when the Mn content is higher than 0.50%, the transformation point becomes too low, which makes it difficult to obtain a desirable structure when rolling is conducted at a temperature of lower than the transformation point. Therefore, the Mn content is determined to be 0.05% or more and 0.50% or less. Incidentally, when the formability is particularly regarded as an important factor, the Mn content is preferably 0.20% or less.

S: 0.008% or less (preferred condition)

[0020] S does not particularly affect the properties of the steel sheet of the present invention. However, when the amount of S is higher than 0.008% and also the amount of N is higher than 0.0044%, nitrides and carbonitrides, BN, Nb(C,N), and AlN, precipitate using MnS generated in a large amount as precipitation nuclei, which causes a decrease in hot ductility. Therefore, the S content is desirably 0.008% or less.

Al: 0.01 to 0.12%

[0021] When the Al amount is lower than 0.01%, a sufficient deoxidation effect cannot be obtained. In addition, an effect decreasing the N solid solution in the steel by forming AlN with N is not sufficiently obtained. On the other hand, when the content of higher than 0.12%, these effects saturate, and inclusions such as alumina tend to be generated. Therefore, the Al amount is determined to be 0.01% or more and 0.12% or less.

N: 0.0010 to 0.0070%

[0022] When the amount of N is lower than 0.0010%, the manufacturing cost of a steel sheet is increased, and also stable manufacturing is difficult. In addition, in the present invention, the ratio of B and N is important as described below. When the amount of N is small, it is difficult to control the amount of B for adjusting the ratio of B and N to a certain range. On the other hand, when the amount of N is higher than 0.0070%, the hot ductility of the steel is deteriorated. This is caused by embrittlement due to precipitation of nitrides and carbonitrides, such as BN, Nb(N,C), and AlN, when the N amount is higher than 0.0070%. In particular, a risk of occurrence of slab cracking during continuous casting is increased. If slab cracking occurs, a step of cutting the corner of the slab cracking portion or grinding it with a grinder is necessary. Since this requires a large amount of labor and costs, productivity is highly decreased. Therefore, the N amount is determined to be 0.0010% or more and 0.0070% or less, preferably, 0.0044% or less.

B: 0.15×N to 0.75xN

[0023] B is an important element that largely affects the properties of a steel sheet in the present invention.

[0024] The present invention provides a method of manufacturing a steel sheet for cans, where the cost is reduced by omitting the recrystallization annealing step. Therefore, the method involves (1) using an ultra-low carbon steel as the steel, (2) adding carbonitride-forming elements, and (3) hot-rolling at a temperature of not higher than Ar_3 point. However, the steel sheets manufactured under these conditions still have a problem that thickness uniformity in the longitudinal direction of a steel sheet coil is insufficient. Accordingly, in the present invention, as a result of in detail investigation of such a phenomenon, it was found that satisfactory thickness uniformity in the longitudinal direction of a steel sheet coil can be obtained by adding an appropriate amount of B to the steel. This is probably based on the following mechanism. First, the nonuniformity in the thickness in the longitudinal direction of a steel sheet coil occurs in the hot-rolled steel sheet. This is thought that since deformation resistance of an ultra-low carbon steel containing a carbonitride-forming element is discontinuously changed when its austenite is transformed into ferrite at the Ar_3 point, variations in the interstand tension and the rolling load are caused by occurrence of transformation between hot-rolling stands, resulting in a variation in the thickness. It is thought that the addition of B inhibits the discontinuous change in the deformation resistance, and thereby that the thickness uniformity is improved. That is, an important aspect of the present invention is that the discontinuous change in deformation resistance is inhibited by appropriately regulating the addition amount of B. As a result of the investigation, it was found that the addition amount of B has to be determined in a proper relationship with the addition amount of N forming BN and that in order to obtain such an effect, the necessary amount of B to be added is 0.15×N or more in mass ratio. On the other hand, if B is added in an amount of 0.75xN or more in mass%, the above-mentioned effect is saturated and also the cost is increased. Therefore, the addition amount of B is determined to be 0.15xN to 0.75xN (0.20xN to 0.97xN in atomic ratio).

