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(54) **HIGH-STRENGTH ULTRA-THICK STEEL WITH EXCELLENT CRYOGENIC STRAIN AGING IMPACT TOUGHNESS AT CORE THEREOF, AND METHOD FOR MANUFACTURING SAME**

(57) An aspect of the present invention is to provide high-strength ultra-thick steel with excellent cryogenic strain aging impact toughness at the core thereof, and a method for manufacturing same. An embodiment of the present invention provides high-strength ultra-thick steel with excellent cryogenic strain aging impact toughness at the core thereof, and a method for manufacturing same, the steel comprising, by wt%, 0.02-0.06% of C,

1.8-2.2% of Mn, 0.7-1.1% of Ni, 0.2-0.5% of Mo, 0.005-0.03% of Nb, 0.005-0.018% of Ti, 80 ppm or less of P, 20 ppm or less of S, and the remainder of Fe and other evitable impurities, wherein the average grain size of grains having a high boundary angle of 15 degrees or greater is 15 μm or less as measured in a range of 3/8t-5/8t in the thickness (t) direction by EBSD.

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Description

Technical Field

- 5 **[0001]** The present disclosure relates to a high-strength ultra-thick steel material having excellent cryogenic strain aging impact toughness in a center zone thereof, and a method for manufacturing the same.

Background Art

- 10 **[0002]** Recently, the development of an ultra-thick high-strength steel material has been necessary in the design of structures such as domestic and foreign ships, and when high-strength steel material is used in designing structures, economic benefits due to reductions of weight of the form of the structure may be obtained, and also a thickness of a plate may be reduced, such that ease of processing and welding work may be secured simultaneously. Also, to improve a transport efficiency of ships, there have been attempts to operate a polar route, and in this case, it is expected that demand for a cryogenic toughness guaranteeing high-strength and ultra-thick material which may guarantee impact toughness at -60°C instead of general steel material guaranteeing impact toughness at -40°C could increase.

- 15 **[0003]** However, generally, in the case of high-strength steel material, since sufficient deformation may not occur in an overall structure due to a decrease in the total reduction ratio during the manufacture of a ultra-thick material, a structure may become coarse, and particularly, in the case of a center zone, a coarse austenite structure may be formed, such that hardenability may increase and it may be difficult to guarantee impact toughness of the center zone.

- 20 **[0004]** Also, when a ship is manufactured, as for a steel material, an original plate material form may not be used as is and the steel material may be processed in the form of a hull through deformation. When such deformation is applied to the steel material, impact toughness due to the deformation may degrade. Also, elements such as carbon and nitrogen may enter a dislocation created by the transformation over time after the transformation, and impact toughness may be further deteriorated due to the increase in strength. To guarantee this phenomenon, a strain aging impact test to measure impact toughness after heat treatment at 250°C for 1 hour after strain of 5% may be included in test items for a base material when after a steel material is developed and certified by each classification society. Therefore, in the case of ultra-thick and high-strength steel material for ships which may guarantee cryogenic toughness, basic impact toughness and also deformation aging impact properties may need to be guaranteed, but to guarantee deformation aging impact for even a center zone of an ultra-thick material, it may be necessary to remarkably improve a microstructure of the center zone, which may be problematic.

- 25 **[0005]** Accordingly, in a high-strength steel material of 500 MPa or more, it may be necessary to improve deformation aging impact toughness of a center zone by controlling impact toughness of 1/4t and 1/2t zone base material and also a microstructure of the center zone.

- 30 **[0006]**
- 35 Summary of Invention

Technical Problem

- 40 **[0006]** An aspect of the present disclosure is to provide a high-strength ultra-thick steel material with excellent cryogenic strain aging impact toughness in a center zone thereof, and a method for manufacturing the same.

Solution to Problem

- 45 **[0007]** An embodiment of the present disclosure provides a high-strength ultra-thick steel material having excellent cryogenic strain aging impact toughness in a center zone thereof including, by wt%, 0.02-0.06% of C, 1.8-2.2% of Mn, 0.7-1.1% of Ni, 0.2-0.5% of Mo, 0.005-0.03% of Nb, 0.005-0.018% of Ti, 80 ppm or less of P, 20 ppm or less of S, and a balance of Fe and inevitable impurities, wherein an average grain size of grains having a high boundary angle of 15 degrees or greater, measured by EBSD, is 15 μm or less in a 3/8t-5/8t zone in a thickness (t) direction.

