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(54) **MANDREL MILL, ITS OPERATING METHOD, AND SEAMLESS PIPE MANUFACTURING METHOD**

(57) The object of the present invention is to provide a mandrel mill capable of producing a seamless pipe without flaws such as necking. The mandrel mill of the present invention includes a plurality of consecutively provided grooved-roll stands and a mandrel bar 3 provided in a roll groove array formed by the grooved-roll stands so as to continuously elongate a hollow shell 2. Roll grooves 4 of at least a first stand and a second stand are arranged so as to satisfy conditions represented by the following formulas (1) to (4):

$$b \leq 10a + 1.5 \quad (1)$$

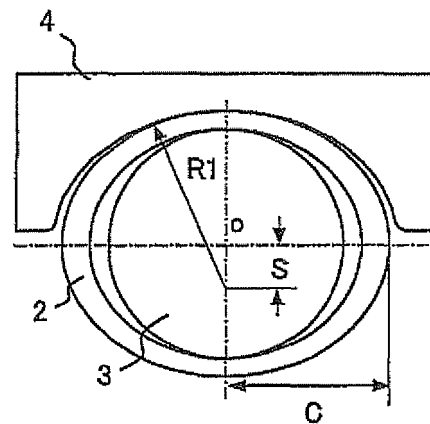
$$b \leq -a + 1.5 \quad (3)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \geq -a + 1.15 \quad (4)$$

wherein  $a = S/R1$ ,  $b = C/(R1-S)$ .

[Figure 1]



## Description

### Technical Field

**[0001]** The present invention relates to a mandrel mill that does not generate holes, roll slip flaws, cornice flaws, and the like, an operating method of the same, and a production method of a seamless pipe.

### Background Art

**[0002]** Ordinarily, as a rolling machine of seamless pipes, there is a mandrel mill that has six to eight units of roll stands, each composed of a pair of upper and lower mill rolls, such that the groove bottom directions of the roll grooves of the anteroposterior stand across from one another at 90°. In the mandrel mill, a hollow shell is continuously elongated by arranging the mandrel bar in a roll groove array formed by the plurality of roll stands.

**[0003]** Fig. 3 is a schematic diagram showing an entire configuration of the mandrel mill. As shown in the figure, the mandrel mill has grooved-roll stands 11 to 14 each composed of a pair of mill rolls 4, and multiple units (four units in the figure) are provided consecutively so that each roll stand across from each other at 90°. A seamless pipe is produced by inserting a mandrel bar 3 in a hollow shell 2 bored in advance with a piercer, and sequentially rolling and elongating this by the roll stands 11 to 14. The roll stands provided are called, in the order from mill entry side, a first stand (11 in the figure), a second stand (12 in the figure), a third stand (13 in the figure), and a fourth stand (14 in the figure). Generally, the wall thickness is first reduced at the first stand.

**[0004]** Patent document 1 discloses an invention of a mandrel mill that includes a plurality of consecutively provided grooved-roll stands crossing with each other and rolls a hollow shell with a mandrel bar provided in a roll groove array formed by the grooved-roll stands, wherein the ellipticity of the groove of a first or/and second stand is in the range of 1.25 to 1.40. This prevents a generation of hole occurrence and pipe end cracking.

**[0005]** Patent document 2 discloses an invention of a mandrel mill that includes a plurality of grooved-roll stands and rolls a hollow shell with a mandrel bar provided in a roll groove array formed by the grooved-roll stands, wherein the circumferential length of the roll groove of a first stand is at least 1.12 times the hot-finished circumferential length of the pipe on the mill exit side.

**[0006]** Patent document 3 discloses an invention of a mandrel mill that includes a plurality of grooved-roll stands and rolls a hollow shell with a mandrel bar provided in a roll groove array formed by the grooved-roll stands, wherein the radius of groove bottom curvature of the roll groove of a first stand is 0.54 times or less the roll groove bottom interval.

**[0007]** Patent document 4 discloses an invention of a mandrel mill that includes a plurality of consecutively pro-

vided grooved-roll stands and elongates a hollow shell continuously with a mandrel bar provided in a roll groove array formed by the grooved-roll stands. In the mandrel mill, the radius R1 of the groove bottom curvature of the roll groove of each stand and a displacement-offset-amount S between the groove bottom curvature center and the mill center have a ratio S/R1 of at least 30, and the ellipticity of a second stand is 1.20 or less.