[0025] Either or both Nb: 4xC to 20xC (0.52xC to 2.58xC in atomic ratio) and Ti: 2xC to 10×C (0.50×C to 2.51×C in atomic ratio)

[0026] Nb is a carbonitride-forming element and has an effect of decreasing strength of a steel by fixing C and N in the steel as precipitates. In order to sufficiently exhibit the effect, an addition amount of 4xC or more in mass ratio is necessary. On the other hand, when the Nb addition amount is too large, the function of decreasing the C in solution is saturated and also the manufacturing cost is increased because that Nb is expensive. Therefore, it is necessary to control the Nb amount to be 20xC or less. Consequently, the Nb amount is within the range of 4xC to 20xC in mass ratio (0.52xC to 2.58xC in atomic ratio).

[0027] Ti is a carbonitride-forming element and has an effect of decreasing strength of a steel by fixing C and N in the steel as precipitates. In order to sufficiently exhibit the effect, an addition amount of 2xC or more in mass ratio is necessary. On the other hand, when the Ti addition amount is too large, the function of decreasing the C in solution is saturated and also the manufacturing cost is increased because that Ti is expensive. Therefore, it is necessary to control the Ti amount to be 10×C or less. Consequently, the Ti amount is within the range of 2xC to 10×C in mass ratio (0.50xC to 2.51×C in atomic ratio).

[0028] In addition, the balance other than the above-mentioned compositions is Fe and inevitable impurities. As the inevitable impurities, for example, the following elements may be contained in the ranges that the functional effects of the present invention are not impaired.

Si: 0.020% or less

[0029] When the Si content is higher than 0.020%, the surface condition of a steel sheet is impaired, which is undesirable as a surface-treated steel sheet and makes the steel harden, resulting in difficulty in hot-rolling. Therefore, the Si content is preferably 0.020% or less.

P: 0.020% or less

[0030] A reduction of the P content improves formability and corrosion resistance, but an excessive reduction causes an increase in the manufacturing cost. From the balance between them, the P content is preferably 0.020% or less.

[0031] In addition to the above-mentioned compositions, inevitable impurities such as Cr and Cu are contained, but these elements do not particularly affect the steel sheet properties of the present invention. Therefore, they can be arbitrarily contained in the ranges that do not affect other properties. In addition, elements other than the compositions mentioned above may be contained in the ranges that do not affect the steel sheet properties.

[0032] Next, the reasons for limiting manufacturing conditions will be described.

[0033] The steel sheet for cans of the present invention is obtained by providing a slab by continuous casting of a steel having chemical compositions adjusted to the above-described ranges, hot-rolling the slab at a finishing temperature of not higher than Ar_3 transformation point, and subjecting the hot-rolled steel sheet to coiling, pickling, and then cold-rolling at a reduction of 50 to 96%. Preferably, the coiling is performed at a coiling temperature of 640 to 750˚C. More preferably, heat treatment at a temperature of 150 to 400˚C is performed after the cold-rolling. These will be described in detail below.

Hot-rolling condition

[0034] Finishing temperature of hot-rolling: Ar_3 transformation point or less

[0035] The finishing temperature of the hot-rolling is an important requirement in the present invention. A steel sheet having a quality that is suitable for manufacturing cans can be obtained by performing the hot-rolling of the steel having compositions satisfying requirements of the present invention at a finishing temperature of not higher than Ar_3 transformation point. It is probably because that the hot-rolling at a temperature not higher than the Ar_3 transformation point makes the grain diameters of the hot-rolled steel sheet sufficiently coarse, which inhibits work hardening in the cold-rolling and thereby inhibits the strength after the cold-rolling from becoming excessive.

[0036] In addition, the Ar_3 transformation point can be determined as a temperature when a change in volume is accompanied by Ar_3 transformation during a heat processing treatment test for reproducing processing and thermal history at hot-rolling is conducted. The Ar_3 transformation point of steel compositions satisfying the requirements of the present invention is approximately 900˚C, and the finishing temperature may be any temperature as long as it is lower than that and is desirably 860˚C or less for surely achieving such a temperature.

