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(54) ROLLED AUSTENITE STAINLESS STEEL PLATE HAVING THICHKESS OF 100 mm OR MORE AND METHOD FOR PRODUCTION THEREOF

(57) Austenitic stainless rolled steel plate of a thickness of 100 mm or more, **characterised by**: containing, by mass%, C: 0.08% or less, N: 0.10% to 0.22%, C+N: 0.12% or more, Si: 0.01% to 2.0%, Mn: 0.1% to 2.0%, Cr: 15% to 27%, Ni: 8% to 20%, Mo: 4% or less, Co: 0.1% or less, Cu: 0.1% to 3%, Al: 0.001% to 0.10%, and Ca: 0.0005% to 0.01%, having a calculated value of the amount of δ-ferrite defined by the following (I) formula (δcal; vol%) of -7% to 4%, and having an elongation in the width direction and length direction at any location in the thickness direction of 30% or more:

$$\delta cal\ (vol\%) = 2.9\times([Cr]+0.3[Si]+[Mo]) - 2.6\times([Ni]+0.3\times[Mn]+0.25\times[Cu]+35\times[C]+20\times[N]) - 18 \quad \ldots (I)$$

where [element abbreviations] means the content of the element (mass%), and the elongation is the value measured at 4K.

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Description

TECHNICAL FIELD

[0001] The present invention relates to extremely low temperature use austenitic stainless rolled steel plate useful at 150K or less used for superconductive coils of thermonuclear reactors and structural materials for LNG (liquefied natural gas). In particular, it relates to rolled steel plate of a thickness of 100 mm or more which conventionally could not be produced.

BACKGROUND ART

[0002] The structural materials forming superconductive coils for thermonuclear reactors promising as a next generation energy source are required to be nonmagnetic and at the same time high in strength properties at the extremely low temperature region of the superconductivity temperature. Further, superconductive coils are expected to become massive apparatuses, so as structural material, thick-gauge plate will be essential.

[0003] In the past, for this application, as disclosed in Japanese Patent Publication (A) No. 60-13063, Japanese Patent Publication (A) No. 61-52351, and Japanese Patent Publication (A) No. 2-57668, austenitic stainless steel greatly reduced in C and having a large amount of N added to secure a low temperature strength and stabilized in the γ-phase had been used.

[0004] JIS G4304 (2005) has provisions on hot-rolled stainless steel plate and steel strip. For example, for SUS316LN, a yield strength of 245 N/mm^2 or more, a tensile strength of 550 N/mm^2, and an elongation of 40 or more are defined.

[0005] However, in steel plate of a thickness of 100 mm or more, obtaining rolled steel plate satisfying this provision over its entire cross-section is difficult in terms of the production process. The reason is that with a rolled product, it is difficult to obtain a fine recrystallized structure over its entire cross-section.

[0006] To secure strength and elongation, to destroy the cast structure of a steel ingot over the entire cross-section and obtain a fine recrystallized structure after heat treatment, it is necessary to evenly introduce working strain to the entire cross-section. For this reason, it is effective to increase the reduction ratio as much as possible.

[0007] However, in thick-gauge products, due to the restrictions of the rolling machines, there are limits to the thickness of the material before rolling. Further, there are also limits to the reduction ratio.

[0008] Therefore, cross-sectional locations where work strain cannot be introduced arise. In particular, work strain does not easily enter from the location of 1/4 of the plate thickness to the center location, so even if heat treating is done for the steel, the cast structure remains. This becomes coarser resulting in occurrence of locations with low strength or elongation.

[0009] Japanese Patent Publication (A) No. 60-13063 discloses austenitic stainless steel for extremely low temperature structures with high N and Mn, but does not disclose stainless steel of a thickness of 100 mm or more.

[0010] Japanese Patent Publication (A) No. 61-52351 discloses austenitic stainless steel high in N, Mn, and Al and superior in extremely low temperature yield strength and toughness, which is used as structural materials, but does not disclose stainless steel of a thickness of 100 mm or more.

[0011] Japanese Patent Publication (A) No. 2-57668 discloses austenitic stainless steel containing Nb, high in Mn, and superior in reheating resistance property, which is used at extremely low temperature, but does not disclose stainless steel of a thickness of 100 mm or more.

[0012] Japanese Patent Publication (A) No. 7-316653 discloses a method of production of stainless steel plate of 100 mm or more superior in properties at extremely low temperature, but does not disclose the addition of Cu or Ti to the stainless steel.

[0013] Further, the above publication discloses a method of working and heat treatment for obtaining a uniform granular structure over the entire cross-section, but does not disclose homogenization by increasing the fineness of the solidified structure.

[0014] Japanese Patent Publication (A) No. 7-310120 discloses a method of hot-rolling austenitic stainless thick-gauge steel plates of 50 mm thickness and 100 mm thickness, but does not disclose the compositions of the stainless steel.

[0015] Japanese Patent Publication (A) No. 8-104920 discloses a method of production of high strength austenitic stainless steel plate (containing Ti). In this stainless steel plate, Ti is added to increase the fineness of the solidified structure and prevent the occurrence of surface defects at the time of rolling. However, in the above method of production, the solution treatment is omitted. Further, the above publication does not disclose stainless steel plate of a thickness of 100 mm or more.

[0016] Japanese Patent Publication (A) No. 11-131138 discloses the method of production of very thick steel plate of stainless steel of 97 mm thickness comprising using forging to eliminate porosity without causing cracks in the surface of the continuously cast slab. However, the above publication does not disclose stainless steel plate of a thickness of 100 mm or more and compositions of the stainless steel plate.

[0017] Above, as prior art, stainless steel superior in yield strength, toughness, and other mechanical properties at an extremely low temperature was disclosed, but very thick rolled products of 100 mm or more thickness superior in mechanical properties over the entire cross section and its method of production have not been disclosed.

