

Description

TECHNICAL FILED

5 **[0001]** The present invention relates to a method and an apparatus for properly adjusting rolling positions of rolling rolls constituting a three-roll mandrel mill in the mandrel mill used to produce the seamless tubes and pipes.

BACKGROUND ART

10 **[0002]** In the production of the seamless tubes and pipes (hereinafter, referred to as tubes) by a Mannesmann-mandrel mill method, firstly, a round billet or a square billet which is of a raw material is heated in a range of 1200 to 1260 °C with a rotary hearth type heating furnace, and then a piercer pierces and rolls the round billet or the square billet to produce a hollow shell by using a plug and rolling rolls. Then, a mandrel bar is inserted into the bore of the hollow shell in a skewered manner, usually the hollow shell is elongated by the mandrel mill comprising five to eight stands while an
15 outer surface of the hollow shell is constrained by the caliber rolling rolls, and thereby the hollow shell is reduced to a predetermined wall thickness. Then, after the mandrel bar is extracted, the tube material whose wall thickness is reduced is subjected to a sizing process, whereby the tube material is formed and rolled in a predetermined outer diameter to obtain a product by a reducer mill.

[0003] Conventionally, a two-roll mandrel mill is often used as the mandrel mill. In the two-roll mandrel mill, a pair of
20 caliber rolling rolls facing each other is arranged in each stand, and the rolling rolls are arranged so that the reduction orientation of the rolling rolls is alternately disposed out of phase by 90° between adjacent stands. There is also partially applied a four-roll mandrel mill in which the four caliber rolling rolls are arranged in each stand so that an angle formed by the reduction directions is 90°. There is also proposed a three-roll mandrel mill. In the three-roll mandrel mill, the
25 three caliber rolling rolls are arranged in each stand so that the angle formed by the reduction directions is 120°, and the rolling rolls are arranged while the rolling positions of the rolling rolls are alternately out of phase by 60° between the adjacent stands.

[0004] In order to secure wall thickness accuracy of a rolled material (tube material) to suppress the wall thickness eccentricity in the mandrel mill, it is important to control the rolling position of each of rolling rolls constituting the mandrel mill at a proper position.

30 **[0005]** Therefore, in the two-roll mandrel mill, there is used a rolling position control method, in which the flange portions of the caliber rolling rolls facing each other are brought into contact with each other once and the rolling position of each rolling roll is set at a zero point at this point (for example, see Japanese Patent Application Publication No. 9-174118). However, in the case of the three-roll mandrel mill or the four-roll mandrel mill, since there are a lot of relative relationships among the rolling positions of the rolling rolls, the zero point cannot correctly be adjusted by the method used in the two-
35 roll mandrel mill. Therefore, there is a problem that the rolling position of each rolling roll cannot be controlled at a proper position.

[0006] In the four-roll mandrel mill, there is proposed a method, in which a wall thickness measuring device with a radiation beam is arranged on an exit side of the mandrel mill, the wall thickness (added value with the wall thicknesses at the opposite portions in the rolled material through which the radiation beam passes) of the rolled material is measured
40 by the wall thickness measuring device, and the rolling position of the rolling roll is adjusted based on the measurement value (for example, see Japanese Patent Application Publication No. 8-71616).

Fig. 1 is a view explaining an arrangement relationship of the rolling rolls in the three-roll mandrel mill. As shown in Fig. 1, in the case of the three-roll mandrel mill, the portion of the rolled material opposite from the position corresponding to a groove bottom portion of each rolling roll becomes the position corresponding to the flange portion of another rolling roll, and generally the wall thickness of the rolled material tends to be easily influenced at the position corresponding to the flange portion depending on the rolling conditions. Therefore, it is difficult to estimate the relationship between the
45 wall thickness and the rolling position of the rolling roll.

Accordingly, it is difficult to adjust the rolling position of the rolling roll based on the measurement value, even if the added value with the wall thicknesses at the opposite portions of the rolled material through which the radiation beam
50 passes is measured by the radiation wall thickness measuring device described in Japanese Patent Application Publication No. 8-71616, namely, even if the added value with the wall thicknesses at the opposite portions to each other in the rolled material through which the radiation beam passes (the added value of the wall thickness at the portion corresponding to the groove bottom portion of each rolling roll and the wall thickness at the position corresponding to the flange portion of another rolling roll) is measured by the radiation wall thickness measuring device.

DESCLOSURE OF THE INVENTION

55 **[0007]** As described above, in the three-roll mandrel mill, unlike the two-roll mandrel mill and the four-roll mandrel mill,

there is not currently proposed an effective method in which the wall thickness accuracy of the rolled material is secured and the wall thickness eccentricity is suppressed by controlling the rolling position of each of rolling rolls constituting the mandrel mill at a proper position.

[0008] In view of the foregoing, it is a task of the present invention to provide a method and an apparatus for properly adjusting the rolling positions of the rolling rolls constituting the three-roll mandrel mill.

[0009] In order to achieve the above task, as a result of earnest studies, the present inventor completes the present invention by finding the fact that the rolling position of each rolling roll can properly be adjusted while the wall thickness accuracy of the rolled material is secured and the wall thickness eccentricity is suppressed, when the wall thickness of the rolled material is measured at the position corresponding to the groove bottom portion of each rolling roll, where the relationship with the rolling position of the rolling roll can be estimated, and when the rolling position of the rolling roll is adjusted based on the measurement value, unlike the conventional method in which the added value of the wall thickness at the portion corresponding to the groove bottom portion of each rolling roll and the wall thickness at the position corresponding to the flange portion of another rolling roll are measured.

That is, the present invention provides a method of adjusting the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the method characterized by including a first step of measuring a wall thickness of a rolled material at a position corresponding to a groove bottom portion of each rolling roll; a second step of computing a deviation between each measured wall thickness and a target wall thickness; and a third step of adjusting the rolling position of each rolling roll based on each computed deviation.

[0010] According to the present invention, the wall thickness of the rolled material is measured at the position corresponding to the groove bottom portion of each rolling roll, the deviation between each measured wall thickness and a target wall thickness is measured, and the rolling position of each rolling roll is adjusted based on each computed deviation. The deviation corresponds to a position displacement of the zero point, which comes to be a position adjustment reference of each rolling roll, that is planned in a rolling schedule. Therefore, when the rolling position is adjusted based on the deviation such that the deviation becomes zero, the rolling position can properly be adjusted for each rolling roll.

[0011] For example, a multi-beam radiation measurement method disclosed in "IRON AND STEEL" (1970 No. 9, pp 1139-1145) may be applied in order to measure the wall thickness of the rolled material at the position corresponding to the groove bottom portion of each rolling roll. In the multi-beam radiation measurement method, the radiation beams are arranged so as to intersect one another at the position (the middle of the wall thickness at the position corresponding to the groove bottom portion) corresponding to the groove bottom portion of each rolling roll of the rolled material.

