(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 995 341 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 158(3) EPC

(43) Date of publication:
26.11.2008 Bulletin 2008/48

(21) Application number: **08722143.8**

(22) Date of filing: **14.03.2008**

(51) Int Cl.:
C22C 38/00 *(2006.01)* ***C22C 38/58*** *(2006.01)*
C21D 8/10 *(2006.01)*

(86) International application number:
PCT/JP2008/054747

(87) International publication number:
WO 2008/117680 (02.10.2008 Gazette 2008/40)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **26.03.2007 JP 2007078691**

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(54) OIL WELL PIPE FOR EXPANSION IN WELL AND TWO-PHASE STAINLESS STEEL FOR USE AS OIL WELL PIPE FOR EXPANSION

(57) An oil country tubular good for expansion according to the invention is expanded in a well. The oil country tubular good for expansion according to the invention is formed of duplex stainless steel having a composition containing, in percentage by mass, 0.005% to 0.03% C, 0.1% to 1.0% Si, 0.2% to 2.0% Mn, at most 0.04% P, at most 0.015% S, 18.0% to 27.0% Cr, 4.0% to 9.0% Ni, at most 0.040% Al, and 0.05% to 0.40% N, and the balance consisting of Fe and impurities, a structure including an austenite ratio in the range from 40% to 90%. The oil country tubular good for expansion according to the invention has a yield strength from 256 MPa to 655 MPa, and a uniform elongation more than 20%. Therefore, the oil country tubular good for expansion according to the invention has a high pipe expansion characteristic.

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present invention relates to an oil country tubular good and duplex stainless steel, and more specifically, to an oil country tubular good to be expanded in a well and duplex stainless steel to be used for such an oil country tubular good for expansion.

BACKGROUND ART

[0002] When a well (oil well or gas well) that yields oil or gas is drilled in general, a plurality of oil country tubular goods called "casings" are inserted into a well drilled using a drill pipe in order to prevent the wall of the well from being collapsed. A conventional method of constructing a well is as follows. To start with, when a well is drilled for a prescribed distance, a first casing is inserted. Then, when the well is further drilled for a prescribed distance, a second casing having an outer diameter smaller than the inner diameter of the first casing is inserted. In this way, according to the conventional construction method, the outer diameters of casings to be inserted are sequentially reduced as the well is drilled deeper. Therefore, as the oil well is deeper, the inner diameters of casings used in the upper part of the well (near the surface of the ground) increase. As a result, the drilling area increases, which pushes up the drilling cost.

[0003] A new technique for reducing the drilling area and thus reducing the drilling cost is disclosed by JP 7-567610 A and the pamphlet of International Publication WO 98/00626. The technique disclosed by these documents is as follows. A casing C3 having a smaller outer diameter than the inner diameter ID1 of casings C1 and C2 already provided in a well is inserted into the well. Then, the inserted casing C3 is expanded, so that its inner diameter is equal to the inner diameter ID1 of the previously provided casings C1 and C2 as shown in Fig. 1. According to the method, the casing is expanded inside the well and therefore it is not necessary to increase the drilling area if the oil well to construct is deep. Therefore, the drilling area can be reduced. Furthermore, the number of necessary steel pipes can be reduced because large size casings are not necessary.

[0004] In this way, the oil country tubular good expanded in a well must have a uniformly deforming characteristic when expanded (hereinafter referred to as "pipe expansion characteristic.") In order to obtain a high pipe expansion characteristic, the deforming characteristic without local constriction during working is required, in other words, uniform elongation that can be evaluated by tensile testing must be high.

[0005] As shown in Fig. 1 in particular, in the bell part 10 where casings vertically placed on each other overlap, the pipe expansion ratio is maximized. In consideration of the expansion ratio at the bell part, the uniform elongation of the oil country tubular good for expansion is preferably more than 20%.