[0018] Compared with rolling, with forging, the limitations on thickness of the material due to the forging machine are smaller than with a rolling machine, the reduction ratio can be increased, and working is possible even in the direction of increase of the plate thickness, so it is possible to introduce work strain over the entire cross-section even in thick-gauge products and as a result it is easy to obtain a fine recrystallized structure over the entire cross-section.

[0019] However, if doing everything by just forging, an increase in cost and a drop in productivity are invited.

DISCLOSURE OF THE INVENTION

[0020] The present invention relates to a structural material for a superconductive coil of a thermonuclear reactor, a structural material for LNG (liquefied natural gas), and other materials used at extremely low temperatures, in particular relates to extremely thick stainless steel plate of 100 mm or more, and has as its object the provision of a rolled product superior in mechanical properties over its entire cross-section and a method of production for obtaining the same.

[0021] In a rolled product of austenitic stainless steel obtained by adding a large amount of N and high in strength at an extremely low temperature, in particular a thick rolled product, the locations of 1/4 of plate thickness to 3/4 of plate thickness from the surface layer are locations resistant to work strain by forging or rolling. At those locations, it is difficult to secure strength and ductility.

[0022] Therefore, the inventors investigated in detail various alloys and first obtained the discovery that by defining the composition, it is possible to secure the lowest required strength and ductility even at an extremely low temperature.

[0023] That is, to secure the required strength and ductility over the entire plate thickness of rolled steel plate, it is effective to adjust the elements effective for high strength to a suitable range and to obtain a further stabler effect, it is effective to adjust the composition to increase the fineness of the solidified structure.

[0024] Next, the inventors obtained the discovery that if suitably combining the forging and rolling processes to crush the cast structure of a steel ingot over its entire cross-section and introduce hot rolling strain to the entire cross-section, the recrystallization is promoted and a uniform recrystallized structure is obtained.

[0025] That is, by forging, then rolling a steel ingot, it is possible to produce a rolled product superior in mechanical properties even the entire cross-section even for extremely thick stainless steel plate of 100 mm or more.

[0026] The present invention was made based on this discovery and has as its gist the following.

(1) Austenitic stainless rolled steel plate of a thickness of 100 mm or more, characterised by:
containing, by mass%, C: 0.08% or less, N: 0.10% to 0.22%, C+N: 0.12% or more, Si: 0.01% to 2.0%, Mn: 0.1% to 2.0%, Cr: 15% to 27%, Ni: 8% to 20%, Mo: 4% or less, Co: 0.1% or less, Cu: 0.1% to 3%, Al: 0.001% to 0.10%, Ca: 0.0005% to 0.01% and a balance of iron and unavoidable impurities,
having a calculated value of the amount of δ-ferrite defined by the following (I) formula (δcal; vol%) of -7% to 4%, and having an elongation in the width direction and length direction at any location in the thickness direction of 30% or more:

$$\delta cal\ (vol\%) = 2.9\times([Cr]+0.3[Si]+[Mo]) - 2.6\times([Ni]+0.3\times[Mn]+0.25\times[Cu]+35\times[C]+20\times[N]) - 18 \quad \ldots(I)$$

where [element abbreviations] means the content of the element (mass%), and the elongation is the value measured at 4K.
(2) Austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in (1), characterised by further containing, by mass%, Ti: 0.010% to 0.030%.
(3) A method of producing austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in (1) or (2), characterized by:

forging steel of a thickness of 650 mm or more at an area reduction ratio of 0.5 or more, then
hot rolling by a reduction ratio of 1.5 or more, then
treating by solution heat treatment,

wherein, the area reduction ratio (A) of forging is defined as follows:

Cross-sectional area of steel ingot before forging (thickness × width): A_0
Cross-sectional area of steel ingot after forging (thickness × width): A_1

$$A=(A_0-A_1)/A_0,$$

further, the reduction ratio (R) of rolling is defined as follows:

Slab thickness before rolling: B_0
Slab thickness after rolling: B_1

$$R=B_0/B_1.$$

(4) A method of producing austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in (1) or (2), said method of producing austenitic stainless rolled steel plate of a thickness of 100 mm or more, characterized by:

alternately processing a steel ingot of a thickness of 500 mm or more by forging of an area reduction ratio of 0.3 or more in a direction where the thickness decreases and forging of an area reduction ratio of 0.15 or more in a direction where the thickness increases at least one time, then
hot rolling by a reduction ratio of 1.5 or more, then
applying solution heat treatment,

wherein, the area reduction ratio (C) of forging in the direction of decrease or increase of the thickness is defined as follows:

Cross-sectional area of steel ingot after n-th forging (thickness × width): C_n
Cross-sectional area of steel ingot after n-1st forging (thickness × width): C_{n-1}

$$C=(C_{n-1}-C_n)/C_{n-1},$$

further, the reduction ratio (R) of rolling is defined as follows:

Slab thickness before rolling: B_0
Slab thickness after rolling: B_1

$$R=B_0/B_1.$$

The "forging" here is free-forging using a press, but sometimes the press process is performed divided into several operations at the same surface and same direction of the steel ingot until the steel ingot as a whole reaches the predetermined cross-sectional shape. In this case, the series of press operations by a press at the same surface and same direction until the steel ingot as a whole reaches the predetermined cross-sectional shape is defined as a "single forging process".

[0027] According to the present invention, it is possible to obtain thick-gauge plate of a thickness of 100 mm or more having a high strength and ductility at an extremely low temperature. The austenitic stainless rolled steel plate of the present invention can be applied as a structural material for superconductive coils for thermonuclear reactors (ITER) expected to serve as a next generation energy source.

[0028] Further, the austenitic stainless steel plate of the present invention can be applied for increasingly larger superconductive equipment, for structures for LNG (liquefied natural gas), etc. and is expected to contribute greatly to the future energy industry and other various industrial fields. The present invention therefore has a great industrial and social effect.

