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(54) NON-ORIENTED ELECTROMAGNETIC STEEL SHEET

(57) A non-oriented electrical steel sheet contains: C: not less than 0.003 mass% nor more than 0.05 mass%; N: not less than 0.001 mass% nor more than 0.01 mass%; and Si: not less than 2.8 mass% nor more than 3.5 mass%. The non-oriented electrical steel sheet further contains at least one kind selected from a group consisting of Ni: 4.0 mass% or less and Mn: 2.0 mass% or less, in a total amount of 0.5 mass% or more, and further contains Ti, a value R_{Ti} being not less than 1 nor more than 10, the value R_{Ti} being expressed by [Ti]/(4x([C]+[N])) when a Ti content is expressed as [Ti] mass%, a C content is expressed as [C] mass%, and an N content is expressed as [N] mass%. An Al content is 3.0 mass% or less, and a P content is 0.2 mass% or less.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a non-oriented electrical steel sheet suitable for a rotor of a high-speed rotary machine.

BACKGROUND ART

[0002] A non-oriented electrical steel sheet is used for a rotor of a rotary machine or the like, for example. In general, centrifugal force acting on the rotor is in proportion to a rotation radius, and is in proportion to the square of a rotation speed. For the above reason, extremely large stress acts on the rotor of the high-speed rotary machine. Thus, tensile strength of the non-oriented electrical steel sheet for a rotor is preferably high. That is, the non-oriented electrical steel sheet for a rotor preferably has high tension. As described above, high tensile strength (high tension) is required for the non-oriented electrical steel sheet for a rotor.

[0003] On the other hand, in a non-oriented electrical steel sheet used for not only a rotor of a rotary machine but also an iron core, it is important that its core loss is low. Particularly, in the non-oriented electrical steel sheet for a rotor of a high-speed rotary machine, it is important that its high-frequency core loss is low. As described above, a low high-frequency core loss is also required for the non-oriented electrical steel sheet for a rotor. That is, high efficiency when the rotary machine is used at a high frequency is also required.

[0004] However, the high tension and the low high-frequency core loss are in a relationship such that they are contrary to each other physically, and it is extremely difficult to achieve both of them.

[0005] There has been proposed a technique in which the achievement of these is considered, but there has been no technique capable of easily manufacturing a non-oriented electrical steel sheet so far. For example, there has been proposed a technique in which a hot-rolled steel sheet having a high Si content is obtained and thereafter various types of temperature controls are performed, but cold rolling is extremely difficult to be performed because the Si content is high. Further, various types of temperature controls are performed in order to enable cold rolling to be performed, but the above temperature controls are extremely peculiar, resulting that time, labor, and cost required for the above are increased.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Document 1: Japanese Laid-open Patent Publication No. Sho 60-238421
Patent Document 2: Japanese Laid-open Patent Publication No. Sho 61-9520
Patent Document 3: Japanese Laid-open Patent Publication No. Sho 62-256917
Patent Document 4: Japanese Laid-open Patent Publication No. Hei 2-8346
Patent Document 5: Japanese Laid-open Patent Publication No. 2007-186791
Patent Document 6: Japanese Laid-open Patent Publication No. 2007-186790
Patent Document 7: Japanese Laid-open Patent Publication No. 2008-240104

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0007] The present invention has an object to provide a non-oriented electrical steel sheet capable of being manufactured easily and obtaining high tensile strength and a low high-frequency core loss.

SOLUTION TO PROBLEM

[0008] The present inventors have conducted earnest studies on a non-oriented electrical steel sheet from the viewpoint of obtaining favorable mechanical properties while suppressing a core loss low by solid solution strengthening, precipitation strengthening, work strengthening, grain refining strengthening, strengthening by transformation composition, and so on. Further, the present inventors have repeated researches and analyses with regard to what index a high-frequency core loss to be important in an actual high-speed rotary machine becomes, in other words, with regard to at what frequency a core loss is important to be reduced. Further, greater importance is also given to easiness of processes such as cold rolling in a manufacturing process and avoidance of process complication.

