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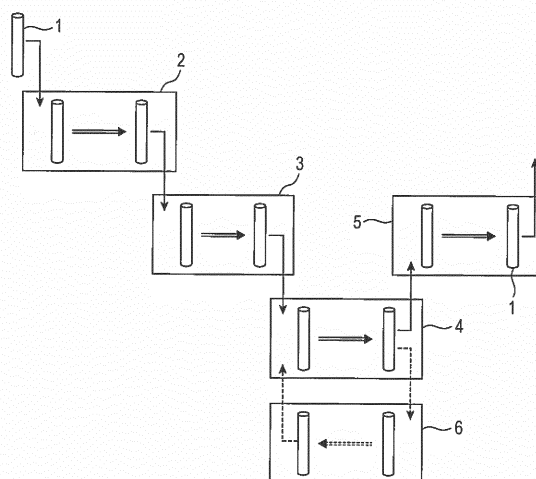
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(54) **MANUFACTURING METHOD AND MANUFACTURING EQUIPMENT FOR SEAMLESS STEEL PIPE OR TUBE WITH EXCELLENT TOUGHNESS**

(57) It is difficult in the related art to realize not only a decrease in material variability due to non-uniform microstructure distribution in the wall thickness direction of a pipe body but also the maintenance of satisfactory productivity of the whole heat treatment line at the same time.

A method includes determining in advance whether or not the pipe body is made of a steel grade having an Ms point lower than 200°C; leaving the pipe body of a steel grade having an Ms point lower than 200°C additionally at room temperature (it is preferable to be transported to a holding bed 6 and left) until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than 2.0°C after the quenching treatment has been performed, and then performing the tempering treatment; and, on the other hand, performing a tempering treatment on the pipe body of a steel grade not having an Ms point lower than 200°C without leaving the pipe body at room temperature after a quenching treatment has been performed.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a method and a facility for manufacturing a seamless steel pipe excellent in toughness. These are used in particular for manufacturing a product pipe with excellent toughness by performing quenching and tempering, which is thermal refining, on a pipe body, which is an intermediate product (semimanufactured product) of a seamless steel pipe of a steel grade such as stainless steel having a low Ms point (martensitic transformation start temperature) and a low Mf point (martensitic transformation finish temperature).

[0002] Here, "excellent in toughness" refers to, for example, the quality of satisfying ISO standard 13680. That is to say, it means that, when a Charpy impact test is performed on three transverse test pieces (in C direction) which are taken from the central part of the wall thickness of a product pipe at a test temperature of -10°C, the average absorbed energy (vE_{-10}) of the three test pieces is 40 J or more, and the number of test pieces whose absorbed energy is less than 40 J is one or less, where the absorbed energy thereof is 27 J or more (2/3 or more of the required value of 40 J).

Background Art

[0003] Examples of related art for manufacturing a seamless steel pipe include the following techniques.

[0004] Patent Literature 1 discloses a technique for manufacturing a product having high strength and high toughness by controlling a heating temperature and a cooling rate when a quenching heat treatment is performed in order to manufacture a 13Cr seamless stainless steel pipe having a large wall thickness.

[0005] Patent Literature 2 discloses a facility for minimizing a decrease in productive efficiency when a quenching treatment is performed on a steel grade on which quenching treatment cannot be performed at a high cooling rate. In the facility, however, the heat treatment is performed on a first-in first-out basis as long as no trouble occurs.

[0006] Patent Literature 3 discloses a method for manufacturing a seamless steel pipe composed of a martensite-ferrite dual phase steel.

[0007] Patent Literature 4 discloses a technique for decreasing a variation in hardness in the longitudinal direction of a steel pipe after quenching has been performed using a quenching method in which a quenching liquid is made to flow in one direction through the steel pipe, by controlling the flow rate of the liquid in accordance with the measured values of temperatures of the liquid which are determined on the entrance side and exit side of the pipe.