BEST MODE FOR CARRYING OUT THE INVENTION

[0029] In the past, there had been forged products of a thickness of 100 mm or more, but rolled steel plate could not be obtained. The reason is that if trying to obtain a crystal structure uniform in cross-section, it is necessary to introduce strain to the cross-section as a whole and perform solution heat treatment. For this reason, it is necessary to make the slab thickness as great as possible and increase the reduction ratio, but in a rolling machine, there are limits to the slab thickness and therefore production was not possible.

[0030] If the forging process, it is possible to increase the slab thickness, but if doing everything by just forging, an increase in cost and a drop in productivity will be invited.

[0031] According to the present invention, by forging a steel ingot defined in composition effective for improvement of the strength in the first half of the process and rolling it in the second half of the process, it is possible to produce austenitic stainless rolled steel plate of a thickness of 100 mm or more superior in strength and ductility.

[0032] However, at locations of 1/4 to 3/4 of plate thickness from the surface layer, a coarse solidified structure sometimes remains. The elongation at those locations is low, so sometimes the strength-ductility balance of the cross-section as a whole is restricted.

[0033] Therefore, in the present invention, by combining the increased fineness of the solidified structure by the addition of Ti and a forging-rolling process and making the crystal structure of the product finer over the entire cross-section, the strength-ductility balance is improved.

[0034] Next, the limiting conditions of the present invention will be shown.

[0035] C, if added in a large amount, improves the strength at an extremely low temperature, but Cr-carbonitrides precipitate in large amounts in the production process and the toughness at an extremely low temperature deteriorates, so 0.08% was made the upper limit.

[0036] N is an element extremely effective for stabilizing the austenite phase and securing the strength at an extremely low temperature. However, if less than 0.10%, the effect is small, while if over 0.22%, the weldability remarkably deteriorates and weld cracks and blow holes frequently occur, so the N content was made 0.10 to 0.22%.

[0037] The strength at an extremely low temperature is correlated with the amount of (C+N) in the steel. The larger the amount of C+N, the higher the strength. Regarding C and N, the range of content for each is defined, so C+N was made 0.12% or more.

[0038] Si, if less than 0.01%, results in a poor cleanliness of the steel and deteriorated toughness, while if over 2.0%, the hot workability deteriorates and production of thick-gauge plate becomes difficult, so the Si content was made 0.01 to 2.0%.

[0039] Mn also, if less than 0.1%, results in poor cleanliness of the steel, while if over 2.0%, the hot workability deteriorates, so the Mn content was made 0.1 to 2.0%.

[0040] Cr is required to be 15% or more to secure corrosion resistance at the time of working the member, but if over 27%, a brittle σ-phase is formed and the toughness deteriorates, so the Cr content was made 15 to 27%.

[0041] Ni is an element stabilizing the austenite phase and improving the strength, toughness, and ductility at an extremely low temperature, but if less than 8%, the effect of stabilization of the austenite phase is insufficient, so 8% was made the lower limit. However, this is an extremely expensive element, so from the viewpoint of cost, 20%, where the austenite stabilization effect is stabilized, was made the upper limit.

[0042] If Mo, added to secure strength, is over 4%, the σ-phase and other intermetallic compounds are formed and the toughness at extremely low temperatures deteriorates. Further, addition of a large amount leads to an increase in costs, so the Mo content was made 4% or less. Note that if less than 0.5%, the effect of improvement of the strength becomes smaller, so addition of 0.5% or more is desirable.

[0043] Co, when mixed in as an impurity element, radiates and is harmful. To reduce the radiation, the Co content was made 0.1% or less.

[0044] Cu is an element increasing the corrosion resistance, so is deliberately added. If less than 0.1%, there is no such effect, while if over 3%, the hot workability is impeded, so the Cu content was made 0.1% to 3%.

[0045] Al is an element improving the cleanliness of the steel as a deoxidizing material. However, if less than 0.001%, there is no such effect, while if over 0.10%, the hot workability deteriorates, so the Al content was made 0.001 to 0.10%.

[0046] If Ca, added for the purpose of improving the hot workability, is less than 0.0005%, there is no such effect of improvement of the workability, while if over 0.01%, the cleanliness becomes poor, so the Ca content was made 0.0005 to 0.01%.

[0047] Ti is added to increase the fineness of the solidified structure and more stably improve the strength and elongation. If less than 0.010%, there is no effect of addition, while if over 0.030%, coarse nitrides precipitate and the toughness deteriorates, so the Ti content was made 0.010% to 0.030%.

[0048] S included as an unavoidable impurity is an element causing a drop in the hot workability and toughness and is preferably reduced to 0.003% or less.

[0049] P included as an unavoidable impurity is an element harmful to the corrosion resistance and is preferably reduced to 0.040% or less.

[0050] Next, the point of making the calculated value of the δ-ferrite defined by the following equation (I) (δcal; vol%) -7% to 4% will be explained.

$$\delta cal(vol\%) = 2.9\times([Cr]+0.3[Si]+[Mo])-2.6\times([Ni]+0.3\times[Mn] +0.25\times[Cu]+35\times[C]+20\times[N])-18 \quad ...(I)$$

where [element abbreviations] means the content of the element (mass%)

δcal is the calculation formula combining the recommended formula of D.J. KOTECKI & T.A. SIEWERT (Weld. J., 71 (1992), 171s) and the recommended formula of T.A. SIEWERT, C.N. McCOWAN & D.L. OLSON (Weld. J., 67(1988), 289s) and shows the ratio of the amount of δ-ferrite in the solidified structure.

[0051] An actual slab is extremely large, so measurement of the amount of δ-ferrite is difficult. Therefore, a calculation formula finding this by an experiment on a small cross-section steel ingot is used to estimate the amount of precipitation of δ-ferrite.

[0052] The amount of δ-ferrite of a large cross-section steel ingot covered by the present invention was confirmed by a sampling investigation to give a value of about -0, +8% from the amount of precipitation of δ-ferrite predicted by this calculation formula.

