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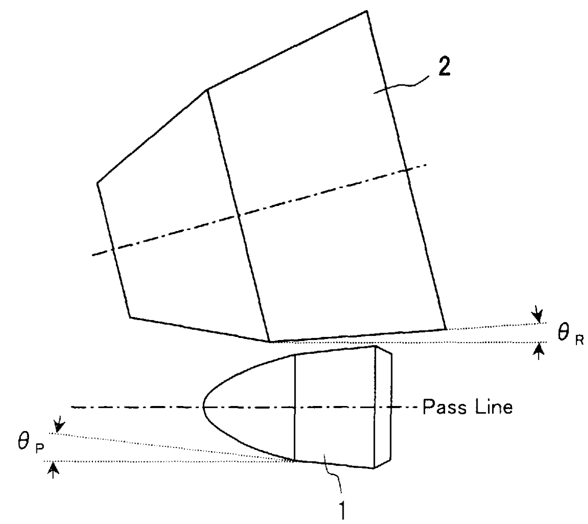
(54) **HIGH-ALLOY SEAMLESS STEEL PIPE MANUFACTURING METHOD**

(57) Pipe-swelling can be prevented by piercing-rolling a high-alloy steel billet heated to a temperature range from 900 to 1250°C with a piercing mill equipped with main rolls having a surface roughness R_{max} of 150 to 500 μm. A ratio (the gap W_G of guide rolls/the gap W_R of the main rolls) is preferably at 1.10 to 1.20. The difference (θ_P - θ_R) is preferably set at 0 to 3.0°, where θ_R is an angle between an exit-side face of each of the main rolls of the piercing mill and the pass line; and θ_P is an angle between a rolling face of the piercing plug and the pass line.

Figure 2



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Description

Technical Field

[0001] The present invention relates to a method for producing a high-alloy seamless steel pipe, in particular, a method for producing a high-alloy seamless steel pipe free from occurrence of outer surface flaws.

Background Art

[0002] The methods such as the Mannesmann pilger mill process, the Mannesmann plug mill process and the Mannesmann mandrel mill process are known as the methods for producing a seamless steel pipe. Frequently used among these is the Mannesmann mandrel mill process in which a hollow blank is obtained by piercing a heated billet with a piercing mill and then the obtained hollow blank having a mandrel bar inserted thereinto is rolled with a mandrel mill.

[0003] There are a lot of patent documents associated with the methods for producing seamless steel pipes. With respect to the techniques for preventing outer surface flaws at the time of piercing-rolling, the following have been disclosed.

[0004] Patent Document 1 discloses an invention in which piercing is conducted in such a way that when a martensite stainless slab containing, by mass percent, Cr: 10.0 to 16.0% and Ni: 1.0 to 8.0% is heated, the lower layer of the oxide scales produced on the surface of the slab contains metal pieces, and has an area ratio of the voids to the whole cross section set at 20% or less and an thickness set at 150 μm or less.

[0005] Patent Document 2 discloses a method for producing a seamless pipe formed of a hardly-workable exterior-scraped stock containing 4.5 mass % or more by means of an inclined roll piercing method. This method uses a stock in which the maximum value of the difference between the maximum step height and the minimum step height in a length of 25 mm in the longitudinal direction of the stock is measured at ten different arbitrary points, and an average value (ten-point average step height) of the thus obtained ten values is 2.0 mm or less.

[0006] In other words, Patent Documents 1 and 2 each describe a technique for reducing the outer surface flaws by regulating the stock itself subjected to piercing-rolling.

[0007] Patent Document 3 describes a technique for reducing the outer surface flaws by regulating the shape of the main rolls in piercing-rolling. This technique is associated with a method for obtaining a seamless metal pipe; a workpiece is being spirally moved and piercing-rolled in the method. A pair of cone-shaped main rolls and a pair of disk rolls disposed alternately around the pass line of the workpiece. A plug is disposed along the pass line and is disposed between the main rolls and the disk rolls. In this method, the disk rolls are inclined at skew angle δ from the pass line so as to non-parallel with the exit-side face angles of the main rolls. And the disk rolls are inclined, toward the sides of the main rolls which are positioned on the approach side of the workpiece toward the disk roll sliding surfaces. The above-described skew angle δ is set in such a way that the relation "$\theta_2 + 2^\circ < \delta < 9^\circ$" ($\theta_2$: the exit-side face angle of each of the main rolls) and the relation "$\delta + \theta_1 < 12^\circ$" ($\theta_1$: the entrance-side face angle of each of the main rolls) are satisfied, and the pipe expansion ratio is set at 1.15 or more. In this way, the occurrence of the outer surface flaws is prevented.