Citation List

Patent Literature

[0008]

PTL 1: Japanese Unexamined Patent Application Publication No. 2008-189945

PTL 2: Japanese Unexamined Patent Application Publication No. 2009-242863

PTL 3: Japanese Unexamined Patent Application Publication No. 2005-336595

PTL 4: Japanese Unexamined Patent Application Publication No. 2001-032022

Summary of Invention

Technical Problem

[0009] A pipe body, which is an intermediate product of a seamless steel pipe of a steel grade of, for example, martensitic stainless steel, is subjected to a heat treatment for quenching and tempering so as to be controlled to at the required level of strength and toughness after having been made into a pipe having a predetermined size by performing tube rolling using hot working. In an ordinary heat treatment process, the pipe body is heated to a temperature equal to or higher than the Ac_1 point and equal to or lower than the Ac_3 point in a heating furnace and then rapidly cooled to near room temperature by performing, for example, water cooling first in a quenching treatment, and the rapidly cooled pipe body is heated to a temperature equal to or lower than the Ac_1 point in another heating furnace and then allowed to cool in a subsequent tempering treatment (refer to, for example, Patent Literature 1). Recently, facilities by which such heat treatments are performed are continuously linable, and treatment conditions such as heating temperatures and heating times are respectively set in accordance with various kinds of products.

[0010] In the case of steel grades such as martensitic stainless steel (refer to Patent Literature 1) and martensite-ferrite dual phase steel (refer to Patent Literature 3), a desired area ratio of a martensite phase is achieved by performing

quenching and tempering described above. Here, an Ms point and an Mf point widely vary in accordance with steel chemical composition which characterizes the steel grade, and there is even a steel grade having an Ms point lower than 100°C and an Mf point lower than room temperature. The temperature of the pipe body after quenching has been performed is commonly confirmed by determining the surface temperature thereof. In the case of the steel grade having a low Ms point and a low Mf point as described above, the influence of a difference in temperature between the surface and the inside of the wall thickness of the pipe body (non-uniform temperature distribution in the wall thickness direction) on a martensitic transformation ratio is non-negligible. That is to say, even if the surface temperature of the pipe body is almost equal to room temperature after quenching has been performed, in the case where a tempering treatment is started before the temperature distribution in the wall thickness direction reaches a uniform and steady state, an unintended microstructure distribution is formed, which is one of the factors causing material variability (a variation in mechanical properties, in particular, toughness) after thermal refining has been performed.

[0011] On the other hand, in the case of the steel grade (referred to as "specific steel grade" for convenience) for which it is intended to achieve a desired area ratio of a martensite phase by performing above described quenching and tempering, since, martensite transformation per se occurs even when cooling is performed at a low cooling rate such as that at which the pipe body is allowed to cool after heating for quenching (heating in a quenching treatment), there is a decrease in the material variability described above by leaving the pipe body at room temperature for a sufficient time after cooling has been performed to room temperature. However, in the case where the specific steel grades and the other steel grades are subjected to a heat treatment in the same heat treatment line on a first-in first-out basis (refer to, for example, Patent Literature 2), there is a problem of a decrease in the productive efficiency for the whole heat treatment line due to an obstacle caused by the fact that it is necessary to leave the specific steel grades at room temperature for a duration of predetermined time or more.

[0012] In conclusion, a quenching method and a quenching facility for decreasing a variation in hardness in the longitudinal direction of a pipe body by performing flow control of a quenching liquid are known (refer to, for example, Patent Literature 4), however, there is a problem in that it is difficult to realize not only a decrease in material variability due to non-uniform microstructure distribution in the wall thickness direction of a pipe body of specific steel grades but also the maintenance of a satisfactory productive efficiency for the whole heat treatment line at the same time in the case where the specific steel grades and other steel grades are subjected to a heat treatment in the same heat treatment line as described above.

Solution to Problem

[0013] The present inventors diligently conducted investigations in order to solve the problems described above, and as a result, found that there is a significant decrease in material variability described above and that there is an improvement in the average value of data (average value of vE_{10}) within the range of the material variability described above, by discriminating pipe bodies made of steel grades having an Ms point lower than 200°C from pipe bodies made of the other steel grades, and in the case of former, after water cooling has been performed for quenching, by additionally leaving the pipe bodies at room temperature until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis (in the wall thickness direction) becomes less than 2.0°C. In the case of latter, it is appropriate that the pipe bodies be subjected to ordinary quenching and tempering. The present invention has been completed on the basis of the knowledge described above, and the subject matter of the present invention is as follows.

(1) A method for manufacturing a seamless steel pipe with excellent toughness including a process of performing quenching and tempering on a pipe body which is an intermediate product of a seamless steel pipe, the method including determining in advance whether or not the pipe body is made of a steel grade having an Ms point lower than 200°C; additionally leaving the pipe body of a steel grade having an Ms point lower than 200°C at room temperature until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than 2.0°C after the quenching treatment has been performed, and then performing the tempering treatment; and, on the other hand, performing a tempering treatment on the pipe body of a steel grade not having an Ms point lower than 200°C without leaving the pipe body at room temperature after a quenching treatment has been performed.