[0009] As a result, details will be described later, but it has been found that contents of Si, Mn, Ni, and so on are set appropriately and a ratio of a content of Ti to a total content of C and N is set appropriately, thereby enabling a high-frequency core loss to be suppressed low while obtaining high tensile strength of, for example, 900 MPa or more. Further, as the high-frequency core loss, it has also been found that it is important that a core loss $W_{10/1000}$, which is a core loss in the case of a magnetic flux density being 1.0 T and an excitation frequency being 1000 Hz, is low. Then, the present inventors have reached the following non-oriented electrical steel sheet.

[0010] A non-oriented electrical steel sheet according to the present invention contains: C: not less than 0.003 mass% nor more than 0.05 mass%; N: not less than 0.001 mass% nor more than 0.01 mass%; and Si: not less than 2.8 mass% nor more than 3.5 mass%. The non-oriented electrical steel sheet further contains at least one kind selected from a group consisting of Ni: 4.0 mass% or less and Mn: 2.0 mass% or less, in a total amount of 0.5 mass% or more, and further contains Ti, a value R_{Ti} being not less than 1 nor more than 10, the value R_{Ti} being expressed by [Ti]/(4x([C]+[N])) when a Ti content is expressed as [Ti] mass%, a C content is expressed as [C] mass%, and an N content is expressed as [N] mass%. An Al content is 3.0 mass% or less, a P content is 0.2 mass% or less, and a balance is composed of Fe and inevitable impurities.

ADVANTAGEOUS EFFECTS OF INVENTION

[0011] According to the present invention, contents of Si, Mn, Ni, and so on and a value R_{Ti} are appropriate, and thus high tensile strength and a low high-frequency core loss can be obtained. Further, the contents of Si and so on are appropriate, and thus processes in a manufacturing process are easy to be performed, and addition of complex processes based on embrittlement and the like can also be avoided.

DESCRIPTION OF EMBODIMENTS

[0012] Hereinafter, the present invention will be explained in detail. First, components of a non-oriented electrical steel sheet according to the present invention will be explained.

[0013] Si has an effect of reducing a core loss such as a high-frequency core loss by increasing electrical resistance of the non-oriented electrical steel sheet to thereby reduce an eddy current loss. Further, Si has an effect of increasing tension of the non-oriented electrical steel sheet by solid solution strengthening. When a Si content is less than 2.8 mass%, these effects is insufficient. On the other hand, when the Si content exceeds 3.5 mass%, a reduction in a magnetic flux density, embrittlement, difficulty in performing processes of cold rolling and the like, and an increase in a material cost are caused. Thus, the Si content is set to not less than 2.8 mass% nor more than 3.5 mass%.

[0014] Al, similarly to Si, has an effect of reducing a core loss such as a high-frequency core loss by increasing the electrical resistance of the non-oriented electrical steel sheet to thereby reduce an eddy current loss. Thus, Al may also be contained as an aim to further reduce a high-frequency core loss. However, when an Al content exceeds 3.0 mass%, a reduction in a magnetic flux density, embrittlement, difficulty in performing processes of cold rolling and the like, and an increase in a material cost are caused. Thus, an upper limit of the Al content is set to 3.0 mass%. Further, when the Al content is less than 0.1 mass%, fine precipitation of A1N is remarkably exhibited to increase a core loss, and thus the Al content is preferably 0.1 mass% or more.

[0015] Ni and Mn contribute to an improvement in tension of the non-oriented electrical steel sheet. That is, Ni has an effect of increasing the tension by solid solution strengthening, and Mn has an effect of increasing the tension by solid solution strengthening and grain refining strengthening. Further, Ni also has an effect of reducing a core loss such as a high-frequency core loss by increasing the electrical resistance of the non-oriented electrical steel sheet to thereby reduce an eddy current loss. Further, Ni also contributes to an improvement in a magnetic flux density in accordance with an increase in a saturated magnetic moment of the non-oriented electrical steel sheet. Mn has an effect of reducing a core loss such as a high-frequency core loss by increasing the electrical resistance of the non-oriented electrical steel sheet to thereby reduce an eddy current loss. When a total amount of a Ni content and a Mn content is less than 0.5 mass%, these effects are insufficient, resulting that tensile strength of 900 MPa or more cannot be obtained. On the other hand, when the Ni content exceeds 4.0 mass%, a reduction in a magnetic flux density ascribable to the reduction in a saturated magnetic moment occurs. Further, when the Mn content exceeds 2.0 mass%, a magnetic flux density is reduced and further a material cost is increased. Thus, it is set in a manner that Ni of 4.0 mass% or less and/or Mn of 2.0 mass% or less are/is contained in a total amount of 0.5 mass% or more.