- 50 **[0008]** Another embodiment of the present disclosure provides a method for manufacturing a high-strength ultra-thick steel material having excellent cryogenic strain aging impact toughness in a center zone thereof including reheating a steel slab including, by wt%, 0.02-0.06% of C, 1.8-2.2% of Mn, 0.7-1.1% of Ni, 0.2-0.5% of Mo, 0.005-0.03% of Nb, 0.005-0.018% of Ti, 80 ppm or less of P, 20 ppm or less of S, and a balance of Fe and inevitable impurities to a temperature of 1000-1080°C; obtaining a bar by rough-rolling the reheated steel slab at a temperature of 850-1050°C; obtaining a hot-rolled steel material by finish-rolling the bar at a temperature of 700-800°C at a total reduction ratio of more than 60%; and cooling the hot-rolled steel material to a temperature of 500°C or less at a cooling rate of 3°C/s or more.
- 55

Advantageous Effects of Invention

[0009] According to an aspect of the present disclosure, high-strength ultra-thick steel material with excellent cryogenic strain aging impact toughness in a center zone thereof which may have yield strength of 500 MPa or more and a transition temperature of -60°C or less during a strain aging impact test for a center zone of a thickness, and a method for manufacturing the same.

Best Mode for Invention

[0010] Hereinafter, an embodiment of steel material of the present disclosure will be described. First, an alloy composition of the present disclosure will be described. The unit of alloy composition described below may be weight % unless otherwise indicated.

C: 0.02-0.06%

[0011] C may be the most important element for securing basic strength in the present disclosure, and accordingly, C may need to be included in steel within an appropriate range. However, when the content of C exceeds 0.06%, a large amount of C may be fixed to dislocation during a strain aging impact test and strength may increase, such that strain aging impact toughness may decrease, and when the content is less than 0.02%, strength may decrease. Thus, the content of C may be preferably in the range of 0.02-0.06%. A lower limit of C may be more preferably 0.024%, even more preferably 0.028%, and most preferably 0.3%. An upper limit of C may be more preferably 0.058%, even more preferably 0.054%, and most preferably 0.05%.

Mn: 1.8-2.2%

[0012] Mn may be a useful element for improving strength through solid solution strengthening and hardenability improvement, and accordingly, 1.8% or more of Mn may need to be added to satisfy yield strength of 500 MPa or more to be obtained in the present disclosure. However, when the content exceeds 2.2%, hardenability may excessively increase such that the formation of coarse upper bainite and martensite may be facilitated such that strain aging impact toughness of a center zone may greatly degrade. Thus, the Mn content may be in the range of 1.8-2.2% preferably. A lower limit of Mn may be more preferably 1.83%, even more preferably 1.86%, and most preferably 1.9%. An upper limit of Mn may be more preferably 2.17%, even more preferably 2.14%, and most preferably 2.1%.

Ni: 0.7-1.1%

[0013] Ni may facilitate cross slip of dislocation and may improve impact toughness and hardenability, and accordingly, Ni may be an important element to improve strength. To improve strain aging impact toughness of the center zone in high-strength steel having yield strength of 500 MPa or more, Ni may be added by 0.7% or more. However, when the content exceeds 1.1%, hardenability may excessively increase, and a large amount of low-temperature transformation phase may be formed, such that toughness may decrease, and manufacturing costs may increase, which may be problematic. Accordingly, the Ni content may be preferably in the range of 0.7-1.1%. The Mn content may be preferably in the range of 1.8-2.2%. A lower limit of Ni may be more preferably 0.73%, even more preferably 0.76%, and most preferably 0.8%. An upper limit of Ni may be more preferably 1.07%, even more preferably 1.03%, and most preferably 1%.

