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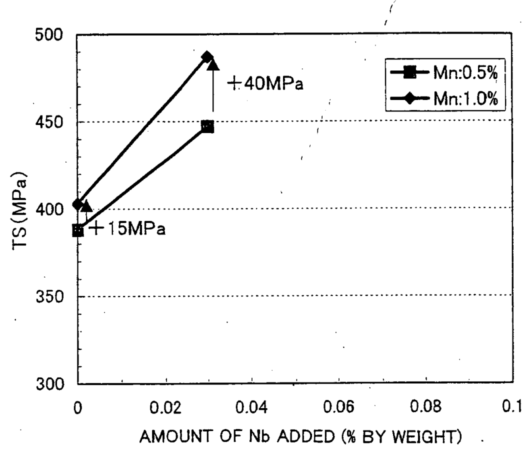
(54) STEEL SHEET FOR CAN AND METHOD FOR PRODUCTION THEREOF

(57) A can steel sheet contains 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.01% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, more than 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, and the balance is Fe and incidental impurities. This can steel sheet substantially has a single-phase ferrite structure having an average crystal grain size of 7 μm or less. The can steel sheet is manufactured by hot-rolling a steel having the above composition at a finish temperature of an Ar_3 transformation point or more, coiling the steel at a coiling temperature of 560°C to 600°C, pickling the steel, cold-rolling the steel at a reduction rate of 80% or more, and annealing the steel at 700°C to 820°C. The resultant steel sheet has strength equivalent to that of a DR steel sheet and elongation superior to that of a DR steel sheet by a combination of solid solution strengthening, precipitation strengthening, and grain refinement strengthening.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to thin steel sheets (hereinafter also referred to as can steel sheets) suitable for surface-treated steel sheets for can manufacture, such as tinplates and electrically chromium-coated steel sheets, and also to methods for manufacturing the steel sheets.

Background Art

[0002] In recent years, cost reduction has been demanded on the materials for can manufacture, including thin steel sheets and cold-rolled steel sheets, to reduce can manufacturing cost. In the industry, accordingly, thinner can steel sheets have been demanded for two-piece cans, which are manufactured by drawing, and three-piece cans, which include a simple cylinder as a main body.

[0003] A simple reduction in the thickness of currently available can steel sheets, however, results in a decrease in the strength thereof. Such can steel sheets are therefore difficult to apply to portions requiring strength, such as bodies of draw-redraw cans (hereinafter also referred to as DRD cans) and welded cans. Accordingly, can steel sheets have been desired to have a smaller thickness with sufficient strength.

[0004] The currently most frequently used method for manufacturing a thinner steel sheet with sufficient strength is double reduction (hereinafter also referred to as DR), in which second cold rolling follows annealing. DR, however, involves higher cost by the cost of the second cold rolling in addition to normal steps including hot rolling, cold rolling, and annealing. Moreover, a steel sheet manufactured by this method has an elongation of only several percent and poor formability. Furthermore, the steel sheet chronically causes, for example, surface flaws and surface dirt which are extremely difficult to completely avoid.

[0005] Various methods for strengthening a thin steel sheet have been proposed as alternatives to DR. Japanese Unexamined Patent Application Publication No. 2001-107186, for example, discloses that large amounts of C and N are added and hardened by baking to achieve can steel sheets having high strength equivalent to that of a steel sheet manufactured by DR. According to the disclosure, the steel sheet has high yield stress after the baking of coating, namely 550 MPa, and the hardness thereof is adjustable according to the amount of N added and heat-treatment conditions. This method is effective for achieving higher strength, though it may cause yield elongation due to strain aging even after temper rolling, and thus may cause stretcher strains during forming.

[0006] Japanese Unexamined Patent Application Publication No. 8-325670 proposes a method for manufacturing a steel sheet having a good balance between strength and elongation by a combination of precipitation strengthening with niobium carbide and crystal grain refinement strengthening with the carbonitrides of Nb, Ti, and B. The present inventors produced a steel sheet containing 0.025% by weight of Nb according to this method. The resultant steel sheet, however, had low tensile strength, namely 510 MPa, and thus could not reach the strength of a steel sheet manufactured by the currently available method, namely DR.