### [0008]

[Patent document 1] Japanese Unexamined Patent Publication No. 2001-113306

[Patent document 2] Japanese Patent Publication No. 2582705

[Patent document 3] Japanese Examined Patent Publication Hei 7-102369

[Patent document 4] Japanese Patent Publication No. 2985719

### [Disclosure of the Invention]

### [Problems to be Solved by the Invention]

**[0009]** Patent document 1 describes that in order to prevent a hole generation on the elongated seamless pipe, it is effective to limit the ellipticity of the groove. However, even though the ellipticity is adjusted, a flaw may occur in some cases on the elongated seamless pipe depending on the offset amount.

**[0010]** Patent document 2 discloses a technique that limits the circumferential length of the roll groove of the first stand, or further the second stand of the mandrel mill, within a certain range relative to a hot-finished circumferential length of the pipe at the mill exit side, a suitable gap is secured between the mandrel bar and the inner surface of the hollow shell that is being elongated, thereby preventing missed stripping. However, in some cases no consideration is given to ellipticity nor offset, which could cause a flaw to occur on the elongated seamless pipe.

**[0011]** Patent document 3 describes that hole occurrence is suppressed. However, even if the offset is reduced, if the ellipticity is not adjusted in an appropriate range, a flaw may occur on the elongated seamless pipe.

**[0012]** Patent document 4 describes that in the mandrel mill, by limiting the ellipticity and offset as well within predetermined ranges, it is possible to suppress a generation of the necking phenomenon and reduce the hole occurrence. However, there is no indication of the relationship between the ellipticity and the offset.

**[0013]** The present inventors conducted an extensive study to solve the problems of the conventional art, and as a result, have found an effective ellipticity-offset balance for preventing flaw generation on an elongated seamless pipe, resulting in a completion of the present invention. It is an objective of the present invention to provide a mandrel mill with minimized flaw occurrence on an elongated seamless pipe.

## [Means to Solve the Problem]

[0014] The gist of the present invention is: a mandrel mill indicated as (1) below; an operating method of the mandrel mill indicated as (2) below; and a production method of a seamless pipe indicated as (3) below.

[0015] (1) A mandrel mill comprising a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands so as to continuously elongate a hollow shell, **characterized in that** roll grooves of at least a first stand and a second stand are arranged so as to satisfy conditions represented by the following formulas (1) to (4).

[0016]

$$b \leq 10a + 1.5 \quad (1)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \leq -a + 1.5 \quad (3)$$

$$b \geq -a + 1.15 \quad (4)$$

[0017] In the formulas above, "a" is a ratio of S/R1 between a groove bottom curvature radius R1 of each grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and a mill center, and "b" is ellipticity.

[0018] (2) An operating method of a mandrel mill including a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands, **characterized in that** a hollow shell is continuously elongated when a groove bottom curvature radius R1, a displacement-offset-amount S, and ellipticity of each of grooved-rolls satisfy conditions represented by the above formulas (1) to (4) in at least a first stand and a second stand, whereby a hole occurrence and flaw generation are prevented.

[0019] (3) A production method of a seamless pipe using a mandrel mill including a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands, **characterized in that** a hollow shell is continuously elongated when a groove bottom curvature radius R1, a displacement-offset-amount S, and ellipticity of each of grooved-rolls satisfy conditions represented by the above formulas (1) to (4) in at least a first stand and a second stand.

## Effects of the Invention

[0020] According to the present invention, a hollow shell is rolled with a good balance between offset and ellipticity, thereby making it possible to suppress the hole occurrence and flaw generation on an elongated seamless pipe. Therefore, flaws such as necking can be suppressed even in the case of rolling a thin wall pipe and a high alloy steel pipe, which are easily subject to defects.

## BEST MODE FOR CARRYING OUT THE INVENTION

[0021] The mandrel mill of the present invention is a mandrel mill that includes a plurality of consecutively provided grooved-roll stands and also a mandrel bar provided in a roll groove array formed by the grooved-roll stands so as to continuously elongate a hollow shell.

[0022] Referring to Fig. 3 shown above, in the mandrel mill of the present invention, multiple units (four units in the figure) of grooved-roll stands 1 each composed of a pair of mill rolls 4 are provided so as to cross each other at 90°. A seamless pipe is produced by inserting a mandrel bar 3 in a hollow shell 2 bored in advance with a piercer, and sequentially elongating this on the roll stands 11 to 14.