[0006] JP 2005-146414 A discloses a seamless oil country tubular good for expansion. The structure of the disclosed oil country tubular good includes a ferrite transformation phase and low temperature transformation phases (such as bainite, martensite, and bainitic ferrite), and has a high pipe expansion characteristic. However, the uniform elongation of each test piece in the disclosed embodiment is not more than 20% (see JP 2005-146414 A, u-E1 in Tables 2-1 and 2-2). Therefore, the bell part described above may not deform uniformly.

DISCLOSURE OF THE INVENTION

[0007] It is an object of the invention to provide an oil country tubular good for expansion having a high pipe expansion characteristic. More specifically, it is to provide an oil country tubular good having a uniform elongation more than 20%.

[0008] In order to achieve the above-described object, the inventors examined the uniform elongation of various types of steel. As a result, the inventors have found that duplex stainless steel having prescribed chemical components has a uniform elongation significantly higher than those of carbon steel and martensitic stainless steel.

[0009] The inventors have further studied and found that in order to produce an oil country tubular good having a uniform elongation more than 20%, the following requirements must be fulfilled.

(1) The austenite ratio in the duplex stainless steel is in the range from 40% to 90%. Herein, the austenite ratio is measured by the following method. A sample is taken from an arbitrary position of an oil country tubular good for expansion. The sample is mechanically polished and then subjected to electrolytic etching in a 30 mol% KOH solution. The etched surface of the sample is observed using a 400X optical microscope with a 25-grating ocular lens, and the austenite ratio is measured by a point count method according to ASTM E562.

(2) The yield strength is adjusted in the range from 276 MPa to 655 MPa. The yield strength herein is 0.2% proof stress according to the ASTM standard. When an oil country tubular good for expansion is kept as-solution treated, the yield strength is within the above-described range. Herein, "as-solution treated" means the state in which after the solution treatment, no other thermal treatment or no other cold working is carried out except for cold straightening.

[0010] The present invention was made based on the above-described findings and the invention can be summarized as follows.

[0011] An oil country tubular good for expansion according to the invention is expanded in a well. The oil country tubular good for expansion according to the invention is formed of duplex stainless steel having a composition containing, in percentage by mass, 0.005% to 0.03% C, 0.1% to 1.0% Si, 0.2% to 2.0% Mn, at most 0.04% P, at most 0.015% S, 18.0% to 27.0% Cr, 4.0% to 9.0% Ni, at most 0.040% Al, and 0.05% to 0.40% N, and the balance consisting of Fe and impurities, and a structure including an austenite ratio in the range from 40% to 90%. The oil country tubular good has a yield strength from 256 MPa to 655 MPa, and a uniform elongation more than 20%.

[0012] Herein, the "uniform elongation" means the distortion (%) at the maximum load point in a tensile test. The austenite ratio is an austenite area ratio.

[0013] The duplex stainless steel may further contain at most 2.0% Cu. The duplex stainless steel may further contain one or more selected from the group consisting of at most 4.0% Mo and at most 5.0% W. The duplex stainless steel may further contain one or more selected from the group consisting of at most 0.8% Ti, at most 1.5% V, and at most 1.5% Nb. The duplex stainless steel may further contain one or more selected from the group consisting of at most 0.02% B, at most 0.02% Ca and at most 0.02% Mg.

[0014] The duplex stainless steel according to the invention is used for the above-described oil country tubular good for expansion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a schematic view for use in illustrating a new method of constructing a well that yields oil or gas.

BEST MODE FOR CARRYING OUT THE INVENTION

[0016] Now, embodiments of the invention will be described in detail.

[0017] An oil country tubular good according to an embodiment of the invention is formed of duplex stainless steel having the following chemical composition and metal structure. Hereinafter, "%" related to elements means "% by mass."