Mo: 0.2-0.5%

[0014] Mo may be an important element for improving strength by improving hardenability, and may be an alloying element having less reduction in toughness as compared to strength improvement, preferably, 0.2% or more of Mo may be added to secure high-strength steel having yield strength of 500 MPa or more. However, when the content exceeds 0.5%, hardenability may excessively increase, and a large amount of low-temperature transformation phase may be formed, such that toughness may decrease. Therefore, the Mo content may be preferably in the range of 0.2-0.5%. A lower limit of Mo may be more preferably 0.23%, even more preferably 0.26%, and most preferably 0.3%. An upper limit of Mo may be more preferably 0.48%, even more preferably 0.44%, and most preferably 0.4%.

Nb: 0.005-0.03%

[0015] Nb may be precipitated in the form of NbC or NbCN and may improve strength of a base material. Also, Nb dissolved during reheating to a high temperature may be very finely precipitated in the form of NbC during rolling, may

prevent recrystallization of austenite, and may refine the structure. To obtain the above effect, Nb may be added 0.005% or more preferably. However, when Nb exceeds 0.03%, brittle cracks may be created in corners of the steel material, and there may be problems of deterioration of toughness due to formation of excessive precipitate and formation of a large amount of martensite. Therefore, the Nb content may be preferably in the range of 0.005-0.03%. A lower limit of Nb may be more preferably 0.008%, even more preferably 0.011%, and most preferably 0.015%. An upper limit of Nb may be more preferably 0.028%, even more preferably 0.026%, and most preferably 0.025%.

Ti: 0.005-0.018%

[0016] Ti may be precipitated as TiN during reheating and may prevent growth of grains in a base material and a welding heat-affected zone such that low-temperature toughness may greatly improve, and Ti may be added by 0.005% or more to effectively precipitate TiN. However, when the content exceeds 0.018%, coarse TiN crystallization may occur such that low-temperature toughness may degrade, which may be problematic. Accordingly, the Ti content may be preferably in the range of 0.005-0.018%. A lower limit of Ti may be more preferably 0.006%, even more preferably 0.008%, and most preferably 0.01%. An upper limit of Ti may be more preferably 0.017%, even more preferably 0.016%, and most preferably 0.015%.

P: 80ppm or less

[0017] P may be an element which may cause brittleness at grain boundaries or may form coarse inclusions, which may lead to brittleness, and to improve brittle crack propagation resistance, the content thereof may be preferably limited to 80 ppm or less.

S: 20ppm or less

[0018] S may be an element which may cause brittleness at grain boundaries or may form coarse inclusions, which may lead to brittleness. To improve brittle crack propagation resistance, the content thereof may be preferably limited to 20 ppm or less.

[0019] A remainder of the present disclosure may be iron (Fe). However, in a general manufacturing process, inevitable impurities may be inevitably added from raw materials or an ambient environment, and thus, impurities may not be excluded. A person skilled in the art of a general manufacturing process may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure.

[0020] In the steel material of the present disclosure, an average grain size of grains having a high boundary angle of 15 degrees or more, measured by EBSD, in the 3/8t-5/8t zone in a thickness (t) direction may be 15 μm or less, preferably. When the average grain size of grains having a high boundary angle of 15 degrees or more, measured by EBSD, in the 3/8t-5/8t zone in the thickness (t) direction exceeds 15 μm , an effective grain size due to grain size coarsening may increase, such that an impact transition temperature may increase, and deformation aging impact toughness may degrade, which may be problematic.

[0021] Meanwhile, a microstructure of the steel material of the present disclosure may be a mixed structure including acicular ferrite, granular bainite, upper bainite.

[0022] The steel material of the present disclosure may have a thickness of 5-90mm.

[0023] The steel material of the present disclosure provided as described above may have yield strength of 500 MPa or more. Also, after 5% of strain and performing heat treatment at 250°C for 1 hour, a transition temperature may be -60°C or less in the strain aging impact test.

[0024] Hereinafter, a method for manufacturing a steel material according to an embodiment of the present disclosure will be described.

[0025] First, a steel slab may be reheated to a temperature of 1000-1080°C. In the reheating of the steel material of the present disclosure, the heating temperature may be preferably 1000°C or higher so as to allow carbonitride of Ti and/or Nb formed during casting to be solid solute. Also, to sufficiently allow carbonitride of Ti and/or Nb to be solid solute, the heating may be performed to 1030°C or higher. However, when the reheating is performed to an excessively high temperature, austenite in the center zone may be coarsened, and thus, the reheating temperature may be preferably 1080 °C or less, and more preferably 1070°C or less.