[0008] Patent Document 4 describes a technique for preventing the occurrence of the outer surface flaws in piercing-rolling by using disk guide rolls which made of a low-alloy steel composed of 0.2 to 0.5% by weight of C, 0.5 to 4% by weight of Cr, 0.5 to 4% by weight of Ni and the balance being Fe and unavoidable elements and have a 50 to 500 μm heat treated scale in the surface layer thereof.

[0009] Patent Document 5 discloses a technique associated with a guide shoe used in inclined piercing or inclined rolling of a seamless steel pipe. In this technique, a guide shoe is divided into two parts, i.e. the main part and the bottom part, in the thickness direction thereof. A plurality of spherical tools constituted with a ceramic or a cermet material are interposed between the main part and the bottom part. The spherical tools are partially made to project from small holes on the guide shoe surface, wherein the small holes are smaller in diameter than the spherical tools; and thus the occurrence of the outer surface flaws is prevented.

[0010]

Patent Document 1: JP2001-96304A
Patent Document 2: JP2003-53403A
Patent Document 3: JP7-124612A
Patent Document 4: JP6-262219A
Patent Document 5: JP11-285709A

Disclosure of the Invention

Problems to be Solved by the Invention

[0011] As described above, the prior arts disclose the techniques for preventing outer surface flaws of seamless steel pipes on the basis of the methods involving the regulation of the surface conditions of the workpiece, the shape modification of the main rolls in piercing-rolling, the surface treatment of the guide shoe, the material regulation of the disk guide rolls and the like; however, none of the conventional techniques pays attention to the surface roughness of the main rolls.

[0012] However, when high-alloy steel is subjected to piercing-rolling, pipe-swelling tends to be generated in the workpiece, and thus the above-described techniques may be insufficient.

[0013] The present invention is achieved for solving the above-described problems, and the object of the invention is to provide a method for producing a high-alloy seamless steel pipe free from occurrence of outer surface flaws.

Means for Solving the Problems

[0014] Figure 1 is a view illustrating the occurrence condition of pipe-swelling in a high-alloy seamless steel pipe. As shown in Figure 1, a workpiece 4 is pierced with a plug 1 and is rolled with main rolls 2 and guide rolls 3 while the outer diameter of the workpiece 4 is being controlled. When pipe-swelling occurs on the location indicated by B in Figure 1 at the time of piercing-rolling, the pipe-swelling develops into outer surface flaws.

[0015] First, the present inventor has discovered that there is a correlation between a pipe-swelling ratio and the outer surface flaws, wherein the pipe-swelling ratio defined as "the outer diameter of the pipe-swelling portion of a workpiece/the gap of the main rolls". The pipe-swelling ratio represent that the fin flaw conditions tends to develop into outer surface flaws of a high-alloy seamless steel pipe. Specifically, a study performed by the present inventor has revealed that when the pipe-swelling ratio is regulated to be less than 1.10, the outer surface flaws of a seamless steel pipe can be dramatically reduced. It is to be noted that "the outer diameter of the fin flaw portion of a workpiece" means the length indicated by A in Figure 1, and "the gap of the main rolls" means the length indicated by W_R in Figure 1.

[0016] Second, the present inventor examined in detail the effects of the various piercing-rolling conditions on the pipe-swelling ratio. Then, the present inventor consequently has discovered that the effect of the surface roughness R_{max} of the main rolls of a piercing mill is most significant, and others such as the following also affect the pipe-swelling ratio:

a ratio (W_G/W_R), wherein W_R is a gap of a main rolls of the piercing mill, and W_G is a gap of a guide rolls of the piercing mill;
a surface temperature of a workpiece at the time of piercing; and
a difference ($\theta_P - \theta_R$), wherein θ_R is an angle between an exit-side face of each of the main rolls of the piercing mill and the pass line, and θ_p is an angle between a rolling face of the piercing plug and the pass line.