1. Chemical Composition

[0018] C: 0.005% to 0.03%

[0019] Carbon stabilizes the austenite phase. In order to effectively secure the effect, the C content is not less than 0.005%. Meanwhile, if the C content exceeds 0.03%, carbide is more easily precipitated, which lowers the grain boundary corrosion resistance. Therefore, the C content is from 0.005% to 0.03%.

[0020] Si: 0.1% to 1.0%

[0021] Silicon deoxidizes the steel. In order to secure the effect, the Si content is not less than 0.1%. Meanwhile, if the Si content exceeds 1.0%, intermetallic compounds are acceleratingly generated, which lowers the hot workability. Therefore, the Si content is from 0.1% to 1.0%.

[0022] Mn: 0.2% to 2.0%

[0023] Manganese deoxidizes and desulfurizes the steel and improves the hot workability as a result. Manganese also increases the solid solubility of N. In order to effectively secure the effect, the Mn content is not less than 0.2%. Meanwhile, if the Mn content exceeds 2.0%, the corrosion resistance is lowered. Therefore, the Mn content is from 0.2% to 2.0%.

[0024] P: 0.04% or less

[0025] Phosphorus is an impurity that promotes central segregation and degrades the sulfide stress cracking resistance. Therefore, the P content is preferably as small as possible. Therefore, the P content is not more than 0.04%.

[0026] S: 0.015% or less

[0027] Sulfur is an impurity and lowers the hot workability. Therefore, the S content is preferably as small as possible. The S content is therefore not more than 0.015%.

[0028] Cr: 18.0% to 27.0%

[0029] Chromium improves the carbon dioxide corrosion resistance. In order to secure sufficient carbon dioxide corrosion resistance for duplex stainless steel, the Cr content is not less than 18.0%. Meanwhile, if the Cr content exceeds 27.0%, intermetallic compounds are acceleratingly generated, which lowers the hot workability. Therefore, the Cr content is from 18.0% to 27.0%, preferably from 20.0% to 26.0%.

[0030] Ni: 4.0% to 9.0%

[0031] Nickel stabilizes the austenite phase. If the Ni content is too small, the amount of ferrite in the steel is excessive, and the characteristic of the duplex stainless steel does not result. The solid solubility of N in the ferrite phase is small, and the increase in the ferrite amount causes nitride to be precipitated, which degrades the corrosion resistance. Meanwhile, an excessive Ni content reduces the ferrite amount in the steel, and the characteristic of the duplex stainless steel does not result. In addition, an excessive Ni content causes a σ phase to be precipitated. Therefore, the Ni content is from 4.0% to 9.0%, preferably from 5.0% to 8.0%.

[0032] Al: 0.040% or less

[0033] Aluminum is effective as a deoxidizing agent. However, if the Al content exceeds 0.040%, inclusions in the steel increase, which degrades the toughness and the corrosion resistance. Therefore, the Al content is not more than 0.040%.

[0034] N: 0.05% to 0.40%

[0035] Nitrogen stabilizes the austenite phase and also improves the thermal stability and the corrosion resistance of the duplex stainless steel. In order to achieve an appropriate ratio between the ferrite phase and the austenite phase in the steel, the N content is not less than 0.05%. Meanwhile, if the N content exceeds 0.40%, a defect attributable to a generated blow hole is caused. The toughness and corrosion resistance of the steel are degraded as well. Therefore, the N content is from 0.05% to 0.40%, preferably from 0.1% to 0.35%.

[0036] Note that the balance of the duplex stainless steel according to the invention consists of Fe and impurities.

[0037] The duplex stainless steel for an oil country tubular good for expansion according to the embodiment further contains Cu in place of part of Fe if necessary.

[0038] Cu: 2.0% or less

[0039] Copper is an optional element and improves the corrosion resistance of the steel. However, an excessive Cu content lowers the hot workability. Therefore, the Cu content is not more than 2.0%. Note that in order to effectively secure the above-described effect, the Cu content is preferably not less than 0.2%. However, if the Cu content is less than 0.2%, the above-described effect can be obtained to some extent.