[0007] Japanese Unexamined Patent Application Publication No. 5-345926 proposes a method for manufacturing a steel sheet reaching a strength level of 60 to 75 in terms of Rockwell hardness (HR30T) (see JIS G 3303) by solid solution strengthening with P and crystal grain refinement strengthening with the carbonitrides of Nb, Ti, and B. In addition, Japanese Unexamined Patent Application Publication No. 2000-119802 proposes a method for manufacturing a high-strength steel sheet having a tensile strength of 540 MPa or more by precipitation strengthening through the addition of alloy elements such as Nb.and Ti. Either method, however, depends on temper rolling at a high reduction rate, namely about 10% to 30%, to achieve high strength, and thus has difficulty in providing strength equivalent to that of a steel sheet manufactured by DR (hereinafter also referred to as DR steel sheets).

[0008] Japanese Unexamined Patent Application Publication No. 2003-34825 proposes a method in which low-carbon steel is subjected to hot rolling in the $\alpha + \gamma$ region, rapid cooling, and annealing at a specified heating temperature. This method can provide a steel sheet having a tensile strength of 600 MPa and a total elongation of 30% or more. Such strengthening by rapid cooling, however, leads to high operating cost.

[0009] The present invention has been created to solve the above problems. An object of the present invention is to provide a can steel sheet having strength equivalent to that of a DR steel sheet and elongation superior to that of a DR steel sheet, and also to provide a method for manufacturing the can steel sheet.

Disclosure of Invention

[0010] The present invention provides a can steel sheet containing 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.01% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, more than 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, and the balance is Fe and incidental impurities. This can steel sheet substantially has a single-phase ferrite structure having an average crystal grain size of 7 μm or less.

[0011] The present invention further provides a method for manufacturing a can steel sheet. This method includes hot-rolling a steel at a finish temperature of an Ar_3 transformation point or more, coiling the steel at a coiling temperature of 560°C to 600°C, pickling the steel, cold-rolling the steel at a reduction rate of 80% or more, and annealing the steel at 700°C to 820°C. The steel used contains 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.01% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, more than 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, and the balance is Fe and incidental impurities.

[0012] The present invention further provides a can steel sheet having high strength and high elongation. This can steel sheet contains 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.010% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, and the balance is Fe and incidental impurities. The can steel sheet substantially has a single-phase ferrite structure, and has an average ferrite crystal grain size of 7 μm or less and a thickness of 0.2 mm or less.

Brief Description of the Drawings

[0013]

Fig. 1 illustrates the relationship between the amount of Nb added and the strength of a can steel sheet when Nb is added together with Mn as a solid solution element.

Best Mode for Carrying Out the Invention

[0014] The present inventors have focused on a combination of solid solution strengthening, precipitation strengthening, and grain refinement strengthening to strengthen a steel sheet. As a result, the inventors have found that higher strength can be achieved with no decrease in elongation by reducing the size of crystal grains through the addition of proper amounts of P and Mn, as solid solution strengthening elements, and a proper amount of Nb, as a precipitation strengthening element and a grain refinement strengthening element. The inventors have further found that the strength and the elongation can be balanced at high levels with a substantial single-phase ferrite structure having a specified average ferrite crystal grain size.

[0015] In the present invention, a high-strength can steel sheet is a thin steel sheet suitable as, for example, a raw plate for a surface-treated steel sheet such as a tinplate (electrically tin-coated steel sheets) and an electrically chromium-coated steel sheet.

[0016] A can steel sheet having high strength and high elongation according to the present invention contains specified amounts of elements described below as a solid solution strengthening element, a precipitation strengthening element, and/or a grain refinement strengthening element. In addition, the can steel sheet substantially has a single-phase ferrite structure having an average crystal grain size of 7 μm or less. These conditions are the most important requirements for the present invention which allow the manufacture of a can steel sheet having a tensile strength of 550 MPa or more and an elongation exceeding 10%. Such a high-strength, high-elongation steel sheet may be manufactured by hot rolling at a finish temperature of an Ar_3 transformation point or more, coiling at a coiling temperature of 560°C to 600°C, pickling, cold rolling at a reduction rate of 80% or more, and annealing at 700°C to 820°C.

[0017] The present invention will now be described in detail.

[0018] In the present invention, the chemical composition of the steel is specified for the following reasons. In the present application, all percentages for the composition of the steel are expressed in terms of weight.