[0017] The present invention has been achieved on the basis of the above-described findings, and the present invention involves a method for producing a high-alloy seamless steel pipe shown in the following (1) to (6).

[0018]

(1) A method for producing a high-alloy seamless steel pipe, including steps of:

billet-heating process;
piercing-rolling process, wherein surface roughness R_{max} of main rolls used in the piercing-rolling process is set at 150 to 500 μm; and
elongation-rolling process.

[0019]

(2) The method for producing a high-alloy seamless steel pipe according to (1),
wherein a ratio (W_G/W_R) is set at 1.10 to 1.20 in the piercing-rolling process, where W_R is the gap of the main rolls of the piercing mill; and W_G is the gap of the guide rolls of the piercing mill.

[0020]

(3) The method for producing a high-alloy seamless steel pipe according to (1) or (2),
wherein surface temperature of a workpiece during the piercing-rolling process is set at 900 to 1250°C.

[0021]

(4) The method for producing a high-alloy seamless steel pipe according to any one of (1) to (3),
wherein a difference ($\theta_P - \theta_R$) is set at 0 to 3.0°, where θ_R is an angle between an exit-side face of each of the main rolls of the piercing mill and the pass line; and θ_P is an angle between a rolling face of the piercing plug and the pass line.

[0022]

(5) The method for producing a high-alloy seamless steel pipe according to any one of (1) to (4),
wherein the main rolls that have been used for piercing a seamless steel pipes of ordinary steel are used.

[0023]

(6) The method for producing a high-alloy seamless steel pipe according to (5),
wherein a flow rate of a roll-cooling water at the time of piercing the seamless steel pipes of ordinary steel is set at 1000 to 1500 l/min.

Advantages of the Invention

[0024] According to the present invention, the pipe-swelling occurring at the time of piercing a high-alloy seamless steel pipe can be prevented and hence the occurrence of the outer surface flaws of the seamless steel pipe can be prevented.

Brief Description of the Drawings

[0025]

Figure 1 is a view illustrating the occurrence condition of pipe-swelling in a high-alloy seamless steel pipe;

Figure 2 is a view illustrating an angle between a main roll and a pass line and an angle between a plug and the pass line;

Figure 3 is a graph showing a relation between the surface roughness of the main rolls and a pipe-swelling ratio in an Example;

Figure 4 is a graph showing a relation between the number of rolled billets of ordinary steel and the surface roughness of the main rolls in another Example;

Figure 5 is a graph showing a relation between a ratio (W_G/W_R) and the pipe-swelling ratio in yet another Example; and

Figure 6 is a graph showing a relation between a difference (θ_P - θ_R) and the pipe-swelling ratio in still yet another Example.

Description of Symbols

[0026]

2: 1: Plug Main roll
3: Guide roll
4: Workpiece

Best Mode for Carrying Out the Invention

[0027] In the present invention, for example, a billet heated with a heating furnace is pierced with a piercing mill to yield a hollow blank; the hollow blank was subjected to elongation rolling with a mandrel mill or the like, and where necessary, further subjected to sizing with a sizing mill or the like to produce a high-alloy seamless steel pipe.

[0028] In the method for producing a high-alloy seamless steel pipe according to the present invention, it is required that a surface roughness R_{max} of main rolls used in the piercing-rolling process have regulated to fall within a range from 150 to 500 μm. When the surface roughness R_{max} of the main rolls is as extremely flat as less than 150 μm, the gripping force of the rolls at the time of piercing is insufficient and the pipe-swelling of the workpiece come to be remarkable. On the other hand, when the surface roughness R_{max} of the main rolls exceeds 500 μm, flaws due to the rolls occur on the workpiece. Therefore, in the piercing-rolling process in the present invention, the surface roughness R_{max} of the main rolls is set at 150 to 500 μm.