[0040] The duplex stainless steel for an oil country tubular good for expansion according to the embodiment further contains one or more selected from the group consisting of Mo and W in place of part of Fe if necessary.

[0041] Mo: 4.0% or less

[0042] W: 5.0% or less

[0043] Molybdenum and tungsten are optional elements. These elements improve the pitting corrosion resistance and the deposit corrosion resistance. However, an excessive Mo content and/or an excessive W content causes a σ phase to be more easily precipitated, which embrittles the steel. Therefore, the Mo content is not more than 4.0% and the W content is not more than 5.0%. In order to effectively secure the above described effect, the Mo content is preferably not less than 2.0% and the W content is preferably not less than 0.1%. However, if the Mo content and the W content are less than the described lower limits, the above-described effect can be obtained to some extent.

[0044] The duplex stainless steel for an oil country tubular good for expansion according to the embodiment further contains one or more selected from the group consisting of Ti, V, and Nb in place of part of Fe if necessary.

[0045] Ti: 0.8% or less

[0046] V: 1.5% or less

[0047] Nb: 1.5% or less

[0048] Titanium, vanadium, and niobium are optional elements. These elements improve the strength of the steel. However, if the contents of these elements are excessive, the hot workability is lowered. Therefore, the Ti content is 0.8% or less, the V content is 1.5% or less, and the Nb content is 1.5% or less. In order to more effectively secure the above-described effect, the Ti content is preferably not less than 0.1%, and the V content is preferably not less than 0.05%. The Nb content is preferably not less than 0.05%. However, if the Ti, V, and Nb contents are less than the above-described lower limits, the above effect can be obtained to some extent.

[0049] The duplex stainless steel for an oil country tubular good according to the embodiment further contains one or more selected from the group consisting of B, Ca, and Mg in place of part of Fe.

[0050] B: 0.02% or less

[0051] Ca: 0.02% or less

[0052] Mg: 0.02% or less

[0053] Boron, calcium, and magnesium are optional elements. These elements improve the hot workability. However, if the contents of these elements are excessive, the corrosion resistance of the steel is lowered. Therefore, the B content, the Ca content, and the Mg content are each not more than 0.02%. In order to more effectively secure the above-described effect, the B content, the Ca content, and the Mg content are each preferably not less than 0.0002%. However, if the B, Ca, and Mg contents are less than the lower limits, the above-described effect can be obtained to some extent.

2. Metal Structure

[0054] The duplex stainless steel that forms an oil country tubular good for expansion according to the invention has a metal structure including a ferrite phase and an austenite phase. It is considered that the austenite phase as a soft phase contributes to improvement of the uniform elongation.

[0055] The austenite ratio in the steel is from 40% to 90%. Herein, the austenite ratio is an area ratio measured by the following method. A sample is taken from an arbitrary position of an oil country tubular good for expansion and mechanically polished, and then the polished sample is subjected to electrolytic etching in a 30 mol% KOH solution. The etched surface of the sample is observed using a 400X optical microscope with a 25 grating ocular lens, and the austenite ratio is measured by the point count method according to ASTM E562.

[0056] If the austenite ratio is less than 40%, the uniform elongation is reduced to 20% or less. Meanwhile, if the austenite ratio exceeds 90%, the corrosion resistance of the steel is degraded. Therefore, the austenite ratio is from 40% to 90%. The austenite ratio is preferably from 40% to 70%, more preferably from 45% to 65%.

3. Manufacturing Method

[0057] The oil country tubular good for expansion according to the invention is produced by the following method.

[0058] Molten steel having the above-described composition is cast and then formed into billets. The produced billet is subjected to hot working and made into an oil country tubular good for expansion. As the hot working, for example, the Mannesmann method is carried out. As the hot working, hot extrusion may be carried out, or hot forging may be carried out. The produced oil country tubular good for expansion may be a seamless pipe or a welded pipe.