[0023] Fig. 4 is a schematic diagram showing a rolling state of a hollow shell in the mandrel mill. In Fig. 4, (a) to (f) each shows a rolling state of the hollow shell at first to the sixth stands. Additionally, (b) to (f) each shows a figure with the grooved-rolls omitted. In Fig. 4, an example of a mandrel mill with six stands is shown, but the number of the stands is not limited.

[0024] Referring to Fig. 4, in the mandrel mill of the present invention, the rolling is conducted by continuously passing a hollow shell 2 that a mandrel bar 3 is inserted through the pairs of grooved-rolls 4. The wall thickness and diameter reduce gradually through the stands.

[0025] Referring to Fig. 3, in the mandrel mill, a hollow shell 2 is elongated by the grooved-rolls 4 and the mandrel bar 3. Specifically, a part of the hollow shell 2 located at a groove bottom portion of each grooved-roll 4 (a portion of contact between each grooved-roll 4 and the hollow shell 2) is rolled to reduce the wall thickness. On the other hand, a part of the hollow shell 2 located at a flange part (a portion where each grooved-roll 4 and the hollow shell 2 do not make contact) is pulled and elongated in the hollow shell axis direction based on the deformation of the part of the hollow shell 2 located at the groove bottom portion in the hollow shell axis direction that results from rolling.

[0026] That is, the part of the hollow shell 2 located at the flange part receives no internal surface pressure and substantially no external surface pressure, and thus close to uniaxial tension, receiving only tensile force in the hollow shell axis direction. Therefore, the part of the hollow shell 2 located at the flange part easily encounters what is called a necking phenomenon, which refers to a partial reduction in wall thickness. If this necking phe-

nomenon occurs dramatically, a hollow shell that is being elongated will break into generate holes.

**[0027]** In the mandrel mill of the present invention, in order to eliminate such a problem, the roll grooves of at least the first stand and the second stand are arranged so as to satisfy the following formulas (1) to (4).

**[0028]**

$$b \leq 10a + 1.5 \quad (1)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \leq -a + 1.5 \quad (3)$$

$$b \geq -a + 1.15 \quad (4)$$

**[0029]** In the formulas above, "a" is a ratio of S/R1 between a groove bottom curvature radius R1 of each grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and a mill center, and "b" is ellipticity. The groove bottom curvature radius R1 of each grooved-roll and the displacement-offset-amount S between the groove bottom curvature center and the mill center are shown in Fig. 1. The ellipticity is represented by  $C/(R1-S)$  using the curvature radius R1, the displacement-offset-amount S between the groove bottom curvature center and a mill center O, and a longer radius C of the hollow shell are shown in Fig. 1.

**[0030]** Fig. 2 is a figure showing the relationship between: the ratio S/R1 between the groove bottom curvature radius R1 of the grooved-roll and the displacement-offset-amount S between the groove bottom curvature center and the mill center, and the ellipticity in the mandrel mill of the present invention. It is noted that the relationship shown in the figure is regarding the first stand.

**[0031]** Referring to Fig. 2, in the case where the foregoing formula (1) is not satisfied, that is, where the value of the ratio S/R1 is too small relative to ellipticity b, the hollow shell that is being elongated turns into an under-filled state relative to the grooved-roll. The term "under-filled" means such a state that the outer circumferential length of the hollow shell being elongated does not increase sufficiently and thus is excessively small relative to the groove circumferential length (outer circumferential length of a projected groove profile). In the under-filled state, drawing-out failure of the bar (striping failure) or hole occurrence due to necking arises even though the ellipticity is large.

**[0032]** In the case where the foregoing formula (2) is not satisfied, that is, where the value of the ratio S/R1 is

too large relative to the ellipticity b, the hollow shell that is being elongated turns into an over-filled state relative to the grooved-roll. The term "over-filled" means such a state that the outer circumferential length of the hollow shell being elongated increases excessively, resulting in protrusion from the grooved flange. In the over-filled state, the hollow shell protrudes from the grooved flange and a burning flaw occurs on the surface of the hollow shell. In addition, such a phenomenon occurs that the advance speed of a part of the hollow shell corresponding to the roll groove bottom part of the next stand is smaller than the circumferential speed of the roll groove bottom part, resulting in a flaw in the form of a fold on the hollow shell.

**[0033]** In the case where the foregoing formula (3) is not satisfied, that is, where the value of the ellipticity b is too large relative to the ratio S/R1, an over-filled state results as well. In this case, the hollow shell that is being elongated protrudes from the grooved flange to cause burning to occur, resulting in a burning flaw on the surface. In addition, such a phenomenon occurs that the advance speed of the hollow shell in the next stand is smaller than the circumferential speed of the roll groove bottom part, resulting in a flaw in the form of a fold on the hollow shell.