[0029] As the main rolls that meet the above-described surface roughness range, it is recommended to use the main rolls that have been used for piercing seamless ordinary steel pipes. The number of the times of rolling the ordinary steel is not restricted, but it is preferably to use the rolls that have been used for rolling of approximately 3000 to 4000 billets. In particular, it is preferably to reduce the amount of the roll-cooling water at the time of piercing seamless ordinary steel pipes. In this way, it is possible to efficiently set the surface roughness of the main rolls to fall within the above-described range. Usually, the flow rate of the roll-cooling water at the time of piercing seamless ordinary steel pipes is about 2000 to 2500 l/min; it is recommended to set the flow rate at 1000 to 1500 l/min. In this way, it is possible to reduce the number of the rolled billets required for regulating the roll surface roughness so as to fall within the above-described range.

[0030] The piercing is preferably performed in such a way that the ratio (W_G/W_R) falls within a range from 1.10 to 1.20, wherein W_R is the gap of the main rolls of the piercing mill; and W_G is the gap of the guide rolls of the piercing mill. This is because there is a possibility that when the ratio (W_G/W_R) is less than 1.10, biting failure is caused, and when the ratio (W_G/W_R) exceeds 1.20, pipe-swelling occur, and the flaws may result in outer surface flaws.

[0031] The surface temperature of a workpiece at the time of piercing preferably falls within a range from 900 to 1250°C. This is because there is a possibility that when the piercing temperature is lower than 900°C, the deformation resistance of the workpiece subjected to the piercing-rolling is increased to cause the occurrence of pipe-swelling, and when the piercing temperature exceeds 1250°C, the workpiece is melted to cause the occurrence of internal flaws.

[0032] The piercing is preferably performed in such a way that the difference (θ_P - θ_R) falls within a range from 0 to 3.0°. θ_R is an angle between the exit-side face of each of the main rolls of the piercing mill and the pass line and θ_P is an angle between the rolling face of the piercing plug and the pass line. When the difference (θ_P - θ_R) is less than 0°, the piercing might not be able to be performed, and when the difference (θ_P - θ_R) exceeds 3.0°, pipe-swelling might occur to cause the occurrence of outer surface flaws. It is to be noted that the angle θ_R and the angle θ_P are labeled as θ_R and θ_P in Figure 2, respectively.

Example 1

[0033] The following experiment was performed for the purpose of verifying the advantageous effects of the present invention. Specifically, a billet of 225 mm in outer diameter and 3,000 mm in length was obtained by casting a 13%-Cr steel (SUS 403), the billet was heated to 1200°C. Then the billet was subjected to piercing by using various main rolls (the roll diameters were 1,200 mm) different in the surface roughness R_{max}. Pierced shells of 228 mm in outer diameter and 18.75 mm in wall thickness were produced. The surface roughness of each of the main rolls was regulated on the basis of the number of the billets of ordinary steel (S25C) subjected to the beforehand-performed rolling. The results are shown in Figure 3.

[0034] As shown in Figure 3, when the surface roughness R_{max} of the main rolls was approximately 50 μm, the pipe-swelling ratio (the outer diameter of the fin flaw portion of the workpiece/the gap of the main rolls) exceeded 1.15. Outer surface flaws tend to occur in this condition. However, with the increase of the surface roughness R_{max} of the main rolls, the pipe-swelling ratio decreased, and when the surface roughness R_{max} of the main rolls was 150 μm or more, the pipe-swelling ratio was found to be 1.10 or less.

[0035] Main rolls having a surface roughness R_{max} of 175 μm was actually used in a piercing-rolling process of a real operation, and consequently the rate of occurrence of the outer surface flaws was able to be reduced to 3.0%. The rate was 6.2% before such regulation.

Example 2

[0036] Next, the present inventor investigated how to regulate the surface roughness of the main rolls by rolling ordinary steel pipes. The results are shown in Figure 4.

[0037] As shown in Figure 4, with the increase of the number of the rolled billets of ordinary steel, the surface roughness R_{max} of the main rolls increased. When 3000 or more billets of the ordinary steel were rolled, the surface roughness R_{max} of the main rolls was able to be 150 μm or more. When the cooling water at the time of the rolling of the ordinary steel was reduced, the efficiency of the regulation of the surface roughness of the main rolls was further increased. The cooling water flow rate was set at approximately 2500 l/min in the usual cases (examples represented by □ in Figure 4), and the cooling water flow rate was set at 1500 l/min in the water-reduced cases (examples represented by ○ in Figure 4).