(2) A facility for manufacturing a seamless steel pipe with excellent toughness including a facility where a pipe body which is an intermediate product of a seamless steel pipe is subjected to quenching and tempering, the facility including a means for determining in advance whether or not the pipe body is made of a steel grade having an Ms point lower than 200°C and a holding bed for leaving only the pipe body of a steel grade having an Ms point lower than 200°C among the pipe bodies which have been subjected to the quenching treatment additionally at room temperature until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than

2.0°C before performing the tempering treatment.

Advantageous Effects of Invention

[0014] According to the present invention, since steel grades having an Ms point lower than 200°C are left additionally at room temperature until the temperature distribution in the wall thickness direction becomes sufficiently uniform after a quenching treatment has been performed and before a tempering treatment is performed so that a product pipe having a decreased material variability and excellent toughness is obtained, and since the other steel grades are normally subjected to a heat treatment on a first-in first-out basis without being disturbed by the pipe bodies left as described above, it is possible to manufacture seamless steel pipes excellent in toughness while maintaining satisfactory productivity of the whole heat treatment line.

Brief Description of Drawings

[0015] [Fig. 1] Fig. 1 is a schematic plan view illustrating an example of a heat treatment line used for the present invention.

Description of Embodiments

[0016] Fig. 1 is a schematic plan view illustrating an example of a heat treatment line used for the present invention. Among pipe bodies 1, which are intermediate products of seamless steel pipes, a pipe body (also called pipe A for convenience), which has been judged to be a pipe having an Ms point of 200°C or higher, is heated to an appropriate temperature corresponding to its steel grade using a heating furnace for quenching 2, and then cooled so that the temperature of the outer surface of the pipe body becomes almost equal to room temperature by immersing the pipe body in cooling water in a quenching water tank 3. Subsequently, the pipe body is transported through a cooling bed 4 to a heating furnace for tempering 5 in which the pipe body is subjected to a tempering treatment at an appropriate temperature corresponding to its steel grade. Here, the Ms point is calculated using equation (1) described later.

[0017] On the other hand, a pipe body (also called pipe B for convenience), which has been judged to be a pipe having an Ms point lower than 200°C, is treated in the same pathway as a pipe A is treated until the pipe body is transported to the cooling bed 4. However, only a pipe B is transported to a holding bed (also called buffer line) 6, which is a different pathway from that to which the pipe A is transported, and left at room temperature on the buffer line 6 until the temperature difference (referred to as ΔT) between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than 2.0°C. Subsequently, the pipe B is returned to the cooling bed 4 and subjected to a tempering treatment in the same pathway as the pipe A is treated.

[0018] Here, the cooling bed 4 and the holding bed 6 are different facilities from each other in the example of the present invention. However, in the case where there is sufficient room on the cooling bed 4, some part of the cooling bed may be used as a holding bed.

[0019] In the present invention, examples of the specific steel grade described above (a specific steel grade for which it is intended to achieve a desired area ratio of a martensite phase by performing quenching and tempering) include, for example, a steel grade having a chemical composition containing, by mass%, C: 0.005% to 0.05%, Si: 0.05% to 1.0%, Mn: 0.2% to 1.8%, P: 0.03% or less, S: 0.005% or less, Cr: 11% to 20%, Ni: 1.5% to 10%, Mo: 1% to 5%, N: 0.15% or less, and the balance being Fe and inevitable impurities. Here, the chemical composition may further contain, by mass%, one, two, or more selected from among Al: 0.002% to 0.05%, Cu: 3.5% or less, Nb: 0.5% or less, V: 0.5% or less, Ti: 0.3% or less, Zr: 0.2% or less, W: 3% or less, B: 0.01% or less, Ca: 0.01% or less, and REM: 0.01% or less instead of some portion of Fe.

[0020] As described above, in the case of a steel grade whose Mf point is lower than room temperature (which is a kind of specific steel grade described above), a martensitic transformation ratio, that is, the amount of residual austenite at each position in the wall thickness direction of a pipe body is practically determined by the temperature distribution in the wall thickness direction of the pipe body (temperature distribution in a cross section in a direction at a right angle to the pipe axis) when starting tempering. Regarding such a temperature distribution, even in the case where a temperature difference ΔT between the portion having the highest temperature and the portion having the lowest temperature in the temperature distribution in the wall thickness direction of the pipe body is less than 10°C, a difference (variation) in the amount of residual austenite at the positions in the wall thickness direction of the pipe body is non-negligible. Such a variation in the amount of residual austenite is one of the factors which cause the material variability of a product.