[0012] Actually, in the mandrel mill, sometimes a misalignment generates between a center position of the rolled material (the alignment center of the rolled material) and a gravity center position got with each position (the radiation beam intersecting position in the case that the multi-beam radiation method is adopted) where the wall thickness of the rolled material is measured.

Fig. 2 is a view explaining an apparent wall thickness eccentricity which generates when the center position of the rolled material deviates. When the misalignment generates, sometimes the apparent generation of the wall thickness eccentricity is observed even if the wall thickness eccentricity does not actually generate in the rolled material. Although Fig. 2 shows the wall thickness of the whole circumference of the rolled material for the sake of convenience, actually only the wall thickness at the position corresponding to the groove bottom portion of each rolling roll is measured. Such an error of the wall thickness measurement occasionally results in an adjustment error of the rolling position of each rolling roll.

[0013] Accordingly, the method of adjusting the rolling position of the rolling roll preferably includes a step of measuring a center position of the rolled material; and a step of computing a deviation between the measured center position and a gravity center position got with each position where the wall thickness of the rolled material is measured in the first step, wherein each measured wall thickness is corrected based on the computed deviation and then a deviation between the corrected wall thickness and the target wall thickness is computed in the second step.

[0014] According to the present invention, the center position of the rolled material is measured, the deviation between the measured center position and the gravity center position got with each position where the wall thickness of the rolled material is measured is computed, each measured wall thickness is corrected based on the computed deviation, and a deviation between the corrected wall thickness and the target wall thickness is computed. Then, the rolling position is adjusted based on each corrected wall thickness, so that the higher-accuracy adjustment method can be realized.

[0015] For the measurement of the center position of the rolled material, for example, the outer diameter of the rolled material is measured in directions orthogonal to each other, and a center position coordinate can be computed based on the center position of the outer diameter measured in one direction and the center position of the outer diameter measured in the other direction (the direction substantially orthogonal to one direction). In order to correct each measured wall thickness based on the deviation between the measured center position and the gravity center position got with each position where the wall thickness of the rolled material is measured, a correlation between the deviation and the error of the wall thickness measurement (apparent amount of the wall thickness eccentricity) is brought about by experiments or the like in advance, and each measured wall thickness may be corrected based on the correlation.

[0016] Fig. 3 is a view illustrating rolling rolls in the three-roll mandrel mill that are made to adjust a zero-point. As

shown in Fig. 3, although the zero-point adjustment is performed in a state that the flange portions of rolling rolls R1, R2 are in contact with each other and at the position where the flange portions of the rolling rolls R1, R3 are in contact with each other in the three rolling rolls R1, R2, R3 (the rolling position of each rolling roll is moved only by the equal distance from the zero-point position in rolling the rolled material), sometimes the wall thickness of the rolled material is measured as the substantially same value at the position corresponding to the groove bottom portion of each rolling roll. Therefore, the rolling position of each rolling roll is assumed to be proper.

However, even if the wall thickness of the rolled material is measured as the substantially same value at the position corresponding to the groove bottom portion of each rolling roll, in the case shown in Fig. 3, the wall thickness of the rolled material at the position corresponding to the portion extended toward the flange portion side from the groove bottom portion of each rolling roll is different from the wall thickness at the position corresponding to groove bottom portion of each rolling roll. The difference results in the generation of the wall thickness eccentricity in the rolled material.

[0017] As a result of earnest studies on the method of being able to properly adjust the rolling position of each rolling roll even in the above situation, the present inventor completes the present invention by finding the fact that the rolling position of each rolling roll can properly be adjusted while the wall thickness accuracy of the rolled material is secured and the wall thickness eccentricity is suppressed, when the wall thicknesses of the rolled material are measured at the positions which are extended toward both flange portion sides from the groove bottom portion of each rolling roll respectively, and when the rolling position of each rolling roll is adjusted based on the measurement values.

That is, in order to achieve the above task, the present invention provides a method of adjusting the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the method characterized by including a step of measuring a wall thickness of a rolled material at a position corresponding to a portion extended toward one flange portion side from a groove bottom portion of each rolling roll while the wall thickness of the rolled material is measured at a position corresponding to a portion extended toward the other flange portion side; a step of computing a deviation between the measured wall thickness at the position corresponding to the portion extended toward one flange portion side and the measured wall thickness at the position corresponding to the portion extended toward the other flange portion side; and a step of adjusting the rolling position of each rolling roll based on each computed deviation.

[0018] According to the present invention, the wall thickness of the rolled material is measured at a position corresponding to the portion extended toward one flange portion side from the groove bottom portion of each rolling roll while the wall thickness of the rolled material is measured at the position corresponding to the portion extended toward the other flange portion side, and the rolling position of each rolling roll is adjusted based on the deviation between the measurement values. Accordingly, even if the rolling position of each rolling roll is considered to be apparently proper since the wall thickness of the rolled material is measured as the substantially same value at the position corresponding to the groove bottom portion of each rolling roll, the rolling position can be adjusted at the actually proper position.

[0019] An adjustment amount of the rolling position of each rolling roll based on the deviation between both the measurement values may be determined such that the deviation between both measurement values becomes zero based on a geometrical condition of the measurement positions of both the measurement values and the groove bottom positions.

[0020] In order to achieve the above task, the present invention provides an apparatus which adjusts rolling positions of the rolling rolls constituting a three-roll mandrel mill, the apparatus characterized by including a wall thickness measuring device which is provided with a plurality of the radiation sources and a plurality of the detectors, the plurality of the detectors being arranged while facing the radiation sources through a rolled material respectively, the wall thickness measuring device measuring a wall thickness of the rolled material at a position corresponding to a groove bottom portion of each rolling roll; and a rolling position control device which computes a deviation between each measured wall thickness and a target wall thickness, the rolling position control device controlling each rolling roll drive device based on each computed deviation.

[0021] Preferably, the apparatus which adjusts the rolling position of the rolling roll includes a center position measuring device which measures a center position of the rolled material by measuring an outer diameter of the rolled material in directions substantially orthogonal to each other, wherein the rolling position control device computes a deviation between the center position measured by the center position measuring device and a gravity center position that is an intersection point of radiation beams from a plurality of radiation sources constituting the wall thickness measuring device, the rolling position control device corrects each measured wall thickness based on the computed deviation, and then the rolling position control device computes a deviation between each corrected wall thickness and the target wall thickness.