[0059] The oil country tubular good for expansion after the hot working is subjected to solution treatment. The solution treatment temperature at the time is from 1000°C to 1200°C. If the solution treatment temperature is less than 1000°C, a σ phase is precipitated, which embrittles the steel. The yield strength is raised and exceeds 655 MPa because of the precipitation of the σ phase, and therefore the uniform elongation is 20% or less. On the other hand, if the solution treatment temperature exceeds 1200°C, the austenite ratio is significantly lowered and becomes less than 40%. The solution treatment temperature is preferably from 1000°C to 1175°C, more preferably from 1000°C to 1150°C.

[0060] The oil country tubular good for expansion according to the invention is in an as-solution-treated state (so-called as-solution-treated material). More specifically, the tubular good is used as a product right after the solution treatment without being subjected to other heat treatment and cold working (such as cold reduction or pilger rolling) except for cold straightening. In this way, since the oil country tubular good for expansion according to the invention is in an as-solution-treated state, and therefore the yield strength may be in the range from 276 MPa to 655 MPa (40 ksi to 95 ksi). It is considered that in this way, the uniform elongation exceeds 20% and a high expansion characteristic is obtained even in a well. Note that if the yield strength exceeds 655 MPa, the uniform elongation is 20% or less. The oil country tubular good for expansion needs strength in a certain level, and the yield strength is 276 MPa or more.

[0061] Note that if cold working is carried out after the solution treatment, the yield strength exceeds 655 MPa. Therefore, the uniform elongation is less than 20%.

Example

[0062] A plurality of steel products having the chemical compositions in Table 1 were cast and formed into billets. The produced billets were subjected to hot forging and hot rolling and a plurality of steel plates for testing having a thickness of 30 mm, a width of 120 mm, and a length of 300 mm were formed.