[0016] P has an effect of greatly increasing the tension of the non-oriented electrical steel sheet. Thus, P may also be contained as an aim to further improve the tension. In order to achieve the above effect, 0.001 mass% or more of P is preferably contained. However, when P content exceeds 0.2 mass%, P segregates in crystal grain boundaries in a manufacturing process to embrittle a hot-rolled steel sheet, resulting that cold rolling thereafter becomes extremely difficult to be performed. Thus, an upper limit of the P content is set to 0.2 mass%.

[0017] Ti has an effect of reacting with C and N to form a fine precipitate containing Ti carbonitride and increasing the tension of the non-oriented electrical steel sheet by precipitation strengthening and grain refining strengthening. Further, ' Ti being solid-dissolved in the non-oriented electrical steel sheet has an effect of orienting crystal orientations of a surface of the non-oriented electrical steel sheet in {111} when cold rolling, finish annealing, and the like, and increasing the tension of the non-oriented electrical steel sheet. In order to exhibit these effects sufficiently, it is important that appropriate amounts of both Ti to be precipitated as Ti carbonitride and Ti being solid-dissolved in the non-oriented electrical steel sheet are contained.

[0018] When a Ti content is expressed as [Ti] mass%, a C content is expressed as [C] mass%, and an N content is expressed as [N] mass%, if a value R_{Ti} expressed by [Ti]/(4x([C]+[N])) is less than 1, the above-described effects cannot be exhibited sufficiently. Thus, the value R_{Ti} is set to 1 or more. In the case of the value R_{Ti} being 1, all Ti is bonded to C and/or N theoretically, but practically, part of Ti is not bonded to either C or N to be contained in the non-oriented electrical steel sheet as solid solution Ti. Note that the value R_{Ti} is preferably 2 or more, and more preferably 3 or more.

[0019] On the other hand, when the value R_{Ti} exceeds 10, recrystallization is unlikely to occur and further embrittlement is likely to occur. Further, there is sometimes a case that in accordance with an increase in the solid solution Ti, the orientation to {111} is too intensified to increase a core loss. Thus, the value R_{Ti} is set to 10 or less. Incidentally, the value R_{Ti} is preferably 9 or less, and more preferably 7 or less.

[0020] Further, in order to make the value R_{Ti} fall within a range as above, it is set in a manner that the C content is not less than 0.003 mass% nor more than 0.05 mass% and the N content is not less than 0.001 mass% nor more than 0.01 mass%. Incidentally, in the case when the C content exceeds 0.05 mass%, or the N content exceeds 0.01 mass%, core loss properties are remarkably reduced due to magnetic aging or the like.

[0021] Further, in order to make the value R_{Ti} fall within the above-described range, the Ti content is preferably not less than 0.1 mass% nor more than 0.3 mass%, and an upper limit of the Ti content is more preferably 0.25 mass%.

[0022] Note that as metallic elements to form carbonitride in the non-oriented electrical steel sheet, Zr, V, Nb, and Mo are also cited besides Ti. Among them, precipitation strengthening by Ti carbonitride is remarkable.

[0023] The components of the non-oriented electrical steel sheet except the above-described components are Fe and inevitable impurities, for example. Note that as an aim to avoid embrittlement of the crystal grain boundaries with the increase in tension, B may also be contained. In the above case, a B content is preferably 0.001 mass% or more. On the other hand, when the B content exceeds 0.007 mass%, a reduction in a magnetic flux density, embrittlement at the time of hot rolling, and the like are caused. Thus, the B content is preferably 0.007 mass% or less.

[0024] Further, as an aim to further improve various types of magnetic properties, Cu: not less than 0.02 mass% nor more than 1.0 mass%, Sn: not less than 0.02 mass% nor more than 0.5 mass%, Sb: not less than 0.02 mass% nor more than 0.5 mass%, Cr: not less than 0.02 mass% nor more than 3.0 mass%, and/or rare earth metal (REM: rare earth metal): not less than 0.001 mass% nor more than 0.01 mass% may also be contained. That is, one kind or more of the element (elements) selected from a group consisting of these plural kinds of elements may also be contained.