[0026] The reheated steel slab may be rough-rolled at a temperature of 850-1050°C, thereby obtaining a bar. Rough-rolling may be performed to the reheated slab as above to adjust the shape thereof. Through the rough-rolling, destruction of a cast structure such as dendrites formed during casting and also the effect of reducing the grain size through the recrystallization of coarse austenite may be obtained. Meanwhile, to refine the structure by sufficient recrystallization, a total reduction ratio during rough-rolling may be 40% or more preferably.

[0027] The bar may be finish-rolled at a temperature of 700-800°C at a total reduction of more than 60%, thereby

obtaining a hot-rolled steel material. In the present disclosure, finish-rolling may be performed to pancake an austenite structure of the bar and to obtain dislocation. The finish-rolling may be preferably performed at a temperature of 700-800°C such that the deformation applied to the center zone may be maintained as much as possible. When the finish-rolling temperature is less than 700°C, ferrite may be precipitated during deformation and both strength and toughness may be reduced, which may be disadvantageous. When the temperature exceeds 800°C, the particle size may increase, such that impact toughness may deteriorate and sufficient strength may not be secured, which may be disadvantageous. A lower limit of the finish-rolling temperature may be more preferably 720°C, even more preferably 740°C. An upper limit of the finish-rolling temperature may be more preferably 780°C, even more preferably 760°C. In the present disclosure, to refine the particle size of the center zone during the finish-rolling, a total reduction ratio of more than 60% may be applied preferably. The total reduction ratio during the finish-rolling may be more preferably 61% or more, and even more preferably 62%.

[0028] The hot-rolled steel material may be cooled to a temperature of 500°C or less at a cooling rate of 3°C/s or more. When the cooling rate is lower than 3°C/s or the cooling stop temperature is more than 500°C, fine grains may not be properly formed in the present disclosure, such that it may be likely that yield strength may be 500 MPa or less.

Mode for Invention

[0029] Hereinafter, the present disclosure will be described in greater detail through examples. However, it is necessary to note that the following examples are only for describing the present disclosure by examples and not for limiting the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

(Example)

[0030] A steel slab having a thickness of 400mm and an alloy composition listed in Table 1 below was prepared, was reheated to a temperature of 1040-1070°C, was rough-rolled in a temperature range of 930-1020°C, thereby obtaining a bar. The bar was finish-rolled under the conditions listed in Table 2 and a hot-rolled steel material was obtained, and the steel material was cooled to a temperature of 491-342°C at a cooling rate of 3.8-5.4°C/sec. A thickness, an average grain size of grains having a high boundary angle of 15 degrees or more, measured by EBSD, in the 3/8t-5/8t zone in a thickness (t) direction, yield strength, and a strain aging impact transition temperature of the center zone (3/8t-5/8t) were measured and listed in Table 3.

[0031] In this case, the center zone strain aging impact test was carried by taking a sample from the center zone of the steel material, performing a heat treatment at 250°C for 1 hour after 5% of deformation, performing an impact test, and measuring a transition temperature.

[Table 1]

Steel type	Alloy composition (weight%)							
	C	Mn	Ni	Mo	Nb	Ti	P(ppm)	S(ppm)
Inventive steel 1	0.043	1.96	1.05	0.32	0.023	0.017	39	9
Inventive steel 2	0.038	2.06	0.87	0.31	0.016	0.009	44	8
Inventive steel 3	0.046	1.99	0.79	0.28	0.015	0.013	51	10
Inventive steel 4	0.031	2.13	1.07	0.43	0.011	0.012	37	7
Inventive steel 5	0.052	1.86	0.94	0.39	0.021	0.011	62	13
Comparative steel 1	0.083	2.07	0.86	0.35	0.018	0.013	57	15
Comparative steel 2	0.044	2.49	1.06	0.41	0.019	0.011	48	9
Comparative steel 3	0.016	1.67	0.93	0.39	0.015	0.012	46	13
Comparative steel 4	0.042	1.97	0.59	0.36	0.023	0.017	51	11
Comparative steel 5	0.051	2.03	0.94	0.67	0.019	0.013	38	14
Comparative steel 6	0.039	1.96	0.89	0.33	0.046	0.032	38	14