[0021] In order to solve the problem of the variation, a pipe B is left at room temperature until ΔT becomes less than 2.0°C according to the present invention. With this method, since there is a significant decrease in a variation in the amount of residual austenite in the wall thickness direction of the pipe body when starting tempering, there is a significant

decrease in material variability of the product after tempering has been performed, and the average value of data (the average value of vE_{-10}) within the range of the material variability is improved. In the case where tempering is started before ΔT becomes less than 2.0°C , such effect cannot be realized. Here, the reason why the discrimination criterion for a pipe B is set to be that the pipe has an Ms point lower than 200°C is because it was found that, from the results of the experiments conducted by the present inventors, there is practically no problem with considering that this criterion is almost equivalent to the condition that the pipe has an Mf point lower than room temperature.

[0022] In the present embodiment, the Ms point is calculated using equation (1) below which has been derived using regression analysis regarding the relationship between the contents [mass%] of the constituents of the chemical composition of steel and the experimental data of the Ms point which were determined using the thermal expansion curves which were obtained in advance by conducting continuous cooling transformation experiments using thermal expansion test pieces having various chemical compositions for the specified steel grade described above.

$$Ms [^{\circ}\text{C}] = 502 - 810 [\%C] - 1230 [\%N] - 13 [\%Mn] - 30 [\%Ni] - 12 [\%Cr] - 54 [\%Cu] - 6 [\%Mo] \dots (1),$$

where, under the assumption that M is an atomic symbol, symbol [%M] represents the content of a constituent chemical element represented by symbol M in equation (1), and where [%M] is assigned a value of 0 in the case where symbol M represents a chemical element which is not contained in the steel.

[0023] As a preferable embodiment, a waiting time (lead time) from an end of quenching treatment (water cooling) to a start of tempering treatment is set in accordance with the steel grade which is going to be heat-treated. In order to set the lead time, it is preferable that a Ms point be determined in advance using equation (1) above, and a calculation device be prepared by combining measured data of an ambient temperature and surface temperature of a pipe body, and heat-transfer calculation. In the case of a pipe body (pipe B described above) of a steel grade having an Ms point lower than 200°C , if the lead time on the cooling bed 4 on an ordinary first-in first-out basis is shorter than the time which is required for temperature homogenization in order to decrease ΔT to less than 2.0°C , the pipe body is transported to the buffer line 6 temporarily, left there at room temperature until ΔT becomes less than 2.0°C , and then subjected anew to a tempering treatment.

EXAMPLES

[0024] Steel billets having the chemical compositions and the Ms points, which were calculated using equation (1), given in Table 1 were formed into pipes by performing hot working, and thereafter air-cooled to a temperature of 100°C to room temperature to obtain 10 pipe bodies having an outer diameter of 195.0 mm and a wall thickness of 27.0 mm which were used as starting materials of seamless steel pipes.

[0025] Five pipe bodies (P1 through P5) which were selected as the examples of the present invention by conducting a random sampling from among the pipe bodies prepared as described above were subjected to a heat treatment (quenching and tempering) as described hereafter. The heat treatment line illustrated in Fig. 1 was used. In a quenching treatment, the pipe bodies were heated to a temperature of 950°C , and then water-cooled. After water cooling and recuperation had been performed, the surface temperature (measured value) of the pipe bodies was 30°C to 36°C . The pipe bodies were left at room temperature (in atmospheric air) for 8 hours or more, then charged into a heating furnace for tempering when ΔT (calculated value) became 1.2°C to 1.8°C , and subjected to a tempering treatment at a temperature of 600°C .

[0026] The other five pipe bodies (P6 through P10), which were used as comparative examples, were subjected to a quenching treatment under the same conditions for the examples of the present invention, then charged into a heating furnace for tempering on an ordinary first-in first-out basis without performing time management for decreasing ΔT to less than 2.0°C and subjected to a tempering treatment at a temperature of 600°C . In this case, ΔT (calculated value) was 6.0°C when the pipe bodies were charged into the heating furnace for tempering.