C: 0.04% to 0.1%

[0019] The steel sheet requires a crystal grain size of 7 μm or less to achieve a tensile strength of 550 MPa or more and an elongation exceeding 10% after annealing. The amount of C added is important to achieve such properties; C is one of the main requirements for the present invention. In particular, a required amount of carbon must be assigned to precipitation because the strength and the grain size depend largely on the amount and density of carbide. In addition, the amount of C added is 0.04% or more in consideration of strengthening by the solid solution of C. If, on the other hand, the amount of C added exceeds 0.1%, a pearlite phase precipitates in the second phase and decreases the elongation. Accordingly, the content of C is 0.04% to 0.1%.

Si: 0.01% to 0.5%

Si is an element for strengthening the steel sheet by solid solution strengthening, though an excessive amount of Si added significantly impairs corrosion resistance. Accordingly, the content of Si is 0.01% to 0.5%. The content of Si is preferably 0.01% to 0.3% to further inhibit impairment in the corrosion resistance.

Mn: 0.5% to 1.5%

Mn is an element for increasing the strength of the steel sheet by solid solution strengthening, reducing the size of crystal grains, and further increasing the strength of the steel sheet by grain refinement strengthening. Mn is one of the main requirements for the present invention. The above effects appear significantly by adding 0.5% or more of Mn. An excessive amount of Mn added, however, impairs the corrosion resistance. Accordingly, the content of Mn is 0.5% to 1.5%. The content of Mn is preferably 0.5% to 1.0% to inhibit a large increase in recrystallization temperature.

P: 0.01% to 0.15%

P is an element having a high solid solution strengthening ability, and is therefore one of the main requirements for the present invention. This effect appears significantly by adding 0.01% or more of P. An excessive amount of P added, however, impairs the corrosion resistance of the steel sheet. Accordingly, the content of P is 0.01% to 0.15%. The content of P is preferably 0.01% to 0.1% to further inhibit impairment in the corrosion resistance.

S: 0.01% or less

The content of S is preferably minimized because the element occurs in the steel as an inclusion which is disadvantageous in view of the elongation and corrosion resistance of the steel sheet. Accordingly, the content of S is 0.01% or less, usually about 0.0001% to 0.01%.

Al: 0.01% or less

An increase in the content of Al raises the recrystallization temperature, and the annealing temperature must be raised accordingly. A rise in annealing temperature increases the amount of A1N formed and decreases the amount of solid solution of N, thus decreasing the strength of the steel sheet. In the present invention, particularly, the annealing temperature must be raised because the recrystallization temperature rises due to other elements added to increase the strength of the steel sheet. Hence the rise in recrystallization temperature due to Al is preferably minimized. Accordingly, the content of Al is 0.01% or less, usually about 0.003% to 0.01%.

N: 0.002% to 0.012%

N is deliberately added because the element has a high solid solution strengthening ability to increase the strength of the steel sheet. The effective amount of N required for increasing the strength is 0.002% or more. An excessive amount of N added, however, causes the problem of strain aging of the steel sheet. Accordingly, the content of N is 0.002% to 0.012%

Nb: more than 0.025% to 0.1%

Nb is one of the main requirements for the present invention. This element, which has a high carbide-forming ability, precipitates fine carbide grains to increase the strength of the steel sheet. In addition, the element refines the carbide grains to increase the strength of the steel sheet.

[0020] Fig. 1 illustrates the relationship between the amount of Nb added and the strength of the can steel sheet when Nb is added together with Mn as a solid solution element. Fig. 1 shows that the addition of Nb together with Mn as a solid solution element provides a larger increase in the strength of the steel sheet than the intrinsic effect of solid solution strengthening. The possible cause is described below. In comparison with the addition of a solid solution element (Mn in this example) alone, the addition of the solid solution element (Mn in this example) together with Nb precipitates Nb-C which suppresses the diffusion of the solid solution element (Mn in this example) and thus inhibits the growth of recrystallized grains in annealing. That is, the solid solution element itself achieves the effect of grain refinement strengthening which adds to the effect of solid solution strengthening. This effect starts to appear significantly when the amount of Nb added exceeds 0.025%.

[0021] Nb, however, raises the recrystallization temperature. If the amount of Nb added exceeds 0.1%, the steel sheet hardens significantly in hot rolling and thus deteriorates in formability in cold rolling.

[0022] Accordingly, the content of Nb is more than 0.025% to 0.1%. The content of Nb is preferably more than 0.025% to 0.05% in view of formability in cold rolling.

[0023] The reason for the specified structure is then described below.