Example 3

[0038] Next, the present inventor investigated the relation between the ratio (W_G/W_R) and the pipe-swelling ratio. W_R is the gap of the main rolls of the piercing mill; and W_G is the gap of the guide rolls of the piercing mill. In this experiment, the main rolls having a surface roughness R_{max} of 175 μm regulated by rolling ordinary steel were used, the ratio (W_G/W_R) were regulated to be various values, and the above-described 13%-Cr steel experiment was subjected to piercing-rolling. Other conditions were the same as the conditions in above-described Example 1. The results are shown in Figure 5. As shown in Figure 5, when the ratio (W_G/W_R) exceeded 1.20, the pipe-swelling ratio increased. Outer surface flaws tend to occur in this condition. When the ratio (W_G/W_R) was small, biting volume is increased and biting failures tend to occur. However, as long as the ratio (W_G/W_R) was 1.10 or more, the biting was able to be performed without any troubles.

[0039] Main rolls having a surface roughness R_{max} of 175 μm and the ratio (W_G/W_R) of 1.15 was actually used in a piercing-rolling process of a real operation, and consequently the rate of occurrence of the outer surface flaws was able to be reduced to 2.0%.

Example 4

[0040] Next, the present inventor investigated the relation between the difference (θ_P - θ_R) and the pipe-swelling ratio, wherein θ_R is an angle between an exit-side face of each of the main rolls of the piercing mill and the pass line; and θ_P is an angle between a rolling face of the piercing plug and the pass line. In this experiment, main rolls having surface roughness R_{max} of 175 μm regulated by rolling ordinary steel were used, the ratio (W_G/W_R) was regulated to be 1.15, the difference (θ_P - θ_R) was regulated to be various values, and the above-described 13%-Cr steel was subjected to piercing-rolling. Other conditions were the same as the conditions in above-described Example 1. The results are shown in Figure 6.

[0041] As shown in Figure 6, with the increase of the difference (θ_P - θ_R), the pipe-swelling ratio also increased. When the difference (θ_P - θ_R) exceeded 3.0°, the pipe-swelling ratio exceeded 1.10, and pipe-swelling failure tend to occur.

[0042] Main rolls having a surface roughness R_{max} of 175 μm, the ratio (W_G/W_R) of 1.15 and the difference (θ_P - θ_R) of 2.0° was actually used in a piercing-rolling process of a real operation, and consequently the rate of occurrence of the outer surface flaws was able to be reduced to 1.5%.

Industrial Applicability

[0043] According to the present invention, it is possible to prevent the pipe-swelling occurring at the time of piercing a high-alloy seamless steel pipe, and hence it is possible to prevent the occurrence of the outer surface flaws of the seamless steel pipe.

Claims

1. A method for producing a high-alloy seamless steel pipe, including steps of:

    billet-heating process;
    piercing-rolling process, wherein surface roughness R_{max} of main rolls used in the piercing-rolling process is set at 150 to 500 μm; and
    elongation-rolling process.

2. The method for producing a high-alloy seamless steel pipe according to claim 1,
    wherein a ratio (W_G/W_R) is set at 1.10 to 1.20 in the piercing-rolling process, where:

    W_R is the gap of the main rolls of the piercing mill and
    W_G is the gap of the guide rolls of the piercing mill.

3. The method for producing a high-alloy seamless steel pipe according to claims 1 or 2, wherein surface temperature of a workpiece during the piercing-rolling process is set at 900 to 1250˚C.

4. The method for producing a high-alloy seamless steel pipe according to any one of claims 1 to 3, wherein a difference (θ_P - θ_R) is set at 0 to 3.0˚, where:

   θ_R is an angle between an exit-side face of each of the main rolls of the piercing mill and the pass line and
   θ_P is an angle between a rolling face of the piercing plug and the pass line.

5. The method for producing a high-alloy seamless steel pipe according to any one of claims 1 to 4, wherein the main rolls that have been used for piercing a seamless steel pipes of ordinary steel are used.