[0037] Furthermore, details of the mechanism are unclear, but when the total reduction and the final reduction in the range of not higher than the Ar_3 transformation point are controlled respectively to 40% or more and to 25% or more, uniformity in structure and stability of material quality are increased. In order to further increase them, it is preferable to control the total reduction to 50% or more and the final reduction to 30% or more.

[0038] Furthermore, a finishing rolling mill entry temperature of 950˚C or less enables the hot-rolling to be certainly controlled to the Ar_3 transformation point or less and the structure to be uniform, which is more preferred in the present invention. Details of the mechanism are not sufficiently revealed, but it is suggested that austenite grain diameter before the start of finishing rolling is involved in it. From the viewpoint of preventing occurrence of scale defects, the temperature is preferably controlled to 920˚C or less.

[0039] Coiling temperature: 640 to 750˚C (preferred condition) It is necessary to adjust the coiling temperature not to cause any hindrance to the subsequent steps: pickling and cold-rolling. That is, if coiling is performed at a temperature higher than 750˚C, problems, such as a significant increase in the scale thickness of the steel sheet, deterioration of descalability in pickling, and coil deformation along with a decrease in high-temperature strength of the steel sheet itself, may occur. On the other hand, if the coiling temperature is lower than 640˚C, the heat retaining effect after the coiling becomes insufficient, and grains of hot-rolled steel sheet are hardly coarsened.

[0040] The hot-rolled steel sheet after pickling and coiling is subjected to pickling for scale removing before cold-rolling. The pickling may be performed according to a common process.

Cold-rolling condition after pickling: reduction of 50 to 96%

[0041] The cold-rolling after pickling is performed at a reduction of 50 to 96%. When the reduction is lower than 50%, the crystalline structure becomes non-uniform, and deformation becomes non-uniform in manufacturing cans, resulting in occurrence of roughness on the surface of a product. In addition, the cold-rolling achieves a function of adjusting the shape and the degree of roughness of the steel sheet. Therefore, a reduction of approximate 50% of more is indispensable condition also from these points. Furthermore, the upper limit depends on the strength and thickness required in a product and ability of facilities for hot-rolling and cold-rolling, but rolling at a reduction of higher than 96% makes it difficult to avoid deterioration of local ductility and is therefore applied to only significantly specific purposes.

Heat treatment temperature after cold-rolling: 150 to 400˚C (preferred condition)

[0042] When heat treatment is performed after cold-rolling, the heat treatment temperature is 150 to 400˚C. Since the recrystallization temperature of the compositions of the present invention is approximate 730˚C or higher, a temperature of 150 to 400˚C does not cause recrystallization, but a decrease in strength and an improvement in ductility can be achieved by performing the heat treatment in such a temperature range due to the quantitative relationship among C, Nb, N, and B specified in the present invention. This phenomenon is probably caused by interaction between solid solution elements, such as C and N, which readily diffuse at such temperature and dislocation introduced in cold-rolling, because softening occurs at relatively low temperature. That is, C and N in solutions in the ferrite phase are in ideal conditions due to the quantitative relationship among C, Nb, Ti, N, and B specified in the present invention, and thereby the decrease in strength and the improvement in ductility may be achieved at relatively low temperature. In particular, the influence of B in the addition condition specified in the present invention is large. B and N form BN to reduce the N solid solution. Segregation of the B in solution at grain boundaries prevents C and N from being segregated at grain boundaries. The heat treatment releases the fixing from the condition that C and N fix the dislocation introduced in cold-rolling in the matrix. These probably achieve the decrease in strength and the improvement in ductility. The lowest temperature that allows such effects is 150˚C. On the other hand, when the temperature is 400˚C or higher, recovery starts preferentially at a part of crystalline grains that are high in strain energy accumulation in cold-rolling to make deformation non-uniform in manufacturing cans, which causes roughness on the surface of a product. Therefore, the heat treatment temperature after cold-rolling is determined to be 150 to 400˚C. Furthermore, in order to stably obtain strength and ductility, the temperature is preferably in the range of 200 to 350˚C. In addition, the heat treatment time is not particularly limited as long as it allows solid solution elements to sufficiently escape dislocation from the elements, which is estimated in the present invention, but is preferably in the range of about 10 to 90 seconds.