[0053] If δ-ferrite appears at the time of solidification, there is an effect in increasing the fineness of the austenitic solidified structure. Further, if the δ-ferrite is finely dispersed in the steel plate, the coarsening of the crystal grains during heating is suppressed.

If δcal is smaller than -7%, the above effect is not manifested, while if over 4%, not only does the above effect become saturated, but also the steel starts to pick up magnetism and the strength and elongation and other mechanical properties deteriorate. For this reason, δcal was made -7% to 4%.

[0054] The directions of elongation of the steel plate include the width direction, length direction, and thickness direction, that is, three directions, but considering actual use, the elongations in the width direction and length direction were defined. If the elongation is 30% or more at any location in the thickness direction at a temperature of ordinary temperature to 4K, there is no practical problem, so the elongation was made 30% or more.

[0055] At locations where more advanced working is required, further higher ductility is necessary, so the elongation is preferably 40% or more.

[0056] Regarding the method of producing the present invention, the technical reason for forging a steel ingot of a thickness of 650 mm or more by an area reduction ratio of 0.5 or more, then hot rolling it by a reduction ratio of 1.5 or more, then treating it by solution heat treatment will be explained.

[0057] To make the cross-sectional structure of the very thick-gauge material uniform, it is desirable to use as thick a steel ingot as possible to increase the reduction ratio. In the present invention, the covered steel ingots, considering the thickness of the product, are limited to steel ingots of a thickness of 650 mm or more.

[0058] Further, to crush the coarse solidified structure, it is desirable to increase the area reduction ratio of the forging able to impart a large strain locally as much as possible. Further, if considering the restrictions on plate thickness in rolling machines and introduction of sufficient work strain in the cast structure over the entire cross-section, the area reduction ratio was made 0.5 or more.

[0059] The hot rolling is a process performed after the forging until obtaining the product thickness. To increase the reduction ratio as much as possible, introduce strain over the entire cross-section, and obtain a uniform recrystallized structure after solution heat treatment, the reduction ratio of the hot rolling was made 1.5 or more.

[0060] The solution heat treatment is performed for the purpose of obtaining sufficient values for the strength and elongation and other mechanical properties and the corrosion resistance by dissolving the component elements and making the metal structure crystal grain size uniform. The solution heat treatment is performed in accordance with the alloy composition and production process at 920 to 1200°C. The steel is rapidly cooled from that temperature.

[0061] By forging a steel ingot of the composition defined above and of a thickness of 650 mm or more by an area reduction ratio of 0.5 or more, then hot rolling it by a reduction ratio of 1.5 or more, then treating it by solution heat treatment, it is possible to produce austenitic stainless rolled steel plate of a thickness of 100 mm or more with an elongation in the width direction and length direction of 30% or more at any location in the thickness direction.

[0062] Further, the technical reason for adding the process of forging the steel ingot by an area reduction ratio of 0.15 or more in the direction where the thickness is increased in the method of production of the present invention will be explained.

[0063] To make the cross-sectional structure of very thick plate uniform, it is important to introduce work strain over the entire cross-section and obtain a recrystallized structure by solution heat treatment. For this reason, it is effective to add a process of not only forging the above-mentioned thick steel ingot in the direction where the thickness is decreased, but also forging the steel ingot in the direction where the thickness is increased and then roll it.

[0064] Here, the area reduction ratio (C) of forging in the direction of decrease or increase of the thickness is defined as follows:

Cross-sectional area of steel ingot after n-th forging (thickness × width): C_n
Cross-sectional area of steel ingot after (n-1)th forging (thickness × width): C_{n-1}

$$C=(C_{n-1}-C_n)/C_{n-1}$$

Further, the reduction ratio of rolling (R) is defined.as follows:

Slab thickness before rolling: B_0
Slab thickness after rolling: B_1

$$R=B_0/B_1$$

[0065] If the area reduction ratio per operation in the forging in the direction where the thickness is increased is less than 0.15, the effect is small. At 0.15 or more, a uniform structure was obtained, so the area reduction ratio was made 0.15 or more. Further, the area reduction ratio per operation in the forging in the direction where the thickness is decreased should be 0.3 or more.

[0066] It is possible to start from either forging in the direction where the thickness is decreased or forging in the direction where the thickness is increased. Further, it is sufficient to perform these alternately at least one time. For example, a forging pattern such as "increasing direction-decreasing direction-increasing direction" or "decreasing direction-increasing direction-decreasing direction" may be employed.

[0067] By forging from a direction perpendicular to the thickness direction, it is possible to impart strain from two directions, increase the sliding surfaces, and evenly introduce work strain in the entire cross-section from other directions, so the process of forging in a direction in which the thickness of the steel ingot increases is believed to have a remarkable effect in formation of a uniform structure.

[0068] In this case, the restriction on the thickness of the steel ingot at the start is eased to 500 mm or more. Further, after forging, the ingot is hot rolled by a reduction ratio of 1.5 or more, then treated by solution heat treatment. This point is the same as with the method explained above.

EXAMPLES

[0069] The steels shown in Table 1 and Table 4 were cast into ingots, forged by reduction ratios of 1.5, 2.0, and 2.5, then hot rolled by reduction ratios of 1.4 to 3.7 to produce thick-gauge plates of thicknesses of 100 to 250 mm. The production conditions and production results of the steel shown in Table 1 are shown in Table 2 and Table 3.

[0070] Furthermore, the production conditions and production results of Invention Steel Nos. 1 to 13 and Comparative Steel Nos. 1 to 11 (claims 1 to 3) shown in Table 4 are shown in Table 5, while the production conditions and production results of Invention Steel Nos. 14 to 18 and Comparative Steel Nos. 12 to 13 (claim 4) shown in Table 4 are shown in Table 6.