[Table 2]

Classification	Steel type	Reheating temperature (°C)	Rough-Rolling		Finish-Rolling		Cooling	
			Finish temperature (°C)		Total reduction ratio (%)		Rate (°C/s)	Stop temperature (°C)
Inventive example 1	Inventive steel 1	1065	953		735		3.7	435
Inventive example 2	Inventive steel 2	1072	975		725		4.6	488
Inventive example 3	Inventive steel 3	1054	892		713		5.7	307
Inventive example 4	Inventive steel 4	1049	888		749		7.9	205
Inventive example 5	Inventive steel 5	1079	915		755		4.4	416
Comparative example 1	Inventive steel 2	1026	865		769		5.1	395
Comparative example 2	Inventive steel 3	1043	903		711		4.7	407
Comparative example 3	Comparative steel 1	1055	930		736		5.3	453
Comparative example 4	Comparative steel 2	1067	972		744		7.1	356
Comparative example 5	Comparative steel 3	1037	901		784		12.3	415
Comparative example 6	Comparative steel 4	1012	859		723		3.8	467
Comparative example 7	Comparative steel 5	1059	938		733		6.5	459
Comparative example 8	Comparative steel 6	1038	896		741		5.0	437

[0032]

[Table 3]

Classification	Thickness (mm)	Average grain size (μm) in 3/8t-5/8t zone	Yield strength (MPa)	Deformation aging impact transition temperature of center zone ($^{\circ}\text{C}$)
Inventive example 1	85	13.3	529	-71
Inventive example 2	80	14.3	564	-65
Inventive example 3	90	12.1	542	-7
Inventive example 4	85	12.8	572	-73
Inventive example 5	80	14.5	523	-64
Comparative example 1	80	21.2	559	-49
Comparative example 2	85	18.9	556	-51
Comparative example 3	85	13.9	635	-36
Comparative example 4	90	18.2	693	-31
Comparative example 5	80	13.5	449	-62
Comparative example 6	80	14.3	508	-44
Comparative example 7	85	18.7	669	-38
Comparative example 8	80	13.8	609	-37

[0033] In the case of Inventive Examples 1 to 5 satisfying the alloy composition and manufacturing conditions suggested in the present disclosure, the average grain size of grains of the 3/8t-5/8t zone was 15 μm or less, and accordingly, yield strength was 500 MPa or more, and the strain aging impact transition temperature was -60°C or less.

[0034] In the case of Comparative Examples 1 and 2, the alloy composition suggested in the present disclosure was satisfied, but the total reduction ratio during finish-rolling was low, such that sufficient deformation was not applied to the center zone, and acicular ferrite which may greatly affect grain size refinement was not sufficiently formed, and a large amount of coarse bainite was formed. Accordingly, it is indicated that the grain size as coarsened, the average grain size of grains of the 3/8t-5/8t zone exceeded 15 μm , and the strain aging impact transition temperature of the center zone exceeded -60°C .

[0035] In the case of Comparative Example 3, by having a value higher than an upper limit of C suggested in the present disclosure, a large amount of coarse bainite phase was formed due to high hardenability, such that very high yield strength was exhibited, and although the average grain size of grains of the 3/8t-5/8t zone was 15 μm or less, a large amount of C was fixed to the dislocation during the strain aging impact test, such that the strain aging impact transition temperature exceeded -60°C .

[0036] In the case of Comparative Example 4, by having a value higher than an upper limit of Mn suggested in the present disclosure, a large amount of coarse bainite phase was formed due to high hardenability, such that very high yield strength was exhibited, but the average grain size of grains of the 3/8t-5/8t zone exceeded 15 μm , and the strain aging impact transition temperature exceeded -60°C .

[0037] In the case of Comparative Example 5, by having a value lower than A lower limit of C and Mn suggested in

the present disclosure, a large amount of soft phase such as polygonal ferrite was formed in the center zone, and accordingly, yield strength was lower than 500Mpa.

[0038] In the case of Comparative Example 6, by having a value lower than an upper limit of Ni suggested in the present disclosure, although the average grain size of grains of the 3/8t-5/8t zone was 15 μm or less, strain aging impact transition temperature exceeded -60°C due to a decrease in toughness due to the low Ni content.