[0024] Single-Phase Ferrite Structure with Average Crystal Grain Size of 7 μm or Less

[0025] The steel sheet according to the present invention substantially has a single-phase ferrite structure. Even a steel sheet containing, for example, about 1% of cementite is determined to substantially have a single-phase ferrite structure as long as the sheet provides the operation and effects of the present invention.

[0026] The present inventors have studied the balance between the strength and elongation of steel sheets having single-phase ferrite structures with varying average ferrite crystal grain sizes. This study has found that a high-strength steel can be achieved with no decrease in elongation if the average ferrite crystal grain size is 7 μm or less. The study has also found that an average crystal grain size exceeding 7 μm results in a poor surface appearance after can manufacture. Such phenomena are associated with extreme variations in surface roughness which occurred particularly on two-piece cans, though the positions and degrees thereof varied. Accordingly, the average ferrite crystal grain size is 7 μm or less. The average ferrite crystal grain size is measured by, for example, an intercept method according to ASTM.

[0027] The can steel sheet according to the present invention preferably has a thickness of 0.2 mm or less to achieve a higher cold rolling rate and a tensile strength of 550 MPa or more.

[0028] A method for manufacturing a can steel sheet having high strength and high elongation according to the present invention will now be described.

[0029] According to a normal process, a molten steel with the above chemical composition is prepared with, for example, a converter, and is cast into a rolling stock by, for example, continuous casting. The resultant rolling stock is subjected to hot rolling. The finish temperature must be set to an Ar_3 transformation point or more to provide a steel sheet in the single-phase γ region. The rolling stock preferably has a low temperature before the hot rolling to refine crystal grains more readily, though the finish rolling temperature must be set in the single-phase γ region. Accordingly, the temperature of the rolling stock is preferably 1,150°C to 1,300°C at the beginning of the rolling. In addition, the coiling temperature must be set to 560°C to 600°C to achieve a crystal grain size of 7 μm or less and thus enhance the strength of the steel sheet after annealing. If the coiling temperature is more than 600°C, coarse crystal grains are produced. If, on the other hand, the coiling temperature in the hot rolling is less than 560°C, the solid solution of N and C remain in the hot-rolled steel sheet and thus impair the formation of a desired aggregate structure in recrystallization annealing after cold rolling.

[0030] After subsequent pickling, the steel sheet is subjected to cold rolling at a reduction rate of 80% or more to develop an aggregation texture after annealing and significantly refine crystal grains. Simultaneously, the steel sheet can achieve a more uniform ferrite structure. A tensile strength of 550 MPa or more is difficult to achieve at reduction rates below 80%. The thickness of the steel sheet after the cold rolling is preferably 0.2 mm or less to provide a reduction rate of 80% or more.

[0031] The steel sheet is then subjected to annealing in the soaking area of 700°C to 820°C. The annealing must be performed at the recrystallization temperature or more of the steel sheet to provide good formability, and must be performed at 700°C or more to provide a more uniform structure. An annealing temperature exceeding 820°C, however, may cause problems in the annealing step.

[0032] Subsequently, temper rolling is preferably performed to adjust the surface shape of the steel sheet. The temper rolling rate is preferably 1.5% or less, more preferably 0.5% to 1.5%, to prevent a decrease in elongation by excessive work hardening.

[0033] The tensile strength may be controlled to a target value according to the composition, the coiling temperature in the hot rolling, the annealing temperature, and the cold rolling rate.

Example 1

[0034] Steels having varying compositions, as shown in Table 1 (the balance is Fe and incidental impurities), were produced with an actual converter and were cast into steel slabs. Can steel sheets were produced under the conditions of Invention Examples 1 to 9 and Comparative Examples 1 to 8 shown in Table 2., as described below.

[0035] The steel slabs were reheated at 1,200°C and were subjected to hot rolling at finish rolling temperatures and coiling temperatures shown in Table 2. After subsequent pickling, cold rolling was performed at reduction rates shown in Table 2 to produce thin steel sheets having a thickness of 0.2 mm. The resultant thin steel sheets were subjected to annealing in a continuous annealing furnace for 30 seconds at heating temperatures and soaking temperatures shown in Table 2. The steel sheets were then cooled at about 10°C/s to 15°C/s by a common method to produce can steel sheets.

[0036] The can steel sheets were subjected to temper rolling at a reduction rate of about 1.5% and were continuously subjected to normal chromium plating to produce electrically chromium-coated steel sheets. The annealing temperatures, which were adjusted according to the amount of Nb added, were kept at the values shown in Table 2.