[0022] In order to achieve the above task, the present invention also provides an apparatus which adjusts rolling positions of the rolling rolls constituting a three-roll mandrel mill, the apparatus characterized by including a wall thickness measuring device which is provided with a plurality of the radiation sources and a plurality of the detectors, the plurality of the detectors being arranged while facing the radiation sources through a rolled material respectively, the wall thickness measuring device measuring a wall thickness of a rolled material at each position corresponding to a portion extended toward one flange portion side from a groove bottom portion of each rolling roll while measuring the wall thickness of the rolled material at a position corresponding to a portion extended toward the other flange portion side; and a rolling

position control device which computes a deviation between the measured wall thickness at the position corresponding to the portion extended toward one flange portion side and the measured wall thickness at the position corresponding to the portion extended toward the other flange portion side, the rolling position control device controlling each rolling drive device based on each computed deviation.

[0023] According to the present invention, the wall thickness of the rolled material is measured at the position corresponding to the groove bottom portion of each rolling roll, the deviation between each measured wall thickness and the target wall thickness determined by the rolling schedule is computed, and the rolling position of each rolling roll is adjusted based on each computed deviation. Since the deviation corresponds to the position displacement of the zero point, which comes to be the position adjustment reference, that is planned in the rolling schedule in each rolling roll, when the rolling position is adjusted based on the deviation such that the deviation becomes zero, the proper rolling position can be adjusted for each rolling roll while the wall thickness accuracy of the rolled material is secured to suppress the wall thickness eccentricity for each rolling roll.

Further, according to the present invention, the wall thickness of the rolled material is measured at the position corresponding to the portion extended toward one flange portion side from the groove bottom portion of each rolling roll, the wall thickness of the rolled material is measured at the position corresponding to the portion extended toward the other flange portion side, and the rolling position of each rolling roll is adjusted based on each of the deviations of the both measured values.

Therefore, the rolling position can be properly adjusted at the actually proper position, even if the rolling position of each rolling roll is considered to be apparently proper since the wall thickness of the rolled material is measured as the substantially same value at the position corresponding to the groove bottom portion of each rolling roll.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Fig. 1 is a view explaining a positional relationship among the rolling rolls in a three-roll mandrel mill;

Fig. 2 is a view explaining an apparent wall thickness eccentricity which appears to generate when a center position of a rolled material is deviated;

Fig. 3 is a view illustrating the rolling rolls in the three-roll mandrel mill that are made to adjust a zero-point;

Fig. 4 is a view showing a schematic configuration of a rolling position adjustment device of the rolling rolls constituting a three-roll mandrel mill according to the first embodiment of the present invention;

Fig. 5 is a view showing a schematic configuration of a wall thickness measuring device according to an embodiment of the present invention;

Fig. 6 is a view explaining a measuring point of a wall thickness measuring device according to an embodiment of the present invention;

Fig. 7 is an explanatory view showing an arrangement relationship among the rolling rolls in the three-roll mandrel mill;

Fig. 8 is a view showing an example of a relationship between a center position deviation amount of the rolled material and an amount of the apparent wall thickness eccentricity;

Fig. 9 is a view explaining the measuring point of a wall thickness measuring device according to another embodiment of the present invention; and

Fig. 10 is a view showing a schematic configuration of a rolling position adjustment device of the rolling rolls constituting a three-roll mandrel mill according to the second embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Preferred embodiments of the present invention will be described below with reference to the accompanying drawings.

1. The First Embodiment

[0025] Fig. 4 is a view showing a schematic configuration of a rolling position adjustment device of the rolling rolls constituting a three-roll mandrel mill according to the first embodiment of the present invention. As shown in Fig. 4, a rolling position adjustment device 100 according to the first embodiment is a rolling position adjustment device of the rolling rolls constituting the three-roll mandrel mill including six stands in total. In the three-roll mandrel mill, each of the three rolling rolls are arranged in each stand in order to stretch and roll the outer surface of a rolled material T while a mandrel bar B is inserted into the bore of the rolled material T.

More specifically, the rolling position adjustment device 100 according to the first embodiment is configured to adjust the rolling positions of the rolling rolls R5 and R6 arranged in the last two stands (the fifth stand and the sixth stand) of the mandrel mill.

Although Fig. 4 shows that the two rolling rolls R5, R6 are arranged in each stand respectively for the sake of convenience,

actually three rolling rolls R5, R6 are arranged while the angle formed by the reduction direction of each rolling roll is 120°.

[0026] The rolling position adjustment device 100 includes a wall thickness measuring device 1 and a rolling position control device 2. The wall thickness measuring device 1 is arranged on the exit side of the mandrel mill, and the wall thickness measuring device 1 measures the wall thickness (hereinafter appropriately referred to as "groove bottom wall thickness") of the rolled material T at the position corresponding to the groove bottom portion of each of the rolling rolls R5, R6. The rolling position control device 2 computes the deviation between each groove bottom wall thickness measured by the wall thickness measuring device 1 and the target wall thickness determined by the rolling schedule at the position corresponding to the groove bottom portion, and the rolling position control device 2 controls the rolling drive devices P5, P6 of the rolling rolls R5, R6 based on the computed deviations respectively.

Although Fig. 4 shows that each of the rolling drive devices P5, P6 is arranged in each stand for the sake of convenience, actually the rolling drive device is arranged in each of the rolling rolls R5, R6 arranged in each stand.

In a preferable mode, the rolling position adjustment device 100 according to the first embodiment includes a center position measuring device 3 which measures the center position of the rolled material T by measuring the outer diameter of the rolled material T from the directions substantially orthogonal to each other.

[0027] Fig. 5 is a view showing a schematic configuration of a wall thickness measuring device according to an embodiment of the present invention. As shown in Fig. 5, a wall thickness measuring device 1 includes a plurality of the radiation sources 11, 12, 13 and a plurality of the detectors 14, 15, 16. The plurality of the detectors 14, 15, 16 are arranged while facing the plurality of the radiation sources 11, 12, 13 through the rolled material T, respectively. The wall thickness measuring device 1 is a so-called multi-beam radiation measuring device in which the radiation beams BE1, BE2, BE3 radiated from the radiation sources 11, 12, 13 are arranged so as to intersect each other at the position (the middle of wall thickness at the position corresponding to the groove bottom portion) corresponding to the groove bottom portion of each rolling roll of the rolled material T.

More specifically, in the fifth stand and the sixth stand, the groove bottom portions of the rolling rolls R5, R6 differ from one another in the position (out of phase by 60°), so that the wall thickness measuring device 1 is configured as shown in Fig. 5. Further, the devices whose intersecting points of the radiation beams differ from each other (out of phase by 60°) are arranged in two stages along the axial direction of the rolled material T, the groove bottom wall thickness of the rolling roll R5 is measured at one stage, and the groove bottom wall thickness of the rolling roll R6 is measured at the other stage.