EXAMPLES

Example 1

Examples will be described below.

[0043] Slabs were produced from various steels shown in Table 1, heated at a heating temperature of 1100 to 1250˚C, and then hot-rolled at finishing temperatures shown in Table 1. The hot-rolled steel sheets were coiled at a coiling temperature of 680˚C, and then pickled and cold-rolled at a rolling reduction of 90%.

[0044] The thus obtained steel sheets were evaluated for thickness variation. The thickness variation was evaluated using the coefficient of variation of the average thickness by measuring thickness after cold-rolling over the entire length in the longitudinal direction of a steel sheet coil with an X-ray thickness gauge set to a cold-rolling facility. One having a coefficient of variation of ±3% or less was determined to be acceptable as a product and shown by ○, and one having a coefficient of variation of higher than ±3% was determined not to be acceptable and shown by X.

[0045] In addition, in Table 1, one hot-rolled at a finishing temperature of not higher than the Ar_3 transformation point, which is inside the scope of the present invention, is shown by ○, and one at a finishing temperature of higher than the Ar_3 transformation point, which is outside the scope of the present invention, is shown by X. The results obtained in the above are shown with the conditions in Table 1.

Table 1

(mass%)

	C	Si	Mn	P	S	Sol.Al	N	Nb	Ti	B	Mass ratio			Finishing temperature		Thickness variation
											Nb/C	Ti/C	B/N	˚C	Ar_3 or less: ○ / higher than Ar_3: ×	±3% or less: ○ / higher than ±3%: ×
1	0.0015	0.01	0.28	0.009	0.011	0.044	0.0025	0.017	-	0.0013	11	-	0.52	820	○	○
2	0.0029	0.01	0.28	0.009	0.011	0.046	0.0023	0.022	-	0.0013	8	-	0.57	820	○	○
3	0.0049	0.01	0.72	0.011	0.011	0.055	0.0025	0.029	-	0.0011	6	-	0.44	855	×	×
4	0.0029	0.01	0.28	0.009	0.011	0.050	0.0019	0.014	-	0.0014	5	-	0.74	820	○	○
5	0.0023	0.01	0.28	0.009	0.010	0.050	0.0019	0.060	-	0.0013	26	-	0.68	820	○	×
6	0.0029	0.01	0.28	0.009	0.011	0.046	0.0009	0.022	-	0.0008	8	-	0.89	820	○	×
7	0.0030	0.01	0.29	0.010	0.011	0.044	0.0012	0.020	-	0.0008	7	-	0.67	820	○	○
8	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	0.022	-	0.0015	7	-	0.22	820	○	○
9	0.0024	0.01	0.32	0.009	0.011	0.038	0.0075	0.024	-	0.0008	10	-	0.11	820	○	×
10	0.0023	0.01	0.32	0.010	0.011	0.038	0.0026	0.023	-	0.0004	10	-	0.15	820	○	○
11	0.0025	0.01	0.33	0.010	0.010	0.036	0.0025	0.023	-	0.0018	9	-	0.72	820	○	○
12	0.0025	0.01	0.33	0.010	0.011	0.036	0.0025	0.020	-	0.0023	8	-	0.92	820	○	×
13	0.0023	0.01	0.28	0.009	0.010	0.050	0.0019	-	0.023	0.0013	-	10	0.68	810	○	○
14	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	-	0.022	0.0015	-	7	0.22	810	○	○
15	0.0025	0.01	0.33	0.010	0.010	0.036	0.0025	-	0.023	0.0018	-	9	0.72	810	○	○
16	0.0024	0.01	0.32	0.009	0.011	0.038	0.0029	-	0.035	0.0008	-	15	0.28	810	○	×
17	0.0029	0.01	0.28	0.009	0.011	0.046	0.0023	0.022	0.029	0.0013	8	10	0.57	820	○	○
18	0.0049	0.01	0.72	0.011	0.011	0.055	0.0025	0.013	0.023	0.0011	3	5	0.44	820	○	×
19	0.0030	0.01	0.29	0.010	0.011	0.044	0.0012	0.020	0.022	0.0008	7	7	0.67	820	○	○