Table 1

	No	Content (mass%)															δcal %
		C	Si	Mn	P	S	Cr	Ni	Mo	Co	Cu	N	Al	Ca	Ti	C+N	
Inv. steel	1	0.018	0.58	1.81	0.020	0.001	18.30	10.8	2.11	0.01	0.31	0.20	0.001	0.002	0.003	0.218	-1.4
	2	0.017	0.62	1.86	0.022	0.0007	18.54	11.01	2.06	0.02	0.22	0.21	0.003	0.001	0.004	0.227	-1.7
	3	0.018	0.44	1.78	0.020	0.002	18.36	10.85	2.04	0.03	0.29	0.20	0.002	0.002	0.010	0.218	-1.7

Table 2

	No	Steel ingot thickness [average] (mm)	Forging area reduction ratio	Hot rolling reduction ratio	Product thickness (mm)	0.2% yield strength [4K] (MPa)									
						Width direction					Length direction				
						Surface layer (front)	1/4t	1/2t	3/4t	Surface layer (back)	Surface layer (front)	1/4t	1/2t	3/4t	Surface layer (back)
Inv. steel	1	730	0.5	1.85	200	1030	1024	1020	1023	1028	1070	1050	1040	1060	1070
	2	730	0.5	1.83	200	1158	1150	1150	1152	1157	1190	1180	1170	1170	1180
	3	730	0.5	1.83	200	1096	1092	1090	1090	1095	1140	1110	1100	1110	1130

Table 3

	No	Tensile strength [4K] (MPa)										Elongation [4k] (MPa)									
		Width direction					Length direction					Width direction					Length direction				
		Surface layer (front)	1/4 t	1/2 t	3/4 t	Surface layer (back)	Surface layer (front)	1/4 t	1/2 t	3/4 t	Surface layer (back)	Surface layer (front)	1/4 t	1/2 t	3/4 t	Surface layer (back)	Surface layer (front)	1/4 t	1/2 t	3/4 t	Surface layer (back)
Inv. steel	1	1660	1650	1640	1650	1670	1690	1670	166C	1660	1680	40	37	37	39	42	43	39	38	42	45
	2	1650	1620	1610	1630	1660	1650	1630	162C	1630	1660	41	41	38	38	41	43	40	39	39	43
	3	1610	1600	1590	1590	1620	1640	1600	1600	1610	1640	47	45	43	44	48	49	45	44	45	48

[0071] First, the examples shown in Tables 1 to 3 will be explained.

[0072] Thick-gauge plates forged and rolled by the production conditions shown in Table 2 were treated by solution heat treatment by the method of heating to 1100°C, then water cooling.

[0073] After this, the plates were evaluated for strength at 4K and the results shown together in Table 2 and Table 3. As the test pieces, JIS Z 2201 No. 14A test pieces (diameter of 6 mm, reference point distance of 30 mm, total length of 110 mm) were used.

[0074] The test pieces were cut out from near the end in the longitudinal direction of the product plate (location corresponding to 100 to 200 mm from top of steel ingot) at the center in the width direction (location corresponding to center in width direction of steel ingot) at five places: the product surface layer (location 10 mm from surface), location 1/4 of plate thickness from surface layer, location 1/2 of plate thickness from surface layer, location of 3/4 of plate thickness, and back surface layer. Note that the strength was evaluated by a tensile test.

[0075] Table 2 and Table 3 show the 0.2% yield strength, tensile strength, and elongation for representative invention steels. The elongation is shown by the value in the width direction and length direction of the thick-gauge plate from the cross-sectional location. In each of the invention steels, the 0.2% yield strength, tensile strength, and elongation were lowest at the locations of 1/4 of plate thickness to 3/4 of plate thickness. The surface layer never gave the lowest values.

[0076] This corresponds to the case structure easily remaining at the rolled steel plate and the structure becoming uneven at a location of 1/4 of plate thickness to 3/4 of plate thickness. Therefore, in the same cross-section, the lowest values of the 0.2% yield strength, tensile strength, and elongation were in the range of 1/4 of plate thickness to 3/4 of plate thickness.

[0077] Based on the above results, for all examples of steel shown in Table 4, the 0.2% yield strength, tensile strength, and elongation exhibited their lowest values at 1/4 of plate thickness to 3/4 of plate thickness in the same cross-section.

Table 4

	No.	Content (mass%)															δcal
		C	Si	Mn	P	S	Cr	Ni	Mo	Co	Cu	N	Al	Ca	Ti	C+N	
Inv-steel	1	0.018	0.58	1.81	0.020	0.001	16.60	10.80	2.11	0.01	0.31	0.20	0.001	0.002	0.003	0.218	-6.4
	2	0.017	0.62	1.86	0.022	0.0007	16.90	11.01	2.06	0.02	0.22	0.21	0.003	0.001	0.004	0.227	-6.5
	3	0.018	0.44	1.78	0.020	0.002	17.20	10.85	2.04	0.03	0.29	0.20	0.002	0.002	0.010	0.218	-5.1
	4	0.016	0.62	1.86	0.018	0.001	17.50	10.98	2.12	0.02	0.22	0.20	0.003	0.001	0.030	0.216	-3.8
	5	0.017	0.51	1.56	0.026	0.002	16.50	10.96	2.01	0.01	0.31	0.16	0.004	0.002	0.005	0.177	-5.0
	6	0.015	0.80	1.87	0.020	0.001	16.80	11.05	2.35	0.02	0.41	0.16	0.002	0.003	0.008	0.175	-3.1
	7	0.016	0.54	1.86	0.028	0.002	18.60	11.07	2.09	0.03	0.33	0.16	0.003	0.002	0.012	0.176	1.0
	8	0.018	0.58	1.78	0.027	0.002	18.80	11.05	2.14	0.01	0.24	0.12	0.001	0.0005	0.003	0.138	3.7
	9	0.017	0.60	1.62	0.024	0.0008	16.60	11.06	2.17	0.02	0.34	0.12	0.002	0.003	0.008	0.137	-2.4
	10	0.015	0.78	1.32	0.020	0.001	17.50	10.58	2.16	0.03	0.32	0.12	0.003	0.002	0.010	0.135	2.2
	11	0.020	0.75	1.52	0.023	0.001	16.80	11.18	2.25	0.03	0.33	0.12	0.003	0.002	0.020	0.14	-2.2
	12	0.019	0.60	1.81	0.022	0.003	16.63	10.70	2.11	0.01	0.13	0.13	0.004	0.002	0.001	0.149	-2.4
	13	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	14	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	15	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	16	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	17	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	18	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1