[0025] Then, the tensile strength of the non-oriented electrical steel sheet composed of these components becomes, for example, 900 MPa or more. Therefore, a rotor of a high-speed rotary machine manufactured by using the above non-oriented electrical steel sheet can achieve sufficient high-speed rotation.

[0026] Further, a high-frequency core loss $W_{10/1000}$ of the non-oriented electrical steel sheet composed of these components becomes, for example, 100 W/kg or less. Therefore, a rotor of a high-speed rotary machine manufactured by using the above non-oriented electrical steel sheet can contribute to high-efficiency and miniaturization of the rotary machine. That is, energy loss caused by converting from electric energy into mechanical energy and heat generation incidental to the conversion can be suppressed. Then, in order to reduce an eddy current loss to thereby make the high-frequency core loss $W_{10/1000}$ become 100 W/kg or less, a thickness of the non-oriented electrical steel sheet is preferably 0.30 mm or less.

[0027] The present inventors confirmed these effects by the following experiments. First, a slab containing C: 0.017 mass%, Si: 3.12 mass%, Al: 0.65 mass%, Ni: 2.54 mass%, P: 0.02 mass%, N: 0.003 mass%, and Ti: 0.18 mass% was hot-rolled, and a hot-rolled steel sheet was obtained. The value R_{Ti} of the above hot-rolled steel sheet is 2.3. Next, the hot-rolled steel sheet was cold-rolled to have four types of thicknesses shown in Table 1, and a cold-rolled steel sheet was obtained. Thereafter, continuous finish annealing at 780°C for 20 seconds was applied to the cold-rolled steel sheet, and a non-oriented electrical steel sheet was obtained. Then, Epstein samples and tensile test pieces were cut out from the non-oriented electrical steel sheet, and magnetic properties and mechanical properties were measured by using them. Results thereof are also shown in Table 1. In Tables as below, "$W_{15/50}$" represents a core loss $W_{15/50}$, "B50" represents a magnetic flux density B50, and "$W_{10/1000}$" represents the core loss $W_{10/1000}$. Further, "YP" represents a yield point, "TS" represents the tensile strength, and "EL" represents elongation.

[0028] [Table 1]

[Table 1]

Sample No.	Thickness (mm)	Magnetic properties			Mechanical properties		
		$W_{15/50}$ (W/kg)	B50 (T)	$W_{10/1000}$ (W/kg)	YP (MPa)	TS (MPa)	EL (%)
1	0.50	9.6	1.58	155	870	921	15
2	0.35	9.0	1.57	112	875	928	16
3	0.20	8.6	1.56	87	876	930	18
4	0.15	8.4	1.56	80	881	935	18

[0029] As shown in Table 1, although in Samples No. 1 and No. 2, the tensile strength of 900 MPa or more was obtained and Samples No. 1 and No. 2 had the high tension, the high-frequency core loss $W_{10/1000}$ exceeded 100 W/kg. This is because the thicknesses of the non-oriented electrical steel sheet exceed 0.03 mm.

[0030] For the above reason as well, the thickness of the non-oriented electrical steel sheet is preferably 0.30 mm or less.

[0031] Incidentally, the non-oriented electrical steel sheet according to the present invention can be manufactured in the following manner, for example. First, a slab having the above-described composition is melted, and the above slab is heated and hot rolled to obtain a hot-rolled steel sheet. Next, the above hot-rolled steel sheet is cold rolled to obtain a cold-rolled steel sheet. Thereafter, finish annealing is performed. Incidentally, in order to avoid a reduction in strength and embrittlement accompanying growth of crystal grains, hot-rolled sheet annealing is preferably not performed, and intermediate annealing during cold rolling is also preferably not performed. As long as the hot-rolled steel sheet having the above-described composition is used, the effects of the improvement in tension and the reduction in a high-frequency core loss can be obtained without performing hot-rolled sheet annealing and intermediate annealing. Further, hot-rolled sheet annealing is omitted, thereby also enabling bending workability to be improved. That is, since the non-oriented electrical steel sheet according to the present invention has the above-described composition, the improvement in tension and the reduction in a high-frequency core loss can be achieved by the relatively simple processes.

EXAMPLE

(First Experiment)

[0032] First, slabs containing components shown in Table 2 and a balance being composed of Fe and inevitable impurities were hot rolled to obtain hot-rolled steel sheets. Next, the hot-rolled steel sheets were cold rolled to obtain cold-rolled steel sheets having thicknesses of 0.20 mm. Thereafter, continuous finish annealing at 750°C for 30 seconds was applied to the cold-rolled steel sheets to obtain non-oriented electrical steel sheets.