(continued)

	C	Si	Mn	P	S	Sol.Al	N	Nb	Ti	B	Mass ratio			Finishing temperature		Thickness variation
											Nb/C	Ti/C	B/N	˚C	Ar_3 or less: ○ / higher than Ar_3: ×	±3% or less: ○ / higher than ±3%: ×
20	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	0.022	0.044	0.0015	7	14	0.22	820	○	×
21	0.0029	0.01	0.28	0.009	0.011	0.046	0.0009	0.022	0.021	0.0005	8	7	0.56	820	○	×
22	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	-	0.0010	8	-	0.25	900	×	×
23	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	-	0.022	0.0010	-	8	0.25	890	×	×
24	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	0.029	0.0010	8	10	0.25	910	×	×
25	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.010	-	0.0010	3	-	0.25	820	○	×
26	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	-	0.004	0.0010	-	1	0.25	800	○	×
27	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	0.029	0.0003	8	10	0.08	810	○	×

[0046] From Table 1, it is confirmed that the thickness variation is ±3% or less in Examples of the present invention, and, thus, steel sheets having suppressed thickness variations in the longitudinal direction of the resulting steel sheet coils are obtained. That is, it is confirmed that inhibition of thickness variation, which is a first object of the present invention, can be achieved by satisfying the requirements specified in Claim 1, as shown in Table 1.

Example 2

[0047] Slabs were produced from various steels shown in Table 2, heated at a heating temperature of 1100 to 1250˚C, and then hot-rolled at a finishing temperature of 820˚C, which is not higher than the Ar_3 transformation point. The hot-rolled steel sheets were coiled at temperatures shown in Table 2, and then pickled and cold-rolled at rolling reductions shown in Table 2.

[0048] The thus obtained steel sheets were evaluated for thickness variation. The thickness variation was evaluated using the coefficient of variation of the average thickness by measuring thickness after cold-rolling over the entire length in the longitudinal direction of a steel sheet coil with an X-ray thickness gauge set to a cold-rolling facility. The evaluation results are shown in Table 2. One having a coefficient of variation of ±3% or less was determined to be acceptable as a product and shown by ○, and one having a coefficient of variation of higher than ±3% was determined not to be acceptable and shown by X.

[0049] Then, the steel sheets were subjected to heat treatment at heat treatment temperatures shown in Table 2 for 30 seconds. Then, two types of surface treatment were performed. One was subjected to Cr plating on its surface to give a tin-free steel (hereinafter, referred to as TFS) and further laminated with a PET resin film. The other was subjected to Sn plating on its surface to give a tin plate.

[0050] The TFS laminated with a PET resin film was formed into a drawn and redrawn (DRD) can having a drawing ratio of 2.2, and surface roughness was evaluated by visually investigating the can body and can bottom. The evaluation was performed by comparing with excellent, good, and poor boundary samples. Here, one not having surface roughness was determined as being excellent, one slightly having surface roughness within a practically acceptable level was determined as being good, and one having surface roughness at a practically unacceptable level was determined as being poor. The evaluation results are shown by ○ for excellent one, △ for good one, and X for poor one. The obtained results are shown in Table 2.

[0051] Furthermore, the tin plate was formed into a welded can having a diameter of 52 mm. The can was subjected to flange forming at an expansion ratio of 6% or 8% and was evaluated for occurrence of flange cracking. The evaluation results were determined in such a manner that one not having cracking in the flange forming at both ratios of 6% and 8% was ○, one having cracking in the flange forming at a ratio of 8% but not having cracking at a ratio of 6% was △, and one having cracking in both flange forming at ratios of 6% and 8% was X. The obtained results are shown in Table 2.