6. The method for producing a high-alloy seamless steel pipe according to claim 5, wherein the flow rate of the roll-cooling water at the time of piercing the seamless steel pipes of ordinary steel is set at 1000 to 1500 l/min.

Figure 1

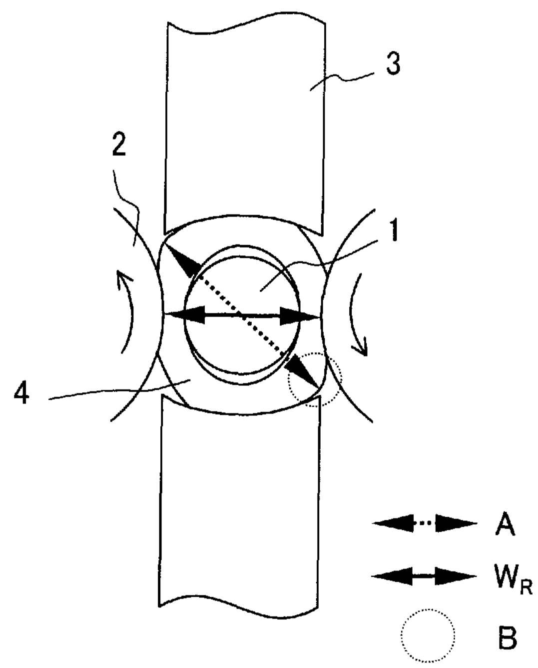


Figure 2

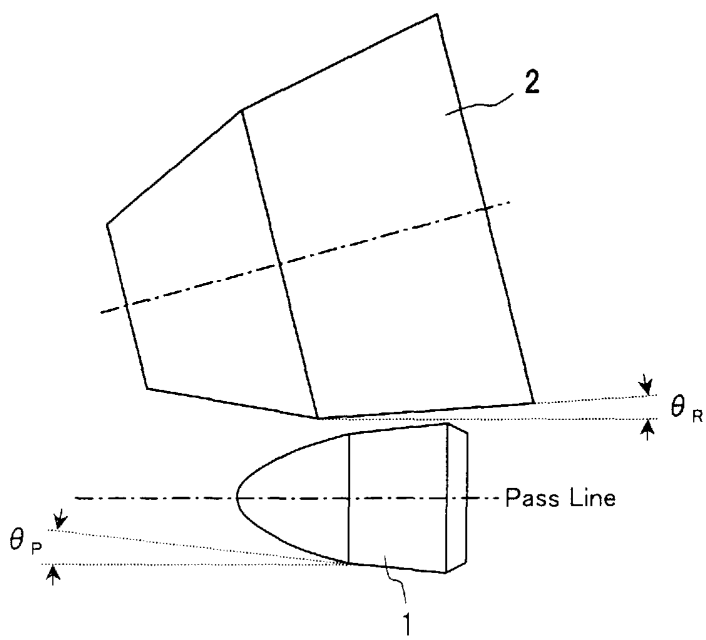


Figure 3

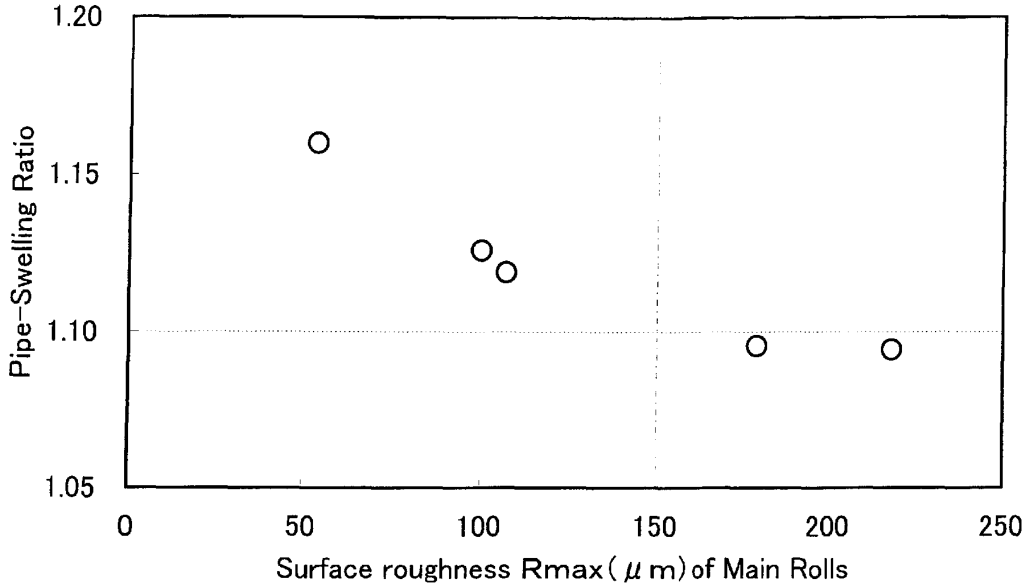


Figure 4

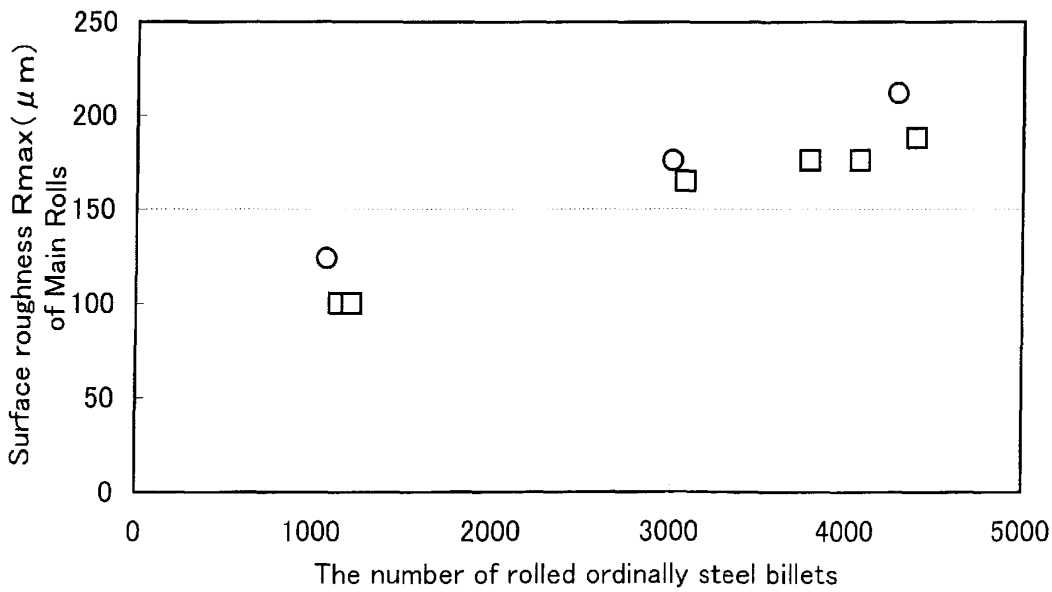


Figure 5

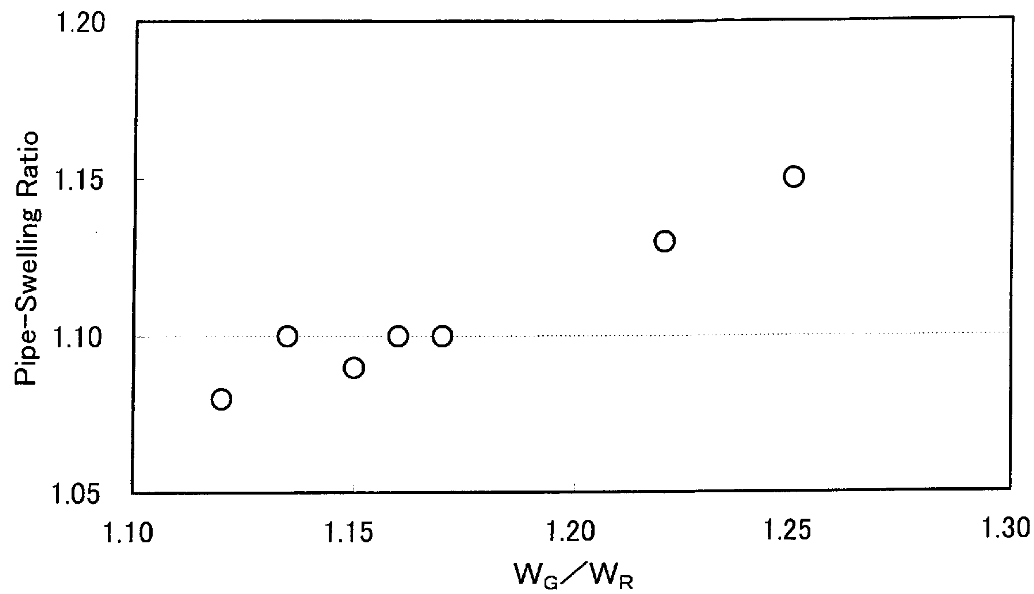
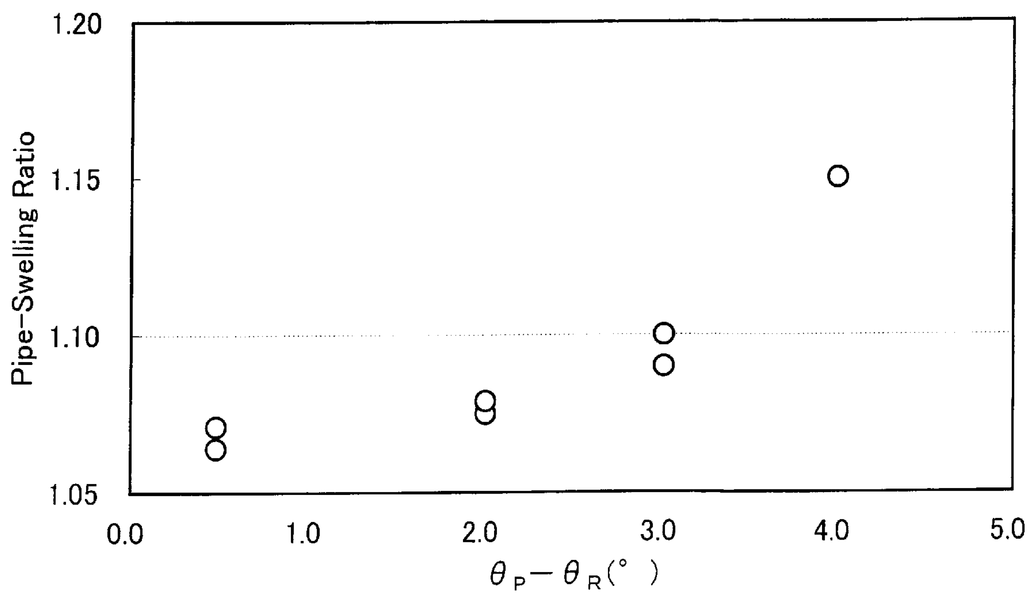


Figure 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/072006

A. CLASSIFICATION OF SUBJECT MATTER