[0027] Using three V-notched test pieces (S1, S2, and S3) which were taken from each of the tempered pipe bodies in accordance with JIS Z 2202 (sampling position was the central part of the wall thickness of the pipe body, the length of the test piece was 10 mm, the longitudinal direction of the test piece was the circumferential direction of the pipe body (C direction), and the depth direction of the V notch was the longitudinal direction of the pipe body (L direction)), a Charpy impact test was conducted in accordance with JIS Z 2242 and vE_{-10} was obtained.

[0028] The obtained results are given in Table 2. As Table 2 indicates, in the case of the examples of the present invention, the average value of vE_{-10} values (the number of the samples was 15) was 87.7 J, where there was no test piece having a vE_{-10} value of less than 40 J. In addition, the variation in the vE_{-10} value was very small as indicated by

a standard deviation of 3.8 J. On the other hand, in the case of the comparative examples, the average value of the $vE_{.10}$ values (the number of the samples was 15) was 81.7 J. However, there were two test pieces having a $vE_{.10}$ value of less than 40 J. In addition, in the case of the comparative examples, there was a decrease in the average value and there was an increase in variation as indicated by a standard deviation of 17.9 J. By checking the results for each pipe body, there are pipe bodies having a $vE_{.10}$ value equivalent to that of the present invention among the comparative examples. On the other hand, there are pipe bodies having a significantly decreased $vE_{.10}$ value, which results in a decrease in the average value and an increase in variation.

[0029] As described above, according to the present invention, mechanical properties with increased stability can be obtained.

[Table 1]

Chemical Composition (mass%)													Ms Point (°C)
C	Si	Mn	P	S	Cr	Ni	Mo	V	N	O	Cu	Al	
0.027	0.29	0.37	0.017	0.0009	16.7	3.8	2.4	0.047	0.051	0.0027	0.94	0.0015	33

[Table 2]

	Pipe Body Code	vE _{.10} (J)				
		Test Piece S1	Test Piece S2	Test Piece S3	Average Value Ave.	Standard Deviation σ
Example	P1	91.2	89.3	82.4	87.7	3.8
	P2	84.9	93.1	87.2		
	P3	85.4	80.1	89.7		
	P4	85.6	91.5	92.4		
	P5	85.3	86.7	90.4		
Comparative Example	P6	92.5	89.4	72.4	81.7	17.9
	P7	91.2	89.6	92.3		
	P8	39.8	90.2	39.3		
	P9	91.5	89.7	90.5		
	P10	82.3	90.1	84.6		

Reference Signs List

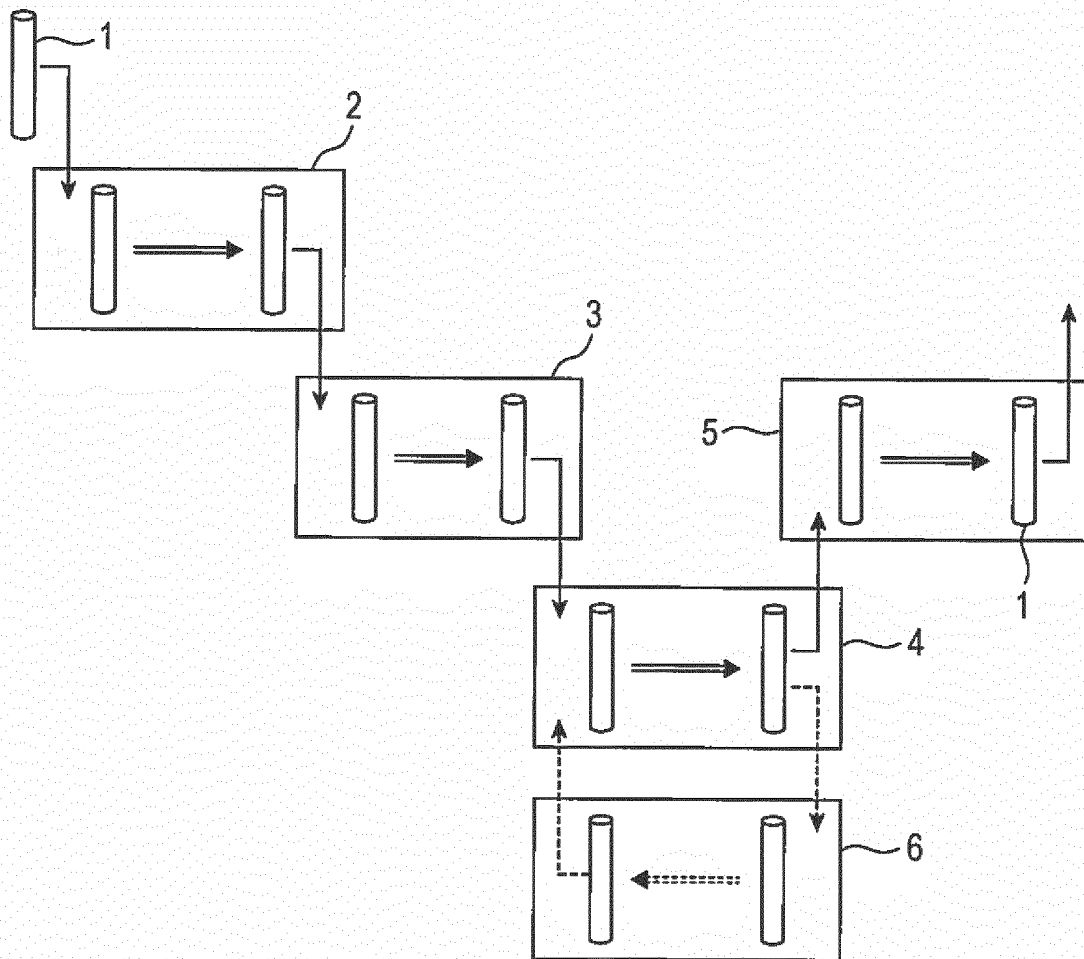
[0030]