[0033] [Table 2]

[Table 2]

Sample No.		Components								R_{Ti}
		C	Si	Al	Ni	Mn	P	N	Ti	
Comparative examples	11	0.0059	3.02	0.73	2.01	1.02	0.04	0.0030	0.000	0.00
	12	0.0067	3.07	0.77	2.16	1.11	0.03	0.0027	0.023	0.61
Examples	13	0.0046	3.01	0.70	2.12	0.95	0.03	0.0029	0.257	8.57
	14	0.0055	3.04	0.73	2.04	1.01	0.04	0.0026	0.168	5.12

[0034] Then, Epstein samples and tensile test pieces were cut out from the non-oriented electrical steel sheets. Next, magnetic properties were measured by using the Epstein samples, and mechanical properties were measured by using the tensile test pieces. Results thereof are shown in Table 3.

[0035] [Table 3]

[Table 3]

Sample No.		Magnetic properties			Mechanical properties		
		$W_{15/50}$ (W/kg)	B50 (T)	$W_{10/1000}$ (W/kg)	YP (MPa)	TS (MPa)	EL (%)
Comparative examples	11	4.8	1.60	47	688	775	24
	12	5.6	1.59	58	703	785	22
Examples	13	8.1	1.57	84	871	922	17
	14	7.7	1.58	79	902	953	16

[0036] As shown in Table 3, in Comparative examples No. 11 and 12, the high-frequency core loss $W_{10/1000}$ was less than 100 W/kg, but the tensile strength was low, which was less than 900 MPa, because the value R_{Ti} was less than 1. Particularly, in Comparative example No. 11, Ti was not contained at all, and thus the tensile strength was remarkably low.

[0037] On the other hand, in Examples No. 13 and 14, the value R_{Ti} and so on were set appropriately, and thus the high-frequency core loss $W_{10/1000}$ of 100 W/kg or less and the tensile strength of 900 MPa or more could be obtained. Further, the yield point was also high as compared with Comparative examples No. 11 and 12.

(Second Experiment)

[0038] First, slabs containing components shown in Table 4 and a balance being composed of Fe and inevitable impurities were hot rolled to obtain hot-rolled steel sheets. Next, the hot-rolled steel sheets were cold rolled to obtain cold-rolled steel sheets having thicknesses of 0.25 mm. Thereafter, continuous finish annealing at 775°C for 30 seconds was applied to the cold-rolled steel sheets to obtain non-oriented electrical steel sheets.

[Table 4]

[Table 4]

Sample No.		Components									R_{Ti}
		c	Si	Al	Ni	Mn	p	B	N	Ti	
Comparative examples	21	0.0066	3.24	0.61	1.85	1.30	0.03	0.0028	0.0024	0.000	0.00
	22	0.0070	3.28	0.60	1.81	1.29	0.02	0.0027	0.0027	0.032	0.82
Examples	23	0.0069	3.25	0.63	1.90	1.31	0.03	0.0029	0.0025	0.278	7.39
	24	0.0073	3.30	0.58	1.88	1.33	0.03	0.0030	0.0023	0.146	3.80

[0039] Then, Epstein samples and tensile test pieces were cut out from the non-oriented electrical steel sheets. Next, magnetic properties were measured by using the Epstein samples, and mechanical properties were measured by using the tensile test pieces. Results thereof are shown in Table 5.

[0040] [Table 5]

[Table 5]

Sample No.		Magnetic properties			Mechanical properties		
		$W_{15/50}$ (W/kg)	B50 (T)	$W_{10/1000}$ (W/kg)	YP (MPa)	TS (MPa)	EL (%)
Comparative	21	5.4	1.62	63	708	796	26
examples	22	6.1	1.61	67	745	804	24
Examples	23	8.9	1.59	92	889	931	20
	24	8.7	1.60	90	910	962	21

[0041] As shown in Table 5, in Comparative examples No. 21 and 22, the high-frequency core loss $W_{10/1000}$ was less than 100 W/kg, but the tensile strength was low, which was less than 900 MPa, because the value R_{Ti} was less than 1. Particularly, in Comparative example No. 21, Ti was not contained at all, and thus the tensile strength was remarkably low.