[0037] After the crystal structures and average crystal grain sizes of the resultant electrically chromium-coated steel sheets were examined, the strength and elongation thereof was evaluated by a tensile test. The test results are shown in Table 3.

[0038] Each test and test method are as follows.

[0039] The tensile test was performed with JIS No. 5 tensile test pieces to measure the yield points, tensile strength, and elongation thereof. Also, the Rockwell hardness was measured.

[0040] The crystal structures were examined by polishing samples, corroding the crystal grain boundaries thereof with nital, and observing them by optical microscopy.

[0041] The average crystal grain sizes of the above crystal structures observed were measured by an intercept method according to ASTM.

[0042] Table 3 shows that the steels of Examples 1 to 9 had a single-phase ferrite structure with an average crystal grain size of 7 μm or less, and thus excelled in both strength and elongation.

[0043] On the other hand, the steel j of Comparative Example 1 and the steel n of Comparative Example 5, which had low amounts of P added, had elongation equivalent to those of the invention examples, but exhibited lower strength. The steel k of Comparative Example 2, which had a low amount of Nb added, had elongation equivalent to those of the examples, but exhibited lower strength. The steel 1 of Comparative Example 3, which had a mixed structure of ferrite and pearlite with an average crystal grain size exceeding 7 μm, had high strength, but exhibited lower elongation. Comparative Examples 4 and 6, in which the temper rolling was performed at high reduction rates, namely 20% and

33%, respectively, achieved high strength, though they are equivalent to a known method, namely DR. In Comparative Example 8, the tensile strength is only 500 MPa even after the baking of coating at 210°C for 20 minutes.

Example 2

[0044] The type of steel used was limited to the steel a of Example 1 shown in Table 1 to examine the effect of differences in production conditions.

[0045] Electrically chromium-coated steel sheets were produced with the steel a under the production conditions of Examples 1, 10, and 11 and Comparative Example 9 shown in Table 2. Other conditions followed the description of Example 1. The same tests as in Example 1 were made on the resultant electrically chromium-coated steel sheets. The results are listed in Table 3.

[0046] Table 3 shows that a single-phase ferrite structure with an average crystal grain size of 7 μm or less can be achieved under the production conditions of Invention Examples 1, 10, and 11 to provide a steel sheet having a tensile strength of 550 MPa or more with no decrease in elongation.

[0047] On the other hand, the steel sheet produced under the conditions of Comparative Example 9 had an average ferrite crystal grain size exceeding 10 μm. This steel sheet had high elongation, but exhibited lower strength. The steel sheet of Comparative Example 7 had high strength, but requires rapid heating and rapid cooling before and after annealing. This steel sheet is therefore difficult to manufacture with conventional equipment.

[0048] In addition, when the steel sheets according to the present invention were drawn, they had excellent surfaces with no roughness. When, on the other hand, the steel sheets of the comparative examples with an average ferrite crystal grain size exceeding 10 μm are drawn, they had rough surfaces.

[0049] The examples also show that a target tensile strength can be reliably achieved at a reduction rate of 1.5% or less in temper rolling after annealing.

[Table 1]

	Type of steel	C	Si	Mn	P	S	N	Nb	Al
Example 1	a	0.05	0.01	0.5	0.04	0.01	0.006	0.03	0.01
Example 2	b	0.05	0.01	1.0	0.04	0.01	0.006	0.03	0.01
Example 3	c	0.05	0.01	0.5	0.075	0.01	0.006	0.03	0.01
Example 4	d	0.05	0.01	0.5	0.04	0.01	0.006	0.05	0.01
Example 5	e	0.05	0.2	0.5	0.04	0.01	0.006	0.03	0.01
Example 6	f	0.04	0.01	1.0	0.075	0.01	0.006	0.03	0.01
Example 7	g	0.04	0.01	1.0	0.075	0.01	0.01	0.03	0.01
Example 8	h	0.04	0.01	1.0	0.01	0.01	0.006	0.03	0.01
Example 9	i	0.04	0.01	1.0	0.075	0.01	0.002	0.05	0.01
Comparative example 1	j	0.05	0.01	0.5	0.008	0.01	0.006	0.03	0.01
Comparative example 2	k	0.05	0.01	0.5	0.04	0.01	0.006	0	0.01
Comparative example 3	l	0.15	0.01	0.5	0.01	0.01	0.002	0.03	0.01
Comparative example 4	m	0.005	-	0.5	0.01	-	0.006	0	0.002
Comparative example 5	n	0.11	0.01	0.55	0.005	0.005	0.0015	0.025	0.055
Comparative example 6	o	0.05	0.005	0.25	0.01	0.009	0.0035	-	0.001
Comparative example 7	p	0.1	0.01	0.5	0.01	0.01	0.003	-	0.03
Comparative example 8	q	0.0095	0.02	0.25	0.009	0.007	0.0095	0.007	0.002