Fig. 6 is a view explaining a measuring point of a wall thickness measuring device according to an embodiment of the present invention. As shown in Fig. 6, the groove bottom wall thicknesses B1- B3 in the fifth stand are measured at one stage, the groove bottom wall thicknesses B4 - B6 in the sixth stand are measured at the other stage, and the wall thickness measuring device 1 is configured to measure all the groove bottom wall thicknesses B1 - B6 as a whole. Since the specific wall thickness measurement method by the multi-beam radiation measuring device adopted in the first embodiment is in public domain, the detailed description of the wall thickness measurement method will be omitted.

[0028] As shown in Fig. 4, the rolling position control device 2 computes the deviation between each of the groove bottom wall thicknesses B1 - B6 measured by the wall thickness measuring device 1 and the target wall thickness, determined by the rolling schedule, at the position corresponding to the groove bottom portion, and the rolling position control device 2 can control the rolling drive devices P5, P6 of the rolling rolls R5, R6 based on the measured deviation, respectively.

More specifically, when the measured groove bottom wall thickness is smaller than the target wall thickness, the rolling drive device can be controlled so as to be moved toward the direction in which the relevant rolling roll is opened (the direction in which the relevant rolling roll recedes from the center of the rolled material T). On the contrary, when the measured groove bottom wall thickness is larger than the target wall thickness, the rolling drive device can be controlled so as to be moved toward the direction in which the relevant rolling roll is closed (the direction in which the corresponding rolling roll is brought close to the center of the rolled material T). Regarding a movement amount of each of the rolling rolls R5, R6 (the position correction amount), it is necessary to correct the position such that the deviation becomes zero. Therefore, the movement amount of each of the rolling rolls R5, R6 is set to the same degree as the deviation.

[0029] However, as described above, the rolling position control device 2 according to the first embodiment includes the center position measuring device 3, the rolling position control device 2 can adopt the configuration in which the measured groove bottom wall thicknesses B1 - B6 are corrected based on the center position of the rolled material T measured by the center position measuring device 3.

[0030] Fig. 7 is a schematic configuration of a center position measuring device according to an embodiment of the present invention. As shown in Fig. 7, the center position measuring device 3 according to the embodiment includes a bar-like light source (for example, the high-frequency fluorescent lamp) 31, a line sensor (for example, the CCD line sensor) 32, a bar-like light source 33, and a line sensor 43. The bar-like light source 31 illuminates the rolled material T from one direction, and the line sensor 32 is arranged while facing the bar light source 31 through the rolled material T. The bar-like light source 33 illuminates the rolled material T from the direction substantially orthogonal to the illumination direction of the bar-like light source 31, and the line sensor 34 is arranged while facing the bar-like light source 33 through

the rolled material T. Therefore, the center position measuring device 3 is configured to measure the outer diameter of the rolled material T (the shadow length of the rolled material T) from the directions substantially orthogonal to each other. The center position coordinate of the rolled material T is computed by a center position X of the outer diameter measured by the combination of the bar-like light source 31 and the line sensor 32 and by a center position Y of the outer diameter measured by the combination of the bar-like light source 33 and the line sensor 34.

[0031] As described above, in the case of the adoption of the configuration in which the measured groove bottom wall thicknesses B1-B6 are corrected based on the center position of the rolled material T measured by the center position measuring device 3, firstly, the rolling position control device 2 computes the deviation between a center position (X,Y) measured by the center position measuring device 3 and the gravity center position of the intersecting point of the radiation beams from the plurality of the radiation sources 11, 12, 13 constituting the wall thickness measuring device 1. Fig. 8 is a view showing an example of a relationship between the deviation amount of the center position of the rolled material and an amount of the apparent wall thickness eccentricity. At this point, the correlation between the deviation and the measurement errors (the apparent wall thickness eccentricity amount) of the measured groove bottom wall thicknesses B1 - B6 is brought about by experiments or the like in advance. For example, the correlation shown in Fig. 8 is obtained. A horizontal axis of Fig. 8 indicates a ratio of the deviation (the deviation amount of the center position of the rolled material) to the rolled material radius, and a vertical axis indicates an apparent wall thickness eccentricity component expressed by the following formula (1).

[Formula 1]

$$\text{apparent wall thickness eccentricity component Ecc} = \frac{4 \times (R^2 + I^2)^{1/2}}{WT_{ave}} \times 100[\%] \quad \dots (1)$$

where,

$$R = \frac{1}{2\pi} \sum_{k=1}^n \left\{ \frac{WT_k \cdot \cos \theta_k + WT_{k+1} \cdot \cos \theta_{k+1}}{2} \times (\theta_{k+1} - \theta_k) \right\}$$

$$I = -\frac{1}{2\pi} \sum_{k=1}^n \left\{ \frac{WT_k \cdot \sin \theta_k + WT_{k+1} \cdot \sin \theta_{k+1}}{2} \times (\theta_{k+1} - \theta_k) \right\}$$

$$WT_{ave} = \frac{1}{2\pi} \sum_{k=1}^n \left\{ \frac{WT_k + WT_{k+1}}{2} \times (\theta_{k+1} - \theta_k) \right\} = \text{average wall thickness [mm]}$$

$$WT_{n+1} = WT_1$$

$$\theta_{n+1} = \theta_1 + 2\pi$$

- n: the number of measuring points
 WT_k: measured wall thickness at kth measuring point [mm]
 θ_k: measured position at kth measuring point (angle of polar coordinate with respect to an origin of rolled material)

center) [rad]

The formula (1) indicates a general formula in the case that the number of the measuring points of the wall thickness is n. In the embodiment, n=3 since the number of the measuring points in each of stages constituting the wall thickness measuring device 1 is three.

[0032] Then, the rolling position control device 2 corrects each of the measured groove bottom wall thicknesses B1 - B6 according to the following formula (2) based on the computed deviation (the apparent wall thickness eccentricity component).

[Formula 2]

$$\overline{W Tk} = W Tk + \frac{1}{2} \cdot \frac{Ecc}{100} \cdot \cos(\theta k - \arg(R + I i)) \quad \dots (2)$$

where,

$\overline{W Tk}$: measured wall thickness at kth measuring point [mm]

i: imaginary number unit

arg(): function for determining phase angle of complex number [rad]

W Tk, Ecc, θk , R, I: the same definition as formula (1)

[0033] Then, the rolling position control device 2 computes the deviation between the target wall thickness and each groove bottom wall thickness corrected according to the formula (2), and the rolling position control device 2 controls the rolling drive devices P5, P6 of the rolling rolls R5, R6 based on each computed deviation.