[0042] On the other hand, in Examples No. 23 and 24, the value R_{Ti} and so on were set appropriately, and thus the high-frequency core loss $W_{10/1000}$ of 100 W/kg or less and the tensile strength of 900 MPa or more could be obtained. Further, the yield point was also high as compared with Comparative examples No. 21 and 22.

INDUSTRIAL APPLICABILITY

[0043] The present invention can be utilized in, for example, the electrical steel sheet manufacturing industry and the electrical steel sheet utilizing industry.

Claims

1. A non-oriented electrical steel sheet containing:

   C: not less than 0.003 mass% nor more than 0.05 mass%;
   N: not less than 0.001 mass% nor more than 0.01 mass%; and
   Si: not less than 2.8 mass% nor more than 3.5 mass%,
   further containing at least one kind selected from a group consisting of Ni: 4.0 mass% or less and Mn: 2.0 mass% or less, in a total amount of 0.5 mass% or more, and
   further containing Ti, a value R_{Ti} being not less than 1 nor more than 10, the value R_{Ti} being expressed by [Ti]/(4x([C]+[N])) when a Ti content is expressed as [Ti] mass%, a C content is expressed as [C] mass%, and an N content is expressed as [N] mass%,
   wherein
   an Al content is 3.0 mass% or less,
   a P content is 0.2 mass% or less, and
   a balance is composed of Fe and inevitable impurities.

2. The non-oriented electrical steel sheet according to claim 1, wherein the Ti content is not less than 0.1 mass% nor more than 0.3 mass%.

3. The non-oriented electrical steel sheet according to claim 1, further containing B: not less than 0.001 mass% nor more than 0.007 mass%.

4. The non-oriented electrical steel sheet according to claim 2, further containing B: not less than 0.001 mass% nor more than 0.007 mass%.

5. The non-oriented electrical steel sheet according to claim 1, further containing at least one kind selected from a group consisting of:

   Cu: not less than 0.02 mass% nor more than 1.0 mass%;
   Sn: not less than 0.02 mass% nor more than 0.5 mass%;
   Sb: not less than 0.02 mass% nor more than 0.5 mass%;
   Cr: not less than 0.02 mass% nor more than 3.0 mass%; and
   rare earth metal: not less than 0.001 mass% nor more than 0.01 mass%.

6. The non-oriented electrical steel sheet according to claim 2, further containing at least one kind selected from a group consisting of:

   Cu: not less than 0.02 mass% nor more than 1.0 mass%;
   Sn: not less than 0.02 mass% nor more than 0.5 mass%;
   Sb: not less than 0.02 mass% nor more than 0.5 mass%;
   Cr: not less than 0.02 mass% nor more than 3.0 mass%; and
   rare earth metal: not less than 0.001 mass% nor more than 0.01 mass%.

7. The non-oriented electrical steel sheet according to claim 3, further containing at least one kind selected from a group consisting of:

   Cu: not less than 0.02 mass% nor more than 1.0 mass%;
   Sn: not less than 0.02 mass% nor more than 0.5 mass%;

Sb: not less than 0.02 mass% nor more than 0.5 mass%;
Cr: not less than 0.02 mass% nor more than 3.0 mass%; and
rare earth metal: not less than 0.001 mass% nor more than 0.01 mass%.

8. The non-oriented electrical steel sheet according to claim 4, further containing at least one kind selected from a group consisting of:

Cu: not less than 0.02 mass% nor more than 1.0 mass%;
Sn: not less than 0.02 mass% nor more than 0.5 mass%;
Sb: not less than 0.02 mass% nor more than 0.5 mass%;
Cr: not less than 0.02 mass% nor more than 3.0 mass%; and
rare earth metal: not less than 0.001 mass% nor more than 0.01 mass%.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/050520

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, *C22C38/14*(2006.01)i, *C22C38/60*(2006.01)i, *H01F1/16*(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)
C22C38/00-38/60, H01F1/16

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-186790 A (JFE Steel Corp.), 26 July 2007 (26.07.2007), claims & CN 101310034 A & TW 200730642 A & KR 10-2008-0063521 A & WO 2007/069776 A1	1-8

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search	Date of mailing of the international search report
14 April, 2010 (14.04.10)	27 April, 2010 (27.04.10)

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

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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