Table 1

	test No.	chemical composition (in % by mass, the balance consisting of Fe and impurities)																		structure	heat treatment	ST temp. (°C)	γ (%)	TS (MPa)	YS (MPa)	UE (%)
		C	Si	Mn	P	S	Cr	Ni	Al	N	Cu	Mo	W	Ti	V	Nb	B	Ca	Mg							
inventive steel	1	0.016	0.35	0.49	0.023	0.0005	24.90	6.94	0.020	0.2900	0.50	3.07	2.11	-	0.11	-	0.0025	-	-	D	ST	1085	56	867	623	28.5
	2	0.010	0.25	0.39	0.017	0.0007	22.00	5.40	0.032	0.1400	0.10	2.90	-	-	-	-	-	-	-	D	ST	1070	58	735	490	48.0
	3	0.022	0.40	0.90	0.016	0.0008	25.19	6.20	0.030	0.1400	0.25	3.16	-	-	0.07	-	-	-	-	D	ST	1080	55	821	605	34.0
	4	0.020	0.55	1.10	0.016	0.0012	26.12	6.50	0.020	0.1500	-	-	-	-	-	-	-	-	-	D	ST	1050	62	600	430	50.2
	5	0.014	0.29	0.46	0.023	0.0003	24.88	6.59	0.005	0.2715	0.45	3.08	2.00	-	0.04	-	0.0023	0.0016	-	D	ST	1100	50	849	625	32.8
	6	0.018	0.38	0.57	0.025	0.0005	25.37	6.82	0.016	0.2898	0.52	3.17	2.15	0.005	0.08	0.017	0.0028	0.0023	-	D	ST	1150	48	893	645	26.6
	7	0.020	0.48	1.51	0.022	0.0011	22.39	5.74	0.034	0.1650	-	3.20	-	-	-	-	-	-	-	D	ST	1050	55	734	484	48.4
	8	0.018	0.45	1.56	0.021	0.0009	22.45	5.75	0.025	0.1665	-	3.21	-	-	-	-	-	-	-	D	ST	1050	56	754	531	43.5
	9	0.017	0.31	0.87	0.017	0.0009	24.59	5.66	0.018	0.1200	0.26	3.07	-	-	-	-	-	-	0.002	D	ST	1050	58	780	560	40.3
	10	0.024	0.49	0.95	0.027	0.0020	25.53	6.37	0.031	0.1700	0.48	3.18	-	-	-	-	-	-	-	D	ST	1060	58	830	610	33.5
	11	0.018	0.45	0.85	0.022	0.0007	25.10	7.18	0.028	0.1600	-	3.20	0.42	-	-	-	-	0.0021	-	D	ST	1060	55	805	605	37.5
comparative steel	12	0.070	0.28	1.27	0.008	0.0007	0.20	0.02	0.020	0.0040	-	0.04	-	0.007	0.04	-	-	-	-	C	QT	-	-	596	520	9.5
	13	0.080	0.33	1.32	0.014	0.0009	0.18	0.06	0.030	0.0050	-	0.05	-	0.009	0.05	-	-	-	-	C	QT	-	-	528	445	11.0
	14	0.007	0.23	1.20	0.019	0.0005	0.15	-	0.031	0.0060	-	-	-	-	-	-	-	-	-	C	QT	-	-	535	348	17.0
	15	0.009	0.20	0.42	0.012	0.0014	11.90	5.33	0.020	0.0087	-	1.91	-	0.086	0.06	-	-	-	-	M	QT	-	-	914	751	2.00
	16	0.007	0.20	0.44	0.017	0.0009	12.03	5.44	0.025	0.0077	0.24	1.92	-	0.071	0.06	-	-	-	-	M	QT	-	-	955	948	6.12
	17	0.007	0.20	0.42	0.015	0.0006	11.87	5.82	0.030	0.0076	-	1.91	-	0.100	-	-	-	-	-	M	QT	-	-	890	843	9.15
	18	0.007	0.20	0.44	0.017	0.0009	12.05	5.43	0.022	0.0065	0.24	1.92	-	0.069	0.06	-	-	-	-	M	QT	-	-	860	616	8.34
	19	0.006	0.22	0.42	0.016	0.0005	11.89	5.42	0.021	0.0080	0.24	1.91	-	0.097	0.06	-	-	-	-	M	QT	-	-	904	670	4.00
	20	0.008	0.21	0.41	0.013	0.0007	11.94	5.41	0.030	0.0090	0.23	1.91	-	0.095	0.06	-	-	-	-	M	QT	-	-	917	705	3.20
	21	0.021	0.55	1.08	0.016	0.0012	26.12	6.54	0.020	0.1700	-	2.94	1.55	-	-	-	-	-	-	D	ST	980	60	970	701	15.0
	22	0.020	0.55	1.10	0.016	0.0012	26.01	6.50	0.020	0.1600	-	2.87	1.95	-	-	-	-	-	-	D	ST	1250	32	930	643	18.0
	23	0.016	0.33	0.49	0.023	0.0005	24.60	6.85	0.020	0.2900	0.50	3.04	2.05	-	0.09	-	0.0022	-	-	D	ST+CW	1085	52	1110	1075	1.6

D: duplex stainless steel, C: carbon steel, M: martensitic stainless steel,
QT: quenching & tempering, ST: solution-treatment, ST + CW: solution-treatment + cold working, UE: uniform elongation

[0063] In Table 1, steel types for test numbers are given in the "structure" column. In the table, "D" represents duplex stainless steel, "C" represents carbon steel, and "M" represents martensitic stainless steel. With reference to Table 1, test Nos. 1 to 11 and 21 to 23 were duplex stainless steel. Test Nos. 12 to 14 were carbon steel and test Nos. 15 to 20 were martensitic stainless steel.