Table 2

	C	Si	Mn	P	S	Sol.Al	N	Nb	Ti	B	Mass ratio			Coiling temperature	Cold-rolling reduction	Heat treatment temperature	Evaluation		
	(mass%)										Nb/C	Ti/C	B/N	°C	%	°C	Thickness variation ±3% or less: ○ higher than ±3%: ×	Surface roughness	Flange cracking
1	0.0015	0.01	0.28	0.009	0.011	0.044	0.0025	0.017	-	0.0013	11	-	0.52	640	86	200	○	○	○
2	0.0029	0.01	0.28	0.009	0.011	0.046	0.0023	0.022	-	0.0013	8	-	0.57	680	90	300	○	○	○
3	0.0049	0.01	0.48	0.011	0.011	0.055	0.0025	0.029	-	0.0011	6	-	0.44	740	92	250	○	○	○
4	0.0029	0.01	0.28	0.009	0.011	0.050	0.0019	0.014	-	0.0014	5	-	0.74	680	45	300	×	×	○
5	0.0023	0.01	0.28	0.009	0.010	0.050	0.0019	0.060	-	0.0013	26	-	0.68	680	55	200	×	×	×
6	0.0029	0.01	0.28	0.009	0.011	0.046	0.0009	0.022	-	0.0008	8	-	0.89	680	70	340	×	○	×
7	0.0030	0.01	0.29	0.010	0.011	0.044	0.0012	0.020	-	0.0008	7	-	0.67	700	86	340	○	○	○
8	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	0.022	-	0.0015	7	-	0.22	680	88	120	○	○	△
9	0.0024	0.01	0.32	0.009	0.011	0.038	0.0075	0.024	-	0.0008	10	-	0.11	680	86	250	×	○	×
10	0.0023	0.01	0.32	0.010	0.011	0.038	0.0026	0.023	-	0.0004	10	-	0.15	680	94	340	○	○	○
11	0.0025	0.01	0.33	0.010	0.011	0.036	0.0025	0.020	-	0.0023	8	-	0.92	640	75	160	×	○	×
12	0.0031	0.01	0.87	0.010	0.012	0.049	0.0023	0.025	-	0.0011	8	-	0.48	640	80	250	×	○	×
13	0.0015	0.01	0.28	0.009	0.011	0.044	0.0025	-	0.002	0.0013	-	1.3	0.52	640	86	250	×	○	×
14	0.0029	0.01	0.28	0.009	0.011	0.046	0.0023	-	0.022	0.0013	-	7.6	0.57	720	90	300	○	○	○

(continued)

	C	Si	Mn	P	S	Sol.Al	N	Nb	Ti	B	Mass ratio			Coiling temperature	Cold-rolling reduction	Heattreatment temperature	Evaluation		
											Nb/C	Ti/C	B/N	˚C	%	˚C	Thickness variation ±3% or less: ○ higher than ±3%: ×	Surface roughness	Flange cracking
15	0.0023	0.01	0.28	0.009	0.010	0.050	0.0019	-	0.023	0.0013	-	10	0.68	680	98	300	×	○	×
16	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	-	0.022	0.0015	-	7	0.22	700	92	200	○	○	○
17	0.0025	0.01	0.33	0.010	0.010	0.036	0.0025	-	0.023	0.0018	-	9	0.72	700	90	380	○	○	○
18	0.0049	0.01	0.72	0.011	0.011	0.055	0.0025	0.029	0.023	0.0011	6	5	0.44	720	88	420	×	×	○
19	0.0030	0.01	0.29	0.010	0.011	0.044	0.0012	0.020	0.022	0.0008	7	7	0.67	660	80	120	○	○	△
20	0.0032	0.01	0.30	0.010	0.011	0.042	0.0068	0.022	0.044	0.0015	7	14	0.22	640	86	180	×	×	○
21	0.0029	0.01	0.28	0.009	0.011	0.046	0.0009	0.022	0.021	0.0005	8	7	0.56	590	86	180	×	○	×
22	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	-	0.0010	8	-	0.25	760	90	300	○	△	○
23	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	-	0.022	0.0010	-	8	0.25	620	86	380	○	△	○
24	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	0.029	0.0010	8	10	0.25	620	86	200	○	△	△
25	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.010	-	0.0010	3	-	0.25	680	88	500	○	△	○
26	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	-	0.004	0.0010	-	1	0.25	750	88	400	×	×	○
27	0.0029	0.01	0.28	0.009	0.011	0.046	0.0040	0.022	0.029	0.0003	8	10	0.08	720	88	150	×	○	×