**[0034]** In the case where the foregoing formula (4) is not satisfied, that is, where the value of the ellipticity b is too small relative to the ratio S/R1, an under-filled state results. In this case, problems occur including drawing-out failure of the bar (striping failure) or hole occurrence due to necking.

**[0035]** In the mandrel mill of the present invention, the grooved-rolls of only at least the first stand and the second stand may be arranged so as to satisfy the conditions represented by the foregoing formulas (1) to (4). This is because the rolling reduction rate in the first stand and the second stand is generally larger than that in the other stands during mandrel mill rolling, and the influence that the groove shapes of the first and second stands have on rolling is significantly larger than the influence of the groove shapes of the third and later stands.

**[0036]** As described above, specifying the ratio S/R1 and the ellipticity individually may fail to solve various problems associated with rolling. In the present invention, by operating the mandrel mill under the conditions represented by the foregoing formulas (1) to (4), it is possible to stably produce a seamless pipe without hole occurrence and flaws.

#### Industrial Applicability

**[0037]** According to the present invention, the hollow shell is rolled with a good balance between offset and ellipticity, and thus it is possible to suppress hole occurrence and flaw generation in an elongated seamless pipe. Therefore, a flaw such as necking can be suppressed even in the case of rolling a thin wall pipe and a high alloy steel pipe, which are easily subject to flaws.

## Brief Description of the Drawings

[0038]

Fig. 1 is a schematic diagram showing a positional relationship between a grooved-roll, a hollow shell, and a mandrel bar in a mandrel mill of the present invention.

Fig. 2 is a figure showing a relationship between: the ratio S/R1 between a groove bottom curvature radius R1 of a grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and the mill center, and ellipticity in the mandrel of the present invention.

Fig. 3 is a schematic diagram showing an entire configuration of the mandrel mill.

Fig. 4 is a schematic diagram showing a rolling state of a seamless pipe on the mandrel mill, with (a) to (f) respectively showing a rolling state of the seamless pipe at the first to sixth stands of the mandrel mill.

## Description of reference number

[0039]

11, 12, 13, 14. Roll stand

2. Hollow shell

3. Mandrel bar

4. Grooved-roll

R1. Groove bottom curvature center

O. Mill center

S. Displacement-offset-amount between groove bottom curvature center and mill center

C. Longer radius of pipe material

## Claims

1. A mandrel mill comprising a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands so as to continuously elongate a hollow shell, **characterized in that** roll grooves of at least a first stand and a second stand are arranged so as to satisfy conditions represented by the following formulas (1) to (4):

$$b \leq 10a + 1.5 \quad (1)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \leq -a + 1.5 \quad (3)$$

$$b \geq -a + 1.15 \quad (4)$$

wherein "a" is a ratio of S/R1 between a groove bottom curvature radius R1 of each grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and a mill center, and "b" is ellipticity.

2. An operating method of a mandrel mill including a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands, **characterized in that** a hollow shell is continuously elongated when a groove bottom curvature radius R1, a displacement-offset-amount S, and ellipticity of each of grooved-rolls satisfy conditions represented by the following formulas (1) to (4) in at least a first stand and a second stand, whereby a hole occurrence and flaw generation are prevented:

$$b \leq 10a + 1.5 \quad (1)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \leq -a + 1.5 \quad (3)$$

$$b \geq -a + 1.15 \quad (4)$$

wherein "a" is a ratio of S/R1 between a groove bottom curvature radius R1 of each grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and a mill center, and "b" is ellipticity.

3. A production method of a seamless pipe using a mandrel mill including a plurality of consecutively provided grooved-roll stands and a mandrel bar provided in a roll groove array formed by the grooved-roll stands, **characterized in that** a hollow shell is continuously elongated when a groove bottom curvature radius R1, a displacement-offset-amount S, and ellipticity of each of grooved-rolls satisfy conditions represented by the following formulas (1) to (4) in at least a first stand and a second stand:

$$b \leq 10a + 1.5 \quad (1)$$

$$b \geq 10a - 0.2 \quad (2)$$

$$b \leq -a + 1.5 \quad (3)$$

$$b \geq -a + 1.15 \quad (4)$$

wherein "a" is a ratio of S/R1 between a groove bottom curvature radius R1 of each grooved-roll and a displacement-offset-amount S between a groove bottom curvature center and a mill center, and "b" is ellipticity.