(continued)

	No.	Content (mass%)															δcal
		C	Si	Mn	P	S	Cr	Ni	Mo	Co	Cu	N	Al	Ca	Ti	C+N	
Comp-steel	1	0.09	1.50	1.59	0.021	0.001	19.50	10.50	2.2	0.01	0.3	0.10	0.004	0.002	0.001	0.19	-2.9
	2	0.03	0.80	1.87	0.020	0.001	18.54	11.01	2.11	0.01	0.22	0.09	0.003	0.003	0.001	0.12	2.6
	3	0.015	0.80	1.87	0.020	0.001	18.55	10.90	2.11	0.01	0.3	0.25	0.003	0.002	0.001	0.265	-2.9
	4	0.012	0.80	1.87	0.020	0.001	18.54	11.01	2.11	0.01	0.24	0.10	0.004	0.003	0.001	0.112	5.1
	5	0.012	0.50	1.87	0.020	0.001	18.52	10.98	4.2	0.01	0.21	0.16	0.002	0.002	0.001	0.172	7.8
	6	0.015	0.80	1.87	0.020	0.001	18.54	11.01	2.11	0.01	0.22	0.16	0.004	0.002	0.001	0.175	1.5
	7	0.018	0.58	1.81	0.020	0.001	18.30	10.80	2.1	0.01	0.33	0.20	0.002	0.003	0.001	0.218	-1.5
	8	0.015	0.80	1.87	0.020	0.001	18.54	11.01	2.11	0.01	0.24	0.16	0.004	0.002	0.001	0.175	1.5
	9	0.017	0.62	1.86	0.022	0.0007	18.54	11.01	2.11	0.02	0.21	0.21	0.005	0.003	0.035	0.227	-1.6
	10	0.015	0.42	1.38	0.024	0.01	16.41	13.50	2.60	0.02	0.12	0.12	0.005	0.003	0.040	0.135	-7.5
	11	0.010	0.43	1.60	0.024	0.004	19.60	10.10	2.55	0.02	0.13	0.25	0.005	0.003	0.039	0.260	4.3
	12	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
	13	0.015	0.80	1.87	0.020	0.001	16.60	11.01	2.11	0.01	0.21	0.16	0.004	0.002	0.001	0.175	-4.1
Underlines indicate outside range of present invention																	

[0078] Among the steels shown in Table 4, the Invention Steel Nos. 1 to 13 and Comparative Steel Nos. 1 to 11 were produced by the production conditions shown in Table 5.

[0079] Invention Steel No. 14 was forged, by a forging process before rolling, in the width direction of the steel ingot by an area reduction ratio of 0.25 to increase the thickness from 730 mm to 900 mm, then was forged in the thickness direction by an area reduction ratio of 0.6, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 200 mm.

[0080] Invention Steel No. 15 was forged, by a forging process before rolling, in the longitudinal direction of the steel ingot, by an area reduction ratio of 0.15 to increase the thickness from 730 mm to 900 mm, then was forged in the thickness direction by an area reduction ratio of 0.6, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 200 mm.

[0081] Invention Steel No. 16 was forged, by a forging process before rolling, in the width direction of the steel ingot, by an area reduction ratio of 0.25 to increase the thickness from 500 mm to 614 mm, then was forged in the thickness direction by an area reduction ratio of 0.6, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 137 mm.

[0082] Invention Steel No. 17 was forged, by a forging process before rolling, in the thickness direction of the steel ingot by an area reduction ratio of 0.30 to decrease the thickness from 730 mm to 510 mm, then was forged in the width direction by an area reduction ratio of 0.15 to increase the thickness to 600 mm, then was forged in the thickness direction by an area reduction ratio of 0.30 to decrease the thickness to 358 mm, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 200 mm.

[0083] Invention Steel No. 18 was forged, by a forging process before rolling, in the width direction of the steel ingot, was forged by an area reduction ratio of 0.25 to increase the thickness from 500 mm to 614 mm, then was forged in the thickness direction by an area reduction ratio of 0.6 to decrease the thickness to 430 mm, then was forged in the width direction by an area reduction ratio of 0.25 to increase the thickness to 471 mm, then was forged in the thickness direction by an area reduction ratio of 0.6 to decrease the thickness to 330 mm, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 184 mm.

[0084] Comparative Steel No. 12, for comparison of the difference of strength due to differences in the forging area reduction ratio with Example 14, was forged, by a forging process before rolling, in the width direction of the steel ingot by an area reduction ratio of 0.10 to increase the thickness from 730 mm to 832 mm, then was forged in the thickness direction by an area reduction ratio of 0.57 to decrease the thickness to 358 mm, then was rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 200 mm.

[0085] Comparative Steel No. 13, for comparison of the difference of strength due to differences in the forging area reduction ratio with Example 18, was forged, by a forging process before rolling, in the width direction of the steel ingot by an area reduction ratio of 0.23 to increase the thickness from 500 mm to 631 mm, then was forged in the thickness direction by an area reduction ratio of 0.29 to decrease the thickness to 448 mm, then was rolled in the width direction by an area reduction ratio of 0.13 to increase the thickness to 502 mm, then was forged in the thickness direction by an area reduction ratio of 0.29 to decrease the thickness to 356 mm, then were rolled by a reduction ratio of 1.8 to obtain a product of a thickness of 199 mm.

[0086] Thick-gauge plate forged and rolled by the above production conditions were treated by solution heat treatment by the method of heating to 1100°C then water cooling.

[0087] The results are shown in Table 5 and Table 6. The methods of evaluation were the same as the method of evaluation used in Table 2 and Table 3.