[Table 2]

	Type of steel	Ar_3 transformation point (°C)	Finish rolling temperature (°C)	Coiling temperature (°C)	Cold rolling reduction rate (%)	Heating temperature (°C/s)	Soaking temperature (°C)
Example 1	a	820	890	560	95	15	710
Example 2	b	820	920	590	90	15	720
Example 3	c	820	920	560	90	15	710
Example 4	d	820	920	590	90	15	730
Example 5	e	820	920	590	90	15	710
Example 6	f	830	920	590	90	15	710
Example 7	g	830	920	590	90	15	710
Example 8	h	830	920	590	90	15	710
Example 9	i	830	920	590	90	15	710
Example 10	a	820	920	560	90	15	710
Example 11	a	820	920	590	92	15	710
Comparative example 1	j	820	920	590	90	15	710
Comparative example 2	k	820	920	590	90	15	710
Comparative example 3	l	780	920	590	90	15	710
Comparative example 4 *	m	870	880	500	-	-	700
Comparative example 5	n	790	880 to 910	to 500	85	15	730
Comparative example 6**	o	820	880	650	90	-	690
Comparative example 7	p	790	830	600	-	150	760***

(continued)

	Type of steel	Ar_3 transformation point (°C)	Finish rolling temperature (°C)	Coiling temperature (°C)	Cold rolling reduction rate (%)	Heating temperature (°C/s)	Soaking temperature (°C)
Comparative example 8	q	890	925	540	92	-	750
Comparative example 9	a	820	890	680	90	15	750
*: Reduction rate in temper rolling = 20% **: Reduction rate in temper rolling = 33% ***: Cooling rate after annealing = 1,000°C/s							

[Table 3]

	Type of steel	Yield point (MPa)	Tensile strength (MPa)	Rockwell hardness HR30T	Elongation (%)	Crystal structure	Average crystal grain size (μm)
Example 1	a	510	550	-	23	F*	5
Example 2	b	500	570	-	20	F	5
Example 3	c	520	570	-	20	F	5
Example 4	d	500	550	-	21	F	4
Example 5	e	490	560	-	21	F	5
Example 6	f	550	600	-	19	F	5
Example 7	g	490	560	-	17	F	5.5
Example 8	h	500	560	-	13	F	5
Example 9	i	490	550	-	13	F	3.5
Example 10	a	500	570	-	20	F	4.0
Example 11	a	480	550	-	23	F	5.0
Comparative example 1	j	450	500	-	26	F	5.5
Comparative example 2	k	430	390	-	17	F	10
Comparative example 3	l	500	600	-	10	F+P**	10
Comparative example 4	m	-	-	73	-	-	-
Comparative example 5	n	480	510	-	32	F	3.5
Comparative example 6	o	-	590	73	-	-	7
Comparative example 7	p	360	610	-	33	-	-
Comparative example 8	q	-	500***	70	-	-	-
Comparative example 9	a	420	500	-	32	F	12.0
*: ferrite phase; **: pearlite phase; ***: tensile strength after baking of coating at 210°C for 20 minutes							

Industrial Applicability

[0050] The present invention can provide a can steel sheet having a tensile strength of 550 MPa or more and an elongation exceeding 10% and a method for manufacturing the can steel sheet. This steel sheet can be applied to parts such as bodies of, for example, DRD cans and welded cans. The strength of the steel sheet is enhanced by a combination of solid solution strengthening with many elements and precipitation strengthening with Nb and grain refinement strengthening with Nb. A target tensile strength can therefore be reliably achieved at a reduction rate of 1.5% or less in temper rolling after annealing. In addition, the steel sheet, which contains low amounts of C and N, causes no yield elongation due to strain aging. Accordingly, the steel sheet can make a significant social contribution as a thin steel sheet suitable for a surface-treated steel sheet such as a tinplate and an electrically chromium-coated steel sheet.