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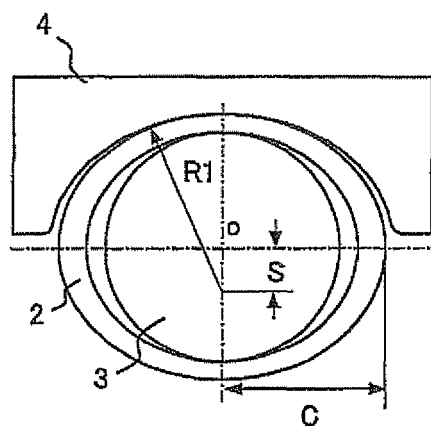
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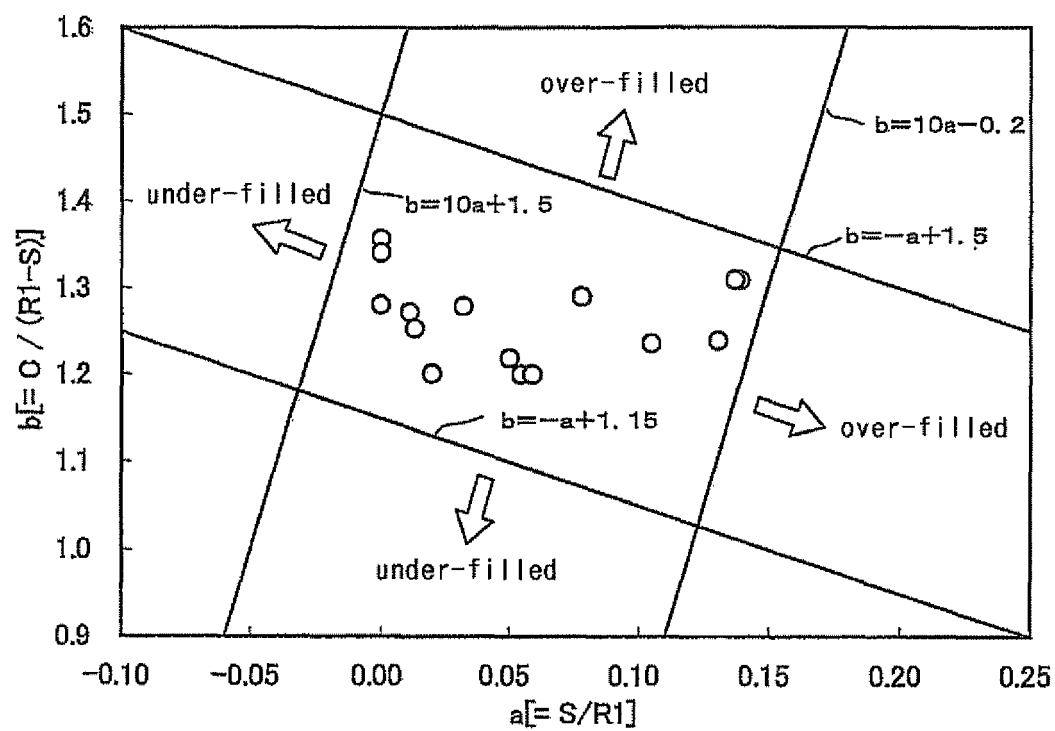
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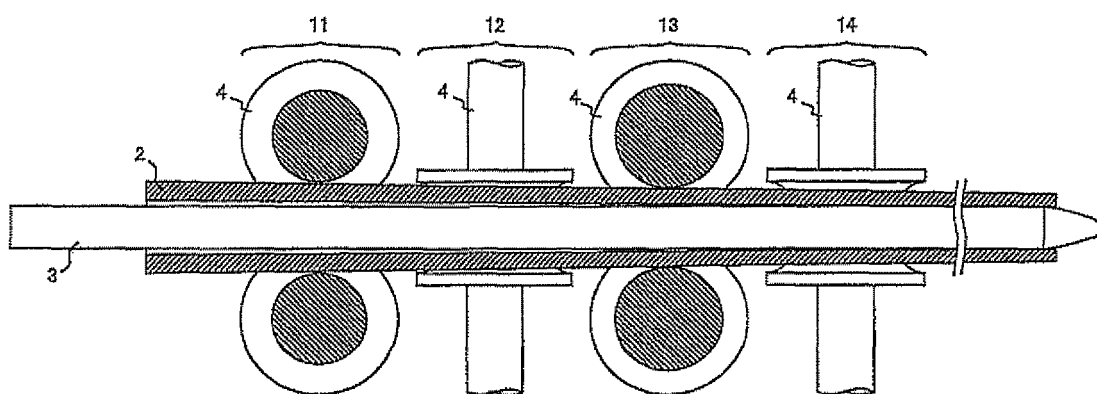
[Figure 1]