[0052] As shown in Table 2, inhibition of thickness variation, which is the first object of the present invention, can be achieved by satisfying the requirements specified in Claim 1. In addition, in real can forming, the surface roughness and flange cracking were acceptable levels.

[0053] Furthermore, it has been confirmed that surface roughness and flange cracking are further satisfactorily inhibited in real can forming by satisfying the requirements specified in Claims 2 and 3.

Industrial Applicability

[0054] The present invention is most suitable for food cans and beverage cans. Furthermore, in addition to them, an organic resin film-laminated steel sheet supposed in the present invention as a material can be suitably used in purposes requiring good stripping properties of can bodies by conventional drawing and ironing (DI) forming and avoiding film damage.

Claims

1. A method of manufacturing a steel sheet for cans, the method comprising providing a slab by continuous casting of a steel consisting of steel compositions containing, in mass%, C: 0.005% or less, Mn: 0.05 to 0.5%, Al: 0.01 to 0.12%, N: 0.0010 to 0.0070%, and B: 0.15xN to 0.75×N (0.20xN to 0.97xN in atomic ratio) and further containing either or both Nb: 4xC to 20×C (0.52xC to 2.58xC in atomic ratio) and Ti: 2xC to 10×C (0.50×C to 2.51×C in atomic ratio) and the balance of Fe and inevitable impurity elements; hot-rolling the slab at a finishing temperature of not higher than Ar_3 transformation point; and subjecting the hot-rolled steel sheet to coiling, pickling, and then cold-rolling at a reduction of 50 to 96%.

2. The method of manufacturing a steel sheet for cans according to Claim 1, wherein the coiling is performed at a temperature of 640 to 750˚C.

3. The method of manufacturing a steel sheet for cans according to Claim 1 or 2, the method further comprising heat treatment at a temperature of 150 to 400˚C after the cold-rolling.

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
C21D9/46(2006.01)i, *C21D8/02*(2006.01)i, *C22C38/14*(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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 8-176673 A (Kawasaki Steel Corp.), 09 July, 1996 (09.07.96), Claims; Par. No. [0005]; table 1 (Family: none)	1-3
A	JP 8-269568 A (Kawasaki Steel Corp.), 15 October, 1996 (15.10.96), Claims; table 1 (Family: none)	1-3
A	JP 6-248339 A (Nippon Steel Corp.), 06 September, 1994 (06.09.94), Claims; table 1 (Family: none)	1-3

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

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
12 June, 2009 (12.06.09)	23 June, 2009 (23.06.09)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/056908

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 8-127816 A (Nippon Steel Corp.), 21 May, 1996 (21.05.96), Claims; table 1 (Family: none)	1-3
A	JP 8-246060 A (Kawasaki Steel Corp.), 24 September, 1996 (24.09.96), Claims; Par. No. [0032]; tables 1, 2 & US 5759306 A & EP 731182 A2	1-3
A	JP 8-081715 A (Nippon Steel Corp.), 26 March, 1996 (26.03.96), Claims; table 1 (Family: none)	1-3

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REFERENCES CITED IN THE DESCRIPTION

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- JP 4280926 A **[0008]**
- JP 8041549 A **[0008]**
- JP 6248339 A **[0008]**