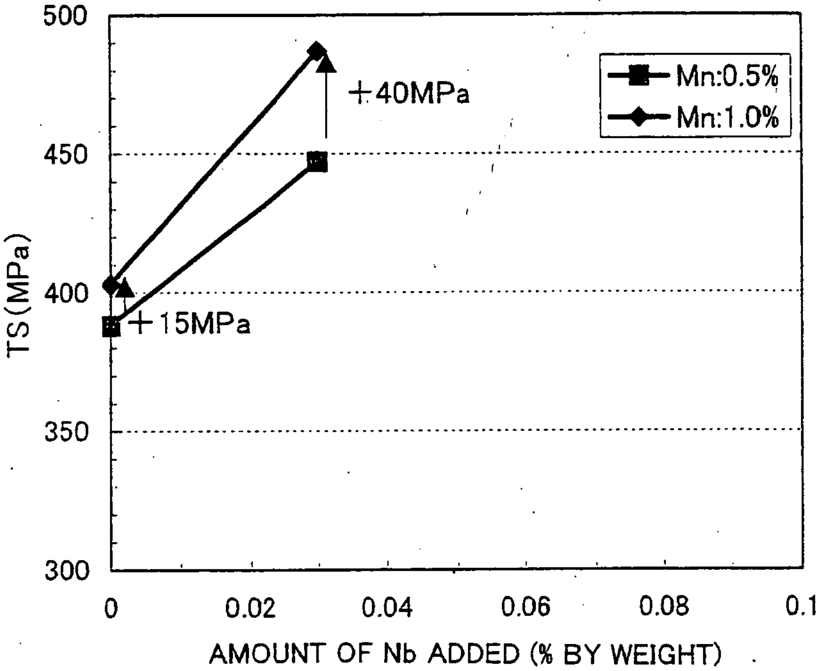
Claims

1. A can steel sheet comprising 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.01% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, more than 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, the balance being Fe and incidental impurities, the can steel sheet substantially having a single-phase ferrite structure having an average crystal grain size of 7 μm or less.

2. A method for manufacturing a can steel sheet, comprising hot-rolling a steel at a finish temperature of an Ar_3 transformation point or more, coiling the steel at a coiling temperature of 560°C to 600°C, pickling the steel, cold-rolling the steel at a reduction rate of 80% or more, and annealing the steel at 700°C to 820°C, the steel comprising 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.01% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, more than 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, the balance being Fe and incidental impurities.

3. A can steel sheet having high strength and high elongation, comprising 0.04% to 0.1% by weight of C, 0.002% to 0.012% by weight of N, 0.5% to 1.5% by weight of Mn, 0.010% to 0.15% by weight of P, 0.01% to 0.5% by weight of Si, 0.025% to 0.1% by weight of Nb, 0.01% or less by weight of Al, and 0.01% or less by weight of S, the balance being Fe and incidental impurities, the can steel sheet substantially having a single-phase ferrite structure, the can steel sheet having an average ferrite crystal grain size of 7 μm or less and a thickness of 0.2 mm or less.

Fig. 1



500
450
400
350
300
TS(MPa)
0
0.02
0.04
0.06
0.08
0.1
AMOUNT OF Nb ADDED (% BY WEIGHT)
Mn:0.5%
Mn:1.0%
+40MPa
+15MPa

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/008399

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl^7 C22C38/00, C21D9/46, C22C38/12

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl^7 C22C38/00, C21D9/46, C22C38/12

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	1996-2005
Kokai Jitsuyo Shinan Koho	1971-2005	Toroku Jitsuyo Shinan Koho	1994-2005

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.
X Y	JP 8-325670 A (Kawasaki Steel Corp.), 10 December, 1996 (10.12.96), Claims; Par. Nos. [0015], [0016], [0020], [0034] to [0038], [0041] (Family: none)	3 1-2
Y	JP 4-337049 A (Kawasaki Steel Corp.), 25 November, 1992 (25.11.92), Claims; Par. Nos. [0001], [0022] (Family: none)	1-2

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 July, 2005 (1907.05)	09 August, 2005 (09.08.05)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001107186 A **[0005]**
- JP 8325670 A **[0006]**
- JP 5345926 A **[0007]**
- JP 2000119802 A **[0007]**
- JP 2003034825 A **[0008]**