Table 5

	No.	Steel ingot thickness [average] (mm)	Forging area reduction ratio A0→A1	A0 (m^2)	Thickness (mm)	Width (mm)	Al (m^2)	Thickness (mm)	Width (mm)	Hot rolling reduction ratio	B0 (mm)	B1 (mm)	Product thickness (mm)	0.2% yield strength [4K] (MPa)		Tensile strength [4K] (MPa)		Elongation [4K] (%)	
														Width dir.	Length dir.	Width dir.	Length dir.	Width dir.	Length dir.
	1	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1020	1040	1640	1660	37	38
	2	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1150	1170	1610	1620	38	39
I	3	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1090	1100	1590	1600	43	44
n	4	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1030	1040	1580	1590	46	47
v	5	730	0.5	1.39	730	1900	0.69	365	1900	2.61	365	140	140	910	930	1520	1560	40	40
-	6	730	0.5	1.39	730	1900	0.69	365	1900	2.61	365	140	140	940	960	1540	1590	42	43
s	7	730	0.5	1.39	730	1900	0.69	365	1900	2.61	365	140	140	920	930	1510	1550	45	45
t	8	730	0.5	1.39	730	1900	0.69	365	1900	3.04	365	120	120	810	830	1440	1480	40	41
e	9	730	0.5	1.39	730	1900	0.69	365	1900	3.65	365	100	100	830	850	1450	1490	41	42
e	10	730	0.5	1.39	730	1900	0.69	365	1900	3.65	365	100	100	820	840	1410	1450	43	44
l	11	650	0.6	1.24	650	1900	0.49	260	1900	2.60	260	100	100	810	820	1390	1430	41	42
	12	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	930	1490	1530	38	39
	13	730	0.5	1.39	730	1900	0.69	365	1900	1.52	365	240	240	910	930	1420	1460	35	36

(continued)

	No.	Steel ingot thickness [average] (mm)	Forging area reduction ratio A0→A1	A0 (m^2)	Thickness (mm)	Width (mm)	Al (m^2)	Thickness (mm)	Width (mm)	Hot rolling reduction ratio	B0 (mm)	B1 (mm)	Product thickness (mm)	0.2% yield strength [4K] (MPa)		Tensile strength [4K] (MPa)		Elongation [4K] (%)	
														Width dir.	Length dir.	Width dir.	Length dir.	Width dir.	Length dir.
C	1	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	940	1490	1530	25	26
o	2	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	940	1490	1530	25	26
m	3	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	940	1490	1530	25	26
p	4	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	940	1490	1530	25	26
-	5	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	920	940	1490	1530	25	26
s	6	650	0.4	1.24	730	1900	0.74	390	1900	1.95	390	200	200	920	940	1490	1530	25	26
t	7	600	0.5	1.14	730	1900	0.57	300	1900	1.50	300	200	200	1040	1060	1630	1670	29	30
e	8	720	0.5	1.37	730	1900	0.68	360	1900	1.44	360	250	250	1040	1050	1630	1660	28	29
e	9	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1110	1140	1580	1590	21	22
l	10	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1110	1140	1580	1610	27	28
	11	730	0.5	1.39	730	1900	0.69	365	1900	1.83	365	200	200	1110	1130	1580	1600	28	29

Underlines indicate outside range of present invention

Table 6

	No.	Steel ingot thickness [average] (mm)	Forging area reduction ratio Cn-1→Cn	C0 (m²)	Thick-ness (mm)	Width (mm)	C1 (m²)	Thick-ness (mm)	Width (mm)	C2 (m²)	Thick-ness (mm)	Width (mm)	C3 (m²)	Thick-ness (mm)	Width (mm)	C4 (m²)	Thick-ness (mm)	Width (mm)	Hot rolling reduction ratio	B0 (mm)	B1 (mm)	Product thickness (mm)	0.2% yield strength [4K] (MPa)		Tensile strength [4K] (MPa)		Elongation [4K] (%)	
																							Width dir.	Length dir.	Width dir.	Length dir.	Width dir.	Length dir.
Inv. steel	14	Initial 730 (max. 900)	Width dir. forging 0.25 C0→C1; Thickness dir. forging 0.6 C1→C2 (Total forging 0.66 C0→C2)	1.39	730	1900	1.04	900	1160	0.42	358	1160	-	-	-	-	-	-	1.8	358	200	200	910	930	1410	1450	41	41
Inv. steel	15	Initial 730 (max. 900)	Length dir. forging 0.15 C0→C1; Thickness dir. forging 0.6 C1→C2 (Total forging 0.66 C0→C2)	1.46	730	length 2000	1.24	900	length 1380	0.50	358	length 1390	-	-	-	-	-	-	1.8	358	200	200	910	930	1420	1460	40	41
Inv. steel	16	Initial 500 (max. 614)	Width dir. forging 0.25 C0→C1; Thickness dir. forging 0.6 C1→C2 (Total forging 0.66 C0→C2)	0.95	500	1900	0.71	614	1160	0.29	246	1160	-	-	-	-	-	-	1.8	246	137	137	900	920	1400	1440	40	41
Inv. steel	17	Initial 730 (max. 730)	Thickness dir. forging 0.30 C0→C1; Width dir. forging 0.15 C1→C2 Thickness dir. forging 0.30 C2→C3 (Total forging 0.58 C0→C3)	1.39	730	1900	0.97	510	1900	0.83	600	1375	0.58	358	1614	-	-	-	1.8	358	200	200	910	930	1410	1440	40	42
Inv. steel	18	Initial 500 (max. 614)	Width dir. forging 0.25 C0→C1; Thickness dir. forging 0.6 C1→C2 Width dir. forging 0.25 C2→C3; Thickness dir. forging 0.6 C3→C4 (Total forging 0.69 C0→C4)	0.95	500	1900	0.71	614	1160	0.50	430	1160	0.42	471	900	0.30	330	900	1.8	330	184	184	910	930	1410	1450	41	42
C. steel	12	Initial 730 (max. 832)	Width dir. forging 0.10 C0→C1; Thickness dir. forging 0.57 C1→C2 (Total forging 0.61 C0→C2)	1.39	730	1900	1.25	832	1500	0.54	358	1500	-	-	-	-	-	-	1.8	358	200	200	890	910	1410	1450	27	28
C. steel	13	Initial 500 (max. 631)	Width dir. forging 0.23 C0→C1; Thickness dir. forging 0.29 C1→C2 Width dir. forging 0.13 C2→C3; Thickness dir. forging 0.29 C3→C4 (Total forging 0.69 C0→C4)	0.95	500	1900	0.73	631	1160	0.52	448	1160	0.45	502	900	0.32	356	900	1.8	356	199	199	910	930	1410	1430	28	29