[0034] Thus, the rolling position control device 2 according to the embodiment is configured to be able to adopt the configuration in which the measured groove bottom wall thicknesses B1 - B6 are corrected based on the center position of the rolled material T measured by the center position measuring device 3. The rolling position control device 2 has an advantage that the rolling position can be adjusted with higher accuracy by adopting the above configuration.

[0035] In the embodiment, the wall thickness measuring device 1 is configured to measure only the groove bottom wall thicknesses B1 - B6. However, the present invention is not limited to the embodiment. For example, the wall thickness measuring device 1 includes other plurality of the radiation sources and other plurality of the detectors which are arranged while facing the relevant radiation sources through the rolled material T, respectively, and the wall thickness of the rolled material T is measured at the position corresponding to the portion extended toward one flange portion side from the groove bottom portion of each of the rolling rolls R5, R6, while the wall thickness of the rolled material T is measured at the position corresponding to the portion extended toward the other flange portion side.

Fig. 9 is a view explaining the measuring point of a wall thickness measuring device according to another embodiment of the present invention. As shown in Fig. 9, for the fifth stand, the wall thicknesses B11, B12 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B1 is measured, the wall thicknesses B21, B22 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B2 is measured, and the wall thicknesses B31, B32 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B3 is measured.

Then, for the sixth stand, the wall thicknesses B41, B42 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B4 is measured, the wall thicknesses B51, B52 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B5 is measured, and the wall thicknesses B61, B62 of the rolled material T are also measured at the positions corresponding to the portions each extended toward the flange portion at both sides from the groove bottom portion in which the groove bottom wall thickness B6 is measured.

[0036] In the case that the above configuration is adopted in the wall thickness measuring device 1, the rolling position control device 2 computes the deviation between the measured wall thickness (for example, the wall thickness B11) at the position corresponding to the portion extended toward one flange portion side and the measured wall thickness (for

example, the wall thickness B12) at the position corresponding to the portion extended toward the other flange side, and the rolling position control device 2 can be configured to further control the rolling drive devices P5, P6 of the rolling roll R5 (R51, R52, R53), R6 based on each computed deviation.

More specifically, for example, when the wall thickness B12 is larger than the wall thickness B11 corresponding to the rolling roll R51, the rolling drive device P5 can be controlled such that the rolling roll R52 adjacent to the measuring position of the larger side (the wall thickness B 12) is moved in the direction in which the rolling roll R52 is opened (the direction in which the rolling roll R52 recedes from the center of the rolled material T), and the rolling drive device P can be controlled such that the remaining two rolling rolls R51, R53 are moved in the direction in which the rolling rolls R51, R53 are closed (the direction in which the rolling rolls R51 and R53 are brought close to the center of the rolled material T). Similarly, the deviations between B21 and B22, B31 and B32, B41 and B42, B51 and B52, as well as B61 and B62 are computed, respectively, and the rolling drive device of the corresponding rolling roll is similarly controlled according to the extent of the positive or negative (large or small) deviation.

Regarding the movement amount (the position correction amount) of each of the rolling rolls R5, R6, it is necessary to correct the position such that the deviation becomes zero. For example, in the case that a straight line connecting the caliber center of the rolling roll and the wall thickness measurement position extended toward the flange portion side from the groove bottom portion forms an angle of 20° with respect to a straight line connecting the caliber center of the rolling roll and the groove bottom portion, the movement amount of the rolling roll is expressed by the following formula (3).

$$\begin{aligned} & \text{the position correction amount (the absolute value) of the rolling roll} \\ & = \text{the wall thickness deviations on both sides} \times 1/\sin(20^\circ) \quad (3) \end{aligned}$$

[0037] The groove bottom wall thicknesses B1 - B3, and B4 - B6 of the rolling rolls P5, P6 are measured as the substantially same value by adopting the above configuration, respectively, so that the rolling position can be re-adjusted at the actually proper position, even if the rolling positions of the rolling rolls P5, P6 are considered to be apparently proper.

2. The Second Embodiment

[0038] Fig. 10 is a view showing a schematic configuration of a rolling position adjustment device of the rolling rolls constituting a three-roll mandrel mill according to the second embodiment of the present invention. As shown in Fig. 10, similarly to the first embodiment, a rolling position adjustment device 100A of the rolling rolls constituting the three-roll mandrel mill according to the second embodiment is a rolling position adjustment device constituting the three-roll mandrel mill including six stands in total. In the three-roll mandrel mill, three rolling rolls are respectively arranged in each stand in order to stretch and roll the outer surface of the rolled material T while the mandrel bar B is inserted into the bore of the rolled material T.

More specifically, the rolling position adjustment device 100A according to the second embodiment is configured to adjust the rolling positions of the rolling rolls R5, R6 arranged in the last two stands (the fifth stand and the sixth stand) of the mandrel mill.

Although Fig. 10 shows that two rolling rolls R5, R6 are respectively arranged in each stand for the sake of convenience, actually the three rolling rolls R5, R6 are respectively arranged while the angle formed by the reduction directions is 120°.

[0039] Similarly to the first embodiment, the rolling position adjustment device 100A includes a wall thickness measuring device 1A and a rolling position control device 2A. The wall thickness measuring device 1A is arranged on the exit side of the mandrel mill, and the rolling position control device 2A controls the rolling drive devices P5, P6 of the rolling rolls R5, R6 based on the measurement result of the wall thickness measuring device 1A, respectively.

Although Fig. 10 shows that each one of the rolling drive devices P5, P6 is arranged in each stand for the sake of convenience, actually the rolling drive device is arranged in each of the rolling rolls R5, R6 arranged in each stand.

[0040] However, unlike the first embodiment, the wall thickness measuring device 1A according to the second embodiment does not measure the groove bottom wall thickness of the rolled material T. The wall thickness measuring device 1A includes the plurality of the radiation sources and the plurality of the detectors which are arranged while facing the radiation sources through the rolled material T, respectively, and the wall thickness measuring device 1A is configured to measure the wall thickness of the rolled material T at each position corresponding to the portion extended toward one flange portion side from the groove bottom portion of each of the rolling rolls R5, R6 and the portion extended toward the other flange portion side.

Referring to Fig. 9 used in the first embodiment, the wall thickness measuring device 1A will be described. The wall thickness measuring device 1A is configured not to measure groove bottom wall thicknesses B1, B2, B3, B4, B5, and B6, but to measure the wall thicknesses B 11, B 12, B21, B22, B31, B32, B41, B42, B51, B52, and B61, B62 of the rolled material T at each position corresponding to the portion extended toward the flange portion at both sides from the groove

bottom portions of the rolling rolls.