[0064] Steel plates with test Nos. 1 to 23 were subjected to heat treatment as described in the "heat treatment" column and cold working in Table 1. More specifically, the steel plates with test Nos. 1 to 11 were subjected to solution treatment in the temperature range from 1050°C to 1150°C ("ST" in the "heat treatment" column in Table 1). The solution treatment temperature for each of the steel plates is shown in the "ST temperature" in Table 1. The steel plates with test Nos. 1 to 11 were each a so-called as-solution-treated material without being subjected to other heat treatment or cold working such as cold reduction after the solution treatment.

[0065] The steel plates with test Nos. 12 to 20 were quenched at 920°C and then tempered in the temperature range from 550°C to 730°C ("QT" in the "heat treatment" column in Table 1). The steel plate with test No. 21 was subjected to solution treatment at a temperature less than 1000°C, and the steel plate with test No. 22 was subjected to solution treatment at a temperature higher than 1200°C. The steel plates with test Nos. 21 and 22 are as-solution-treated materials. The steel plate with test No. 23 was subjected to solution treatment at 1085°C followed by cold drawing.

Measurement of Austenite Ratio

[0066] For the steel plates of duplex stainless steel with test Nos. 1 to 11 and 21 to 23, the austenite ratio was obtained after the heat treatment. More specifically, a test piece was taken from each of these steel plates. The sampled test pieces were mechanically polished and the polished test pieces were subjected to electrolytic etching in a 30 mol% KOH solution. The etched surfaces of the samples were observed using a 400X optical microscope with 25 grating ocular lens in 16 fields. The austenite ratio (%) was obtained for each of the observed fields. The austenite ratios were obtained by the point count method according to ASTM E562. The average of the austenite ratios (%) obtained for each of the fields is given in the "γ" column in Table 1.

Tensile Testing

[0067] A round bar specimen having an outer diameter of 6.35 mm, and a parallel part length of 25.4 mm was taken from each of the steel plates 1 to 23 in the lengthwise direction and subjected to a tensile test at room temperature. The yield strengths (MPa) obtained by the tensile tests are given in the "YS" column in Table 1, the tensile strengths (MPa) are given in the "TS" column in Table 1, and the uniform elongations (%) are given in the "UE" column in Table 1. The 0.2% proof stress according to the ASTM standard was defined as the yield strength (YS). The distortion of a specimen at the maximum load point was defined as the uniform elongation (%).

Test Result

[0068] With reference to Table 1, the steel plates with test Nos. 1 to 11 each had a chemical composition, a metal structure and a yield strength within the ranges defined by the invention, and therefore their uniform elongations all exceeded 20%.

[0069] Meanwhile, the steel plates with test Nos. 12 to 20 were not made of duplex stainless steel and therefore their uniform elongations were not more than 20%.

[0070] The steel plate with test No. 21 is made of duplex stainless steel and has a chemical composition within the range defined by the invention, but its solution-treatment temperature was less than 1000°C. Therefore, the yield strength exceeded the upper limit by the invention and the uniform elongation was not more than 20%. It was probably because the solution-treatment temperature was low and therefore a σ phase was precipitated, which raised the yield strength.

[0071] Since the steel plate with test No. 22 exceeded 1200°C, the austenite ratio was less than 40% and the uniform elongation was not more than 20%. The steel plate with test No. 23 was not an as-solution-treated material, but subjected to cold working after the solution-treatment. Therefore, the yield strength exceeded the upper limit of the range defined by the invention and the uniform elongation was not more than 20%.

[0072] Although the embodiments of the present invention have been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only of how to carry out the invention and is not to be taken by way of limitation. The invention may be embodied in various modified forms without departing from the spirit and scope of the invention.

INDUSTRIAL APPLICABILITY

[0073] The oil country tubular good for expansion and duplex stainless steel according to the invention are applicable to an oil country tubular good and particularly applicable as an oil country tubular good for expansion in a well.