Underlines indicate outside range of present invention

[0088] In the Invention Steels, it was recognized that the crystal grains were uniformly made finer, the strength at 4K was high, and the elongation was also large. On the other hand, in steels where the composition was outside the range defined by the present invention, the effect of making the crystal grains uniformly finer was poor and part of the coarse structure remained, so even if a high strength could be obtained, a high elongation could not be obtained.
[0089] Further, if the thickness of the steel ingot, the area reduction ratio in the forging, and the reduction ratio in the hot rolling were outside the ranges defined by the present invention, the coarse grain structure partially remained, so even if a high strength could be obtained, a high elongation could not be obtained.

INDUSTRIAL APPLICABILITY

[0090] As explained above, according to the present invention, it is possible to obtain thick-gauge plate of a thickness of 100 mm or more high in strength and ductility at extremely low temperatures. The austenitic stainless steel plate of the present invention can be used as a structural material of a superconductive coil for a thermonuclear reactor (ITER) promising as a next generation energy source.
[0091] Further, the austenitic stainless steel plate of the present invention can be applied for increasing larger superconductive equipment, for structures for LNG (liquefied natural gas), etc. and are expected to greatly contribute to the future energy industry and other various industrial fields. The present invention will have a great industrial and social effect.
[0092] Therefore, the present invention has great applicability in industry.

Claims

1. Austenitic stainless rolled steel plate of a thickness of 100 mm or more, **characterised by**:

   containing by mass%,
   C: 0.08% or less,
   N: 0.10% to 0.22%,
   C+N: 0.12% or more,
   Si: 0.01% to 2.0%,
   Mn: 0.1% to 2.0%,
   Cr: 15% to 27%,
   Ni: 8% to 20%,
   Mo: 4% or less,
   Co: 0.1% or less,
   Cu: 0.1% to 3%,
   Al: 0.001% to 0.10%,
   Ca: 0.0005% to 0.01%, and
   a balance of iron and unavoidable impurities,
   having a calculated value of the amount of δ-ferrite defined by the following (I) formula (δcal; vol%) of -7% to 4%, and
   having an elongation in the width direction and length direction at any location in the thickness direction of 30% or more:

$$\delta cal\ (vol\%) = 2.9 \times ([Cr] + 0.3[Si] + [Mo]) - 2.6 \times ([Ni] + 0.3 \times [Mn] + 0.25 \times [Cu] + 35 \times [C] + 20 \times [N]) - 18 \quad \ldots (I)$$

   where [element abbreviations] means the content of the element (mass%), and the elongation is the value measured at 4K.

2. Austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in claim 1, **characterised by** further containing, by mass%, Ti: 0.010% to 0.030%.

3. A method of producing of austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in claim 1 or 2, **characterized by**:

forging steel of a thickness of 650 mm or more at an area reduction ratio of 0.5 or more, then
hot rolling it by a reduction ratio of 1.5 or more, then
treating it by solution heat treatment,

wherein, the area reduction ratio (A) of forging is defined as follows:

Cross-sectional area of steel ingot before forging (thickness × width): A_0
Cross-sectional area of steel ingot after forging (thickness × width): A_1

$$A=(A_0-A_1)/A_0,$$

further, the reduction ratio (R) of rolling is defined as follows:

Slab thickness before rolling: B_0
Slab thickness after rolling: B_1

$$R=B_0/B_1.$$

4. A method of producing austenitic stainless rolled steel plate of a thickness of 100 mm or more as set forth in claim 1 or 2, said method of producing austenitic stainless rolled steel plate of a thickness of 100 mm or more, **characterized by**:

alternately processing a steel ingot of a thickness of 500 mm or more by forging of an area reduction ratio of 0.3 or more in a direction where the thickness decreases and forging of an area reduction ratio of 0.15 or more in a direction where the thickness increases at least one time, then
hot rolling by a reduction ratio of 1.5 or more, then
applying solution heat treatment,

wherein, the area reduction ratio (C) of forging in the direction of decrease or increase of the thickness is defined as follows:

Cross-sectional area of steel ingot after n-th forging (thickness × width): C_n
Cross-sectional area of steel ingot after n-1st forging (thickness × width): C_{n-1}

$$C=(C_{n-1}-C_n)/C_{n-1},$$

further, the reduction ratio (R) of rolling is defined as follows:

Slab thickness before rolling: B_0
Slab thickness after rolling: B_1

$$R=B_0/B_1.$$

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/063186

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *B21B1/02*(2006.01)i, *B21B1/38*(2006.01)i, *B21B3/02*(2006.01)i, *C21D8/02*(2006.01)i, *C22C38/58*(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, B21B1/02, B21B1/38, B21B3/02, C21D8/02, C22C38/58

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	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI, JSTPlus(JDream2), Science Direct

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-269564 A (Nippon Steel Corp.), 15 October, 1996 (15.10.96), Claims; Par. Nos. [0027] to [0033] (Family: none)	1-4
A	JP 7-316653 A (Nippon Steel Corp.), 05 December, 1995 (05.12.95), Claims; Par. Nos. [0020] to [0029] (Family: none)	1-4
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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 September, 2007 (13.09.07)	25 September, 2007 (25.09.07)

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