[0041] The rolling position control device 2A according to the second embodiment is configured to compute the deviation between the measured wall thickness (for example, the wall thickness B11 shown in Fig. 9) at the position corresponding to the portion extended toward one flange portion side and the measured wall thickness (for example, the wall thickness B12 shown in Fig. 9) at the position corresponding to the portion extended toward the other flange portion side, and the rolling position control device 2A is configured to control the rolling drive devices P5, P6 of the rolling roll R5 (R51, R52, and R53), R6 based on the computed deviations.

More specifically, for example, when the wall thickness B12 is larger than the wall thickness B11 corresponding to the rolling roll R51, the rolling drive device P5 can be controlled such that the rolling roll R52 adjacent to the measuring position of the larger side (the wall thickness B12) is moved toward the direction in which the rolling roll R52 is opened (the direction in which the rolling roll R52 recedes from the center of the rolled material T), and the draft device P can be controlled such that the remaining two rolling rolls R51, R53 are moved in the direction in which the rolling rolls R51, R53 are closed (the direction in which the rolling rolls R51, R53 are brought close to the center of the rolled material T). Similarly, the deviations between B21 and B22, B31 and B32, B41 and B42, B51 and B52, as well as B61 and B62 are computed, respectively, and the rolling drive device of the corresponding rolling roll is similarly controlled according to the extent of the positive or negative (large or small) deviation. Regarding the movement amount (the position correction amount) of each of the rolling rolls R5, R6, it is necessary to correct the position such that the deviation becomes zero. For example, in the case that the straight line connecting the caliber center of the rolling roll and the wall thickness measurement position extended toward the flange portion side from the groove bottom portion forms an angle of 20° with respect to a straight line connecting the caliber center of the rolling roll and the groove bottom portion, the movement amount of the rolling roll is expressed by the following formula (3).

$$\begin{aligned} & \text{the position correction amount (the absolute value) of the rolling roll} \\ & = \text{the wall thickness deviations on both sides} \times 1/\sin(20^\circ) \\ & (3) \end{aligned}$$

[0042] The groove bottom wall thicknesses B1 - B3, and B4 - B6 of the rolling rolls P5, P6 are measured as the substantially same value by adopting the above configuration, respectively (this means that the substantially same value is obtained if the measurement is performed, since the groove bottom wall thicknesses B1 - B3, and B4 - B6 are not actually measured in the second embodiment), so that the rolling position can be re-adjusted at the actually proper position, even if the rolling positions of the rolling rolls P5, P6 are considered to be apparently proper.

EXAMPLES

[0043] The features of the present invention will become more clearly by showing examples. The production test was performed by using the rolled material and the mandrel bar having the sizes shown in Table 1. In the production test, each of the 30 seamless steel tubes was rolled under the conditions described below.

Table 1

Mandrel mill hollow shell size	Outer diameter of 205 mm × wall thickness of 15 mm
Mandrel mill finishing size	Outer diameter of 168 mm × wall thickness of 5 mm
Mandrel bar diameter	Outer diameter of 158 mm

The test was performed for the four conditions. (1) Conventional method (the method in which the flange portions of the rolling rolls are brought into contact with each other, and the rolling position of each rolling roll is set at the zero point at that time to control the rolling position), (2) Example 1 (the method of adjusting the rolling position based on the groove bottom wall thickness measurement value), (3) Example 2 (the method in which the groove bottom wall thickness measurement value is corrected by the center position deviation amount of the rolled material and the rolling position is adjusted based on the correction value), (4) Example 3 (the method in which, after the adjustment by Example 2, the rolling position is re-adjusted based on the deviation of the wall thickness measurement value on the flange portion side of the rolling roll), and (5) Example 4 (the method of adjusting the rolling position based on the deviation of the wall thickness measurement value on the flange portion side of the rolling roll).

[0044] Table 2 shows the test result. As shown in Table 2, when compared with the conventional method, the average

values of the wall thickness eccentricity ratio and the frequencies in which the wall thickness eccentricity ratio exceeds 5% are decreased from Example 1 to Example 4. This is largely attributed to the fact that the present invention enables the rolling positions of the rolling rolls constituting the three-roll mandrel mill to be properly adjusted.

Table 2

Production test method	Average value of wall thickness eccentricity ratio	Frequency of over 5% wall thickness eccentricity ratio
Conventional method	6%	50%
Example 1 (rolling position adjustment by groove bottom wall thickness measurement value)	3%	30%
Example 2 (Example 1 + correction by center position deviation amount of rolled material)	1%	7%
Example 3 (Example 2 + rolling position re-adjustment by flange portion-side wall thickness measurement value)	0.1%	0%
Example 4 (rolling position adjustment by flange portion-side wall thickness measurement value)	3.5%	30%

INDUSTRIAL APPLICABILITY

[0045] According to the present invention, the wall thickness of the rolled material is measured at the position corresponding to the groove bottom portion of each rolling roll, the deviation between each measured wall thickness and the target wall thickness determined by the rolling schedule is computed, and the rolling position of each rolling roll is adjusted based on each computed deviation, which allows the proper rolling position adjustment in which the wall thickness accuracy of the rolled material is secured to suppress the wall thickness eccentricity for each rolling roll.

Further, according to the present invention, the wall thickness of the rolled material is measured at the position corresponding to the portion extended toward one flange portion side from the groove bottom portion of each rolling roll, the wall thickness of the rolled material is measured at the position corresponding to the portion extended toward the other flange portion side, and the rolling position of each rolling roll is adjusted based on the deviation of both measured values. Therefore, even if the rolling position of each rolling roll is considered to be apparently proper, actually the rolling position can properly be adjusted. Accordingly, the method and the apparatus of the present invention are widely adopted as means for adjusting the rolling positions of the rolling rolls constituting the three-roll mandrel mill.

Claims

1. A method of adjusting the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the method **characterized by** including:

a first step of measuring a wall thickness of a rolled material at a position corresponding to a groove bottom portion of each rolling roll;
a second step of computing a deviation between said each measured wall thickness and a target wall thickness;
and
a third step of adjusting the rolling position of each rolling roll based on said each computed deviation.

2. A method of adjusting the rolling positions of the rolling roll constituting a three-roll mandrel mill according to claim 1, **characterized by** including steps of:

measuring a center position of the rolled material; and
computing a deviation between said measured center position and a gravity center position formed by each

position where the wall thickness of the rolled material is measured in said first step,
wherein said each measured wall thickness is corrected based on said computed deviation and then a deviation
between the corrected wall thickness and the target wall thickness is computed in said second step.