- 1 pipe body
- 2 heating furnace for quenching
- 3 quenching water tank
- 4 cooling bed
- 5 heating furnace for tempering
- 6 holding bed (buffer line)

Claims

1. A method for manufacturing a seamless steel pipe including a process of performing quenching and tempering on a pipe body which is an intermediate product of a seamless steel pipe, the method comprising determining in advance whether or not the pipe body is made of a steel grade having an Ms point lower than 200°C; additionally leaving the pipe body of a steel grade having an Ms point lower than 200°C at room temperature until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than 2.0°C after the quenching treatment has been performed, and then performing the tempering treatment; and, on the other hand, performing a tempering treatment on the pipe body of a steel grade not having an Ms point lower than 200°C without leaving the pipe body at room temperature after a quenching treatment has been performed.
2. A facility for manufacturing a seamless steel pipe including a facility where a pipe body which is an intermediate product of a seamless steel pipe is subjected to quenching and tempering, the facility comprising a means for determining in advance whether or not the pipe body is made of a steel grade having an Ms point lower than 200°C and a holding bed for leaving the pipe body additionally at room temperature until the temperature difference between the portion having the highest temperature and the portion having the lowest temperature in a cross section in a direction at a right angle to the pipe axis becomes less than 2.0°C before performing the tempering treatment.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/000297

A. CLASSIFICATION OF SUBJECT MATTER

C21D9/08(2006.01)i, C22C38/00(2006.01)n, C22C38/58(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)

C21D9/00-9/40, 9/50

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 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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	JP 57-39129 A (NKK Corp.),	1
A	04 March 1982 (04.03.1982), claims; page 2, upper right column, line 1 to lower left column, line 11; table 1 (Family: none)	2
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 145200/1980 (Laid-open No. 69851/1982) (Nippon Steel Corp.), 27 April 1982 (27.04.1982), claims; fig. 2 (Family: none)	1-2

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

* Special categories of cited documents:

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Date of the actual completion of the international search
03 April, 2014 (03.04.14)Date of mailing of the international search report
15 April, 2014 (15.04.14)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/000297

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9-287023 A (Sumitomo Metal Industries, Ltd.), 04 November 1997 (04.11.1997), paragraph [0026] (Family: none)	1-2
A	JP 2006-274350 A (Sumitomo Metal Industries, Ltd.), 12 October 2006 (12.10.2006), paragraphs [0039], [0099] & US 2008/0047635 A1 & EP 1876254 A1 & WO 2006/103894 A1 & CA 2602526 A1 & AR 52706 A1 & NO 20074257 A & CN 101151387 A & BR PI0608953 A2 & AU 2006229079 A1 & MX 2007011567 A	1-2
A	JP 2002-30342 A (Sumitomo Metal Industries, Ltd.), 31 January 2002 (31.01.2002), entire text; all drawings (Family: none)	1-2

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008189945 A [0008]
- JP 2009242863 A [0008]
- JP 2005336595 A [0008]
- JP 2001032022 A [0008]