Claims

1. An oil country tubular good for expansion in a well formed of duplex stainless steel having a composition comprising, in percentage by mass, 0.005% to 0.03% C, 0.1% to 1.0% Si, 0.2% to 2.0% Mn, at most 0.04% P, at most 0.015% S, 18.0% to 27.0% Cr, 4.0% to 9.0% Ni, at most 0.040% Al, and 0.05% to 0.40% N, and the balance consisting of Fe and impurities, and a structure comprising an austenite ratio in the range from 40% to 90%,
said oil country tubular good having a yield strength from 276 MPa to 655 MPa, and a uniform elongation more than 20%.

2. The oil country tubular good for expansion according to claim 1, wherein said duplex stainless steel further contains at most 2.0% Cu.

3. The oil country tubular good for expansion according to claim 1 or 2, wherein said duplex stainless steel further contains one or more selected from the group consisting of at most 4.0% Mo and at most 5.0% W.

4. The oil country tubular good for expansion according to any one of claims 1 to 3, wherein said duplex stainless steel further contains one or more selected from the group consisting of at most 0.8% Ti, at most 1.5% V, and at most 1.5% Nb.

5. The oil country tubular good for expansion according to any one of claims 1 to 4, wherein said duplex stainless steel further contains one or more selected from the group consisting of at most 0.02% B, at most 0.02% Ca and at most 0.02% Mg.

6. Duplex stainless steel used for oil country tubular goods for expansion, comprising, in percentage by mass, 0.005% to 0.03% C, 0.1% to 1.0% Si, 0.2% to 2.0% Mn, at most 0.04% P, at most 0.015% S, 18.0% to 27.0% Cr, 4.0% to 9.0% Ni, at most 0.040% Al, and 0.05% to 0.40% N, and the balance consisting of Fe and impurities,
said duplex stainless steel comprising an austenite ratio from 40% to 90%, and having a yield strength from 276 MPa to 655 MPa and a uniform elongation more than 20%.

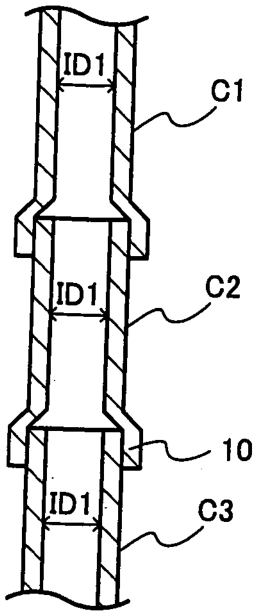
7. The duplex stainless steel according to claim 6, further comprising at most 2.0% Cu.

8. The duplex stainless steel according to claim 6 or 7, further comprising one or more selected from the group consisting of at most 4.0% Mo and at most 5.0% W.

9. The duplex stainless steel according to any one of claims 6 to 8, further comprising one or more selected from the group consisting of at most 0.8% Ti, at most 1.5% V, and at most 1.5% Nb.

10. The duplex stainless steel according to any one of claims 6 to 9, further comprising one or more selected from the group consisting of at most 0.02% B, at most 0.02% Ca, and at most 0.02% Mg.

FIG.1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/054747

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C22C38/58*(2006.01)i, *C21D8/10*(2006.01)n

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)
C22C38/00-38/60, C21D8/10

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 6-256843 A (NKK Corp.), 13 September, 1994 (13.09.94), Claims 1, 2; Par. Nos. [0002], [0029], [0030]; examples (Family: none)	1,6 2-5,7-10
Y	WO 2004/111285 A1 (Sumitomo Metal Industries, Ltd.), 23 December, 2004 (23.12.04), Page 9, line 14 to page 10, line 10 & US 2006/0193743 A1 & EP 1645649 A1 & CA 2528743 A1 & KR 2006/0018250 A & CN 1833043 A	2-5,7-10

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 May, 2008 (07.05.08)	20 May, 2008 (20.05.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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- WO 9800626 A **[0003]**
- JP 2005146414 A **[0006] [0006]**