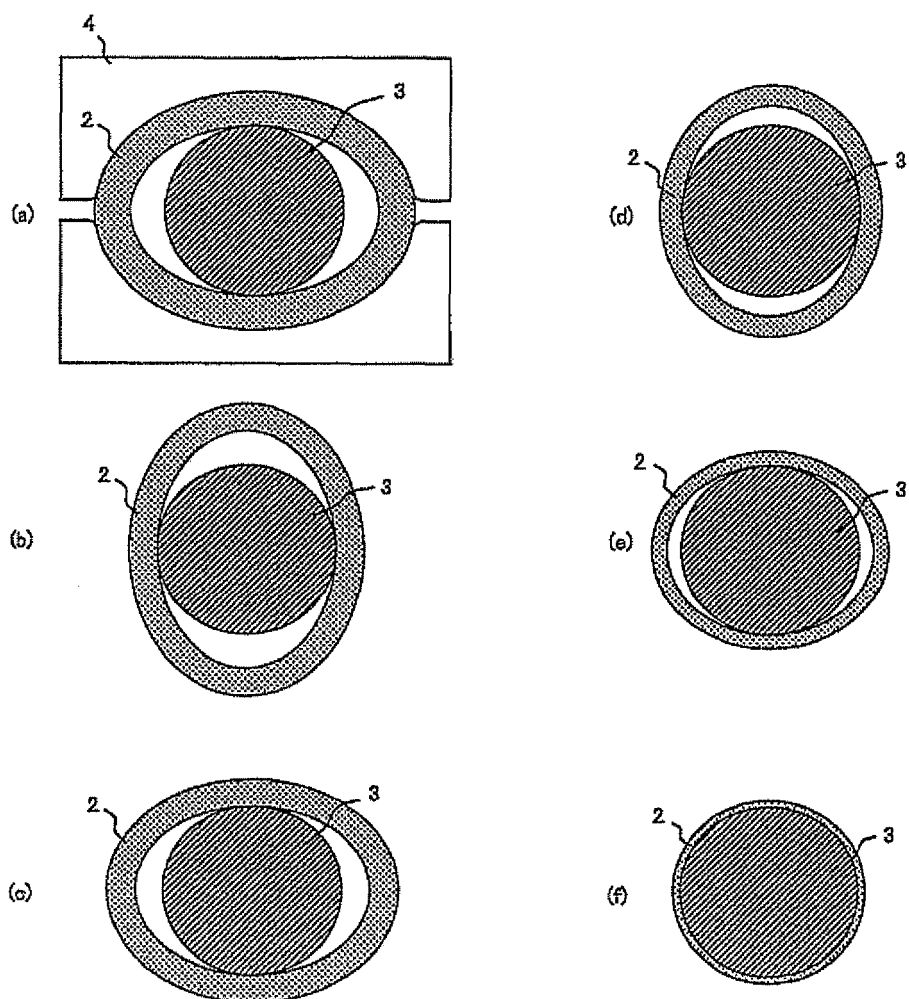
[Figure 2]



[Figure 3]



[Figure 4]



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/070732

| A. CLASSIFICATION OF SUBJECT MATTER<br>B21B17/02(2006.01)i, B21B27/02(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)<br>B21B17/02, B21B27/02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                            |                                                                                   |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008<br>Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                            |                                                                                   |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                            |                                                                                   |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                            |                                                                                   |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                         | Relevant to claim No.                                                             |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 2985719 B2 (Sumitomo Metal Industries, Ltd.),<br>01 October, 1999 (01.10.99),<br>Tables 1, 2; Fig. 1<br>& JP 8-276208 A | 1-3                                                                               |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                            |                                                                                   |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |                                                                                                                            |                                                                                   |
| Date of the actual completion of the international search<br>10 January, 2008 (10.01.08)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                            | Date of mailing of the international search report<br>22 January, 2008 (22.01.08) |
| Name and mailing address of the ISA/<br>Japanese Patent Office                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                            | Authorized officer                                                                |
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Form PCT/ISA/210 (second sheet) (April 2007)

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 2001113306 A [0008]
- JP 2582705 B [0008]
- JP HEI7102369 B [0008]
- JP 2985719 B [0008]