- 5 **3.** A method of adjusting the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the method **characterized by** including steps of

10 measuring a wall thickness of a rolled material at a position corresponding to a portion extended toward one
flange portion side from a groove bottom portion of each rolling roll while the wall thickness of the rolled material
is measured at a position corresponding to a portion extended toward the other flange portion side;
15 computing a deviation between said measured wall thickness at the position corresponding to the portion ex-
tended toward one flange portion side and said measured wall thickness at the position corresponding to the
portion extended toward the other flange portion side; and
adjusting the rolling position of each rolling roll based on said each computed deviation.

- 15 **4.** An apparatus which adjusts the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the apparatus **characterized by** including:

20 a wall thickness measuring device which is provided with a plurality of the radiation sources and a plurality of
the detectors, said plurality of the detectors being arranged while facing said radiation sources through a rolled
material, respectively, the wall thickness measuring device measuring a wall thickness of the rolled material at
a position corresponding to a groove bottom portion of each rolling roll; and
25 a rolling position control device which computes a deviation between said each measured wall thickness and
a target wall thickness, the rolling position control device controlling each rolling drive device based on said
each computed deviation.

- 30 **5.** An apparatus which adjusts the rolling positions of the rolling rolls constituting a three-roll mandrel mill according to
claim 4, **characterized by** including a center position measuring device which measures a center position of the
rolled material by measuring an outer diameter of the rolled material in directions substantially orthogonal to each
other,
wherein said rolling position control device computes a deviation between the center position measured by said
center position measuring device and a gravity center position of an intersection point of radiation beams from the
plurality of the radiation sources constituting said wall thickness measuring device, said rolling position control device
35 corrects said each measured wall thickness based on said computed deviation, and then said rolling position control
device computes a deviation between each corrected wall thickness and the target wall thickness.

- 40 **6.** An apparatus which adjusts the rolling positions of the rolling rolls constituting a three-roll mandrel mill, the apparatus **characterized by** including:

40 a wall thickness measuring device which is provided with a plurality of the radiation sources and a plurality of
the detectors, said plurality of the detectors being arranged while facing said radiation sources through a rolled
material, respectively, the wall thickness measuring device measuring a wall thickness of a rolled material at a
position corresponding to a portion extended toward one flange portion side from a groove bottom portion of
each rolling roll while measuring the wall thickness of the rolled material at a position corresponding to a portion
45 extended toward the other flange portion side; and
a rolling position control device which computes a deviation between said measured wall thickness at the position
corresponding to the portion extended toward one flange portion side and said measured wall thickness at the
position corresponding to the portion extended toward the other flange portion side, the rolling position control
device controlling each rolling drive device based on said each computed deviation.

FIG. 1

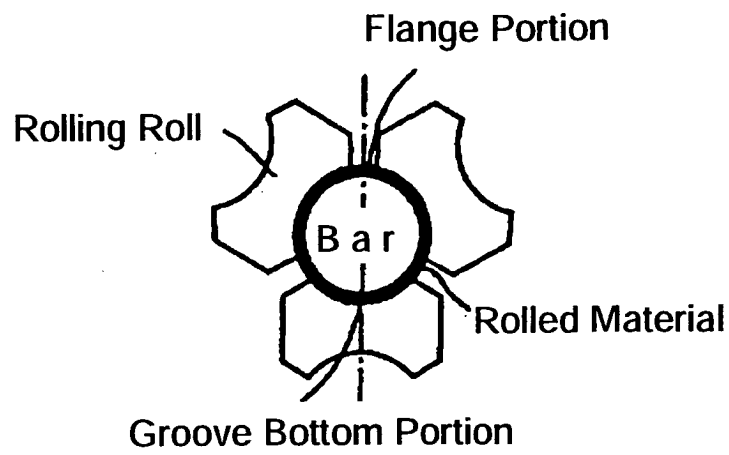


FIG. 2

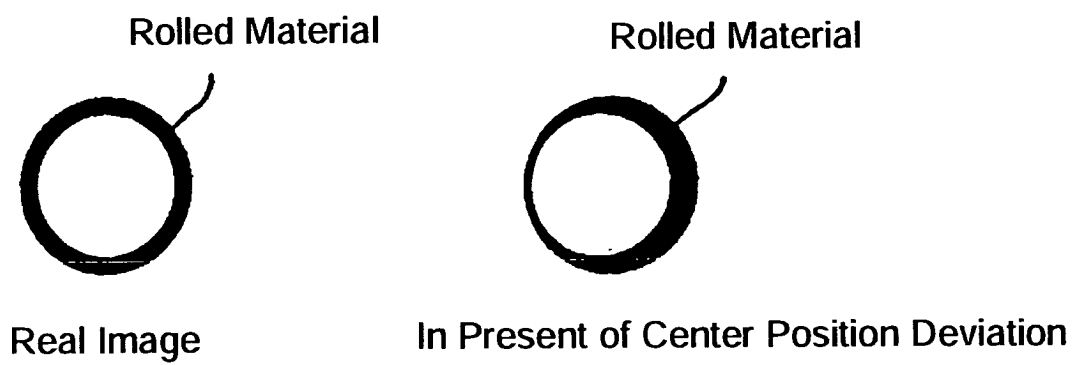


FIG. 3

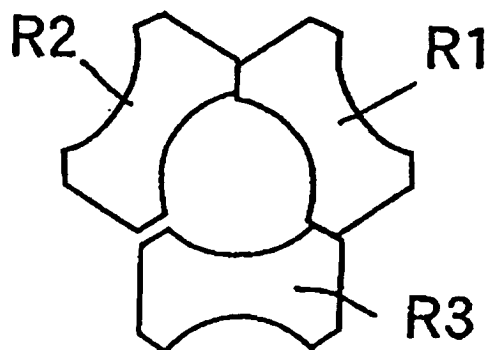


FIG. 4

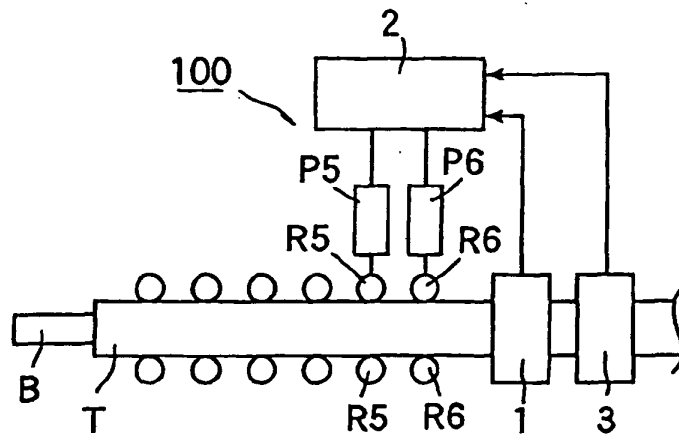


FIG. 5

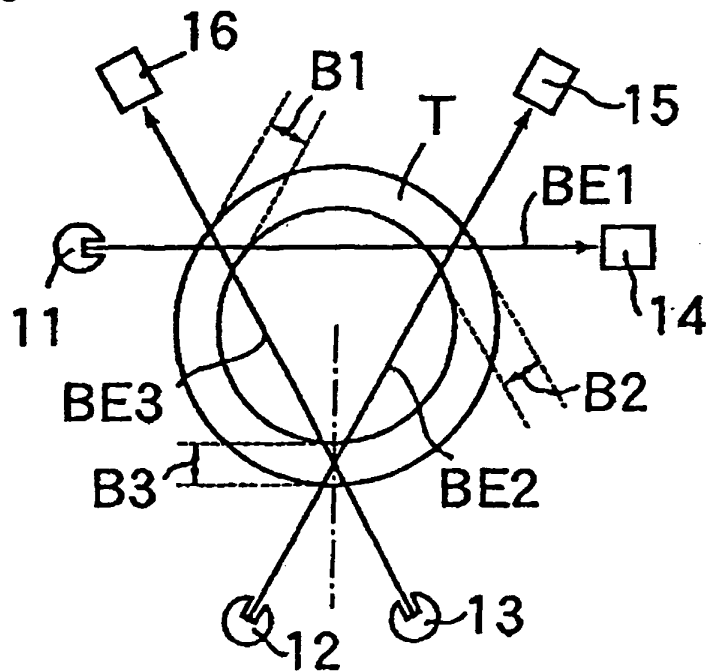


FIG. 6

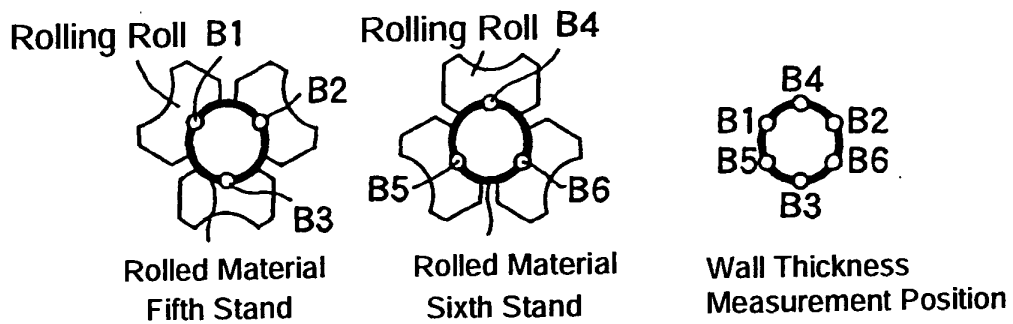


FIG. 7

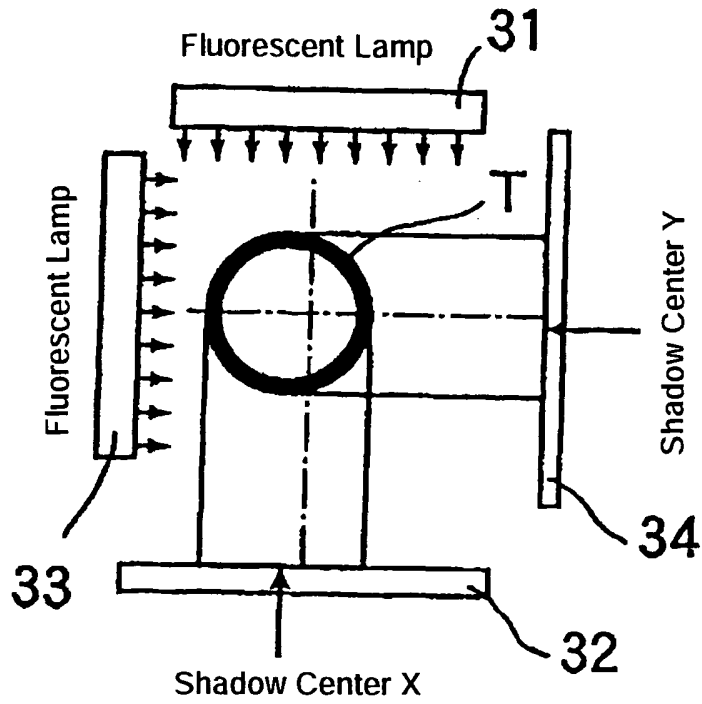


FIG. 8

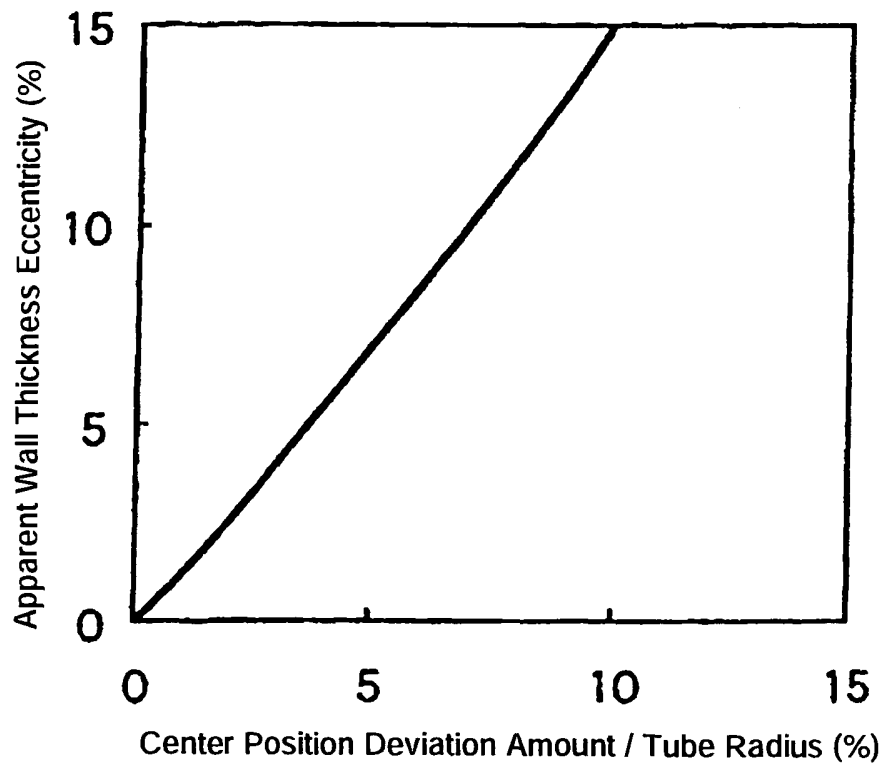


FIG. 9