[0039] In the case of Comparative Example 7, by having a higher value than an upper limit of Mo suggested in the present disclosure, a large amount of coarse bainite phase was formed due to high hardenability, such that very high yield strength was exhibited, but the average grain size of grains of the 3/8t-5/8t exceeded 15 μm , and the strain aging impact transition temperature exceeded -60°C .

[0040] In the case of Comparative Example 8, by having a value higher than an upper limit of Ti and Nb suggested in the present disclosure, strength increased due to excessive hardenability and the formation of precipitate, and the strain aging impact transition temperature exceeded -60°C due to the decrease in toughness caused by precipitation strengthening.

Claims

1. A high-strength ultra-thick steel material having excellent cryogenic strain aging impact toughness in a center zone thereof, the steel material comprising:

by wt%, 0.02-0.06% of C, 1.8-2.2% of Mn, 0.7-1.1% of Ni, 0.2-0.5% of Mo, 0.005-0.03% of Nb, 0.005-0.018% of Ti, 80 ppm or less of P, 20 ppm or less of S, and a balance of Fe and inevitable impurities, wherein an average grain size of grains having a high boundary angle of 15 degrees or greater, measured by EBSD, is 15 μm or less in a 3/8t-5/8t zone in a thickness (t) direction.

2. The steel material of claim 1, wherein the steel material has a microstructure including acicular ferrite, granular bainite, and upper bainite.

3. The steel material of claim 1, wherein the steel material has a thickness of 5-90mm.

4. The steel material of claim 1, wherein the steel material has yield strength of 500 MPa or more.

5. The steel material of claim 1, wherein, after a heat treatment is performed on the steel material at 250°C for 1 hour after deformation of 5%, a transition temperature is -60°C or less in a strain aging impact test.

6. A method for manufacturing a high-strength ultra-thick steel material having excellent cryogenic strain aging impact toughness in a center zone thereof, the method comprising:

reheating a steel slab including, by wt%, 0.02-0.06% of C, 1.8-2.2% of Mn, 0.7-1.1% of Ni, 0.2-0.5% of Mo, 0.005-0.03% of Nb, 0.005-0.018% of Ti, 80 ppm or less of P, 20 ppm or less of S, and a balance of Fe and inevitable impurities to a temperature of $1000-1080^{\circ}\text{C}$;

obtaining a bar by rough-rolling the reheated steel slab at a temperature of $850-1050^{\circ}\text{C}$;

obtaining a hot-rolled steel material by finish-rolling the bar at a temperature of $700-800^{\circ}\text{C}$ at a total reduction ratio of more than 60%; and

cooling the hot-rolled steel material to a temperature of 500°C or less at a cooling rate of 3°C/s or more.

7. The method of claim 6, wherein a total reduction ratio during the rough-rolling is 40% or more.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2020/013062

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; C22C 38/08(2006.01)i; C22C 38/14(2006.01)i; C21D 8/02(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)

C22C 38/04(2006.01); B21B 3/00(2006.01); B21B 3/02(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01)

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

Korean utility models and applications for utility models: IPC as above

Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 후방산란전자회절패턴분석(EBSD), 페라이트(ferrite), 베이나이트(bainite), 냉각(cooling), 압연(rolling), 충격인성(impact toughness)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2014-0023787 A (POSTECH RESEARCH AND BUSINESS DEVELOPMENT FOUNDATION) 27 February 2014 (2014-02-27) See paragraphs [0055]-[0066], claims 1, 3, 5 and 11 and tables 2-3.	1-7
Y	KR 10-2009-0070484 A (POSCO) 01 July 2009 (2009-07-01) See paragraph [0109] and claim 3.	1-7
A	JP 06-004903 B2 (NIPPON STEEL CORP.) 19 January 1994 (1994-01-19) See claims 1 and 5.	1-7
A	KR 10-2014-0098900 A (HYUNDAI STEEL COMPANY) 11 August 2014 (2014-08-11) See claims 1-5.	1-7
A	JP 2006-257499 A (SUMITOMO METAL IND., LTD.) 28 September 2006 (2006-09-28) See paragraphs [0093]-[0100] and claim 1.	1-7

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

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