B21B19/04(2006.01)i, *B21B27/00*(2006.01)i, *B21B27/02*(2006.01)i, *B21B27/10*(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)
B21B19/04, B21B27/00, B21B27/02, B21B27/10

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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 A	WO 2005/115650 A1 (Sumitomo Metal Industries, Ltd.), 08 December, 2005 (08.12.05), Par. Nos. [0062] to [0063]; table 5; Claims & US 2007/0062238 A1 & EP 1757376 A1 & CN 1960816 A	1 2-6
A	JP 4-319006 A (Kawasaki Steel Corp.), 10 November, 1992 (10.11.92), Full text (Family: none)	2-6

☒ 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	Date of mailing of the international search report
05 February, 2009 (05.02.09)	17 February, 2009 (17.02.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/072006

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 10-81937 A (Pacific Steel Mfg. Co., Ltd.), 31 March, 1998 (31.03.98), Full text & US 5813962 A & US 5950310 A & EP 816521 A2 & DE 69706608 D & DE 69706608 T & AU 2836797 A & AU 733467 B & MX 9704871 A	2-6

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

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- JP 2001096304 A **[0010]**
- JP 2003053403 A **[0010]**
- JP 7124612 A **[0010]**
- JP 6262219 A **[0010]**
- JP 11285709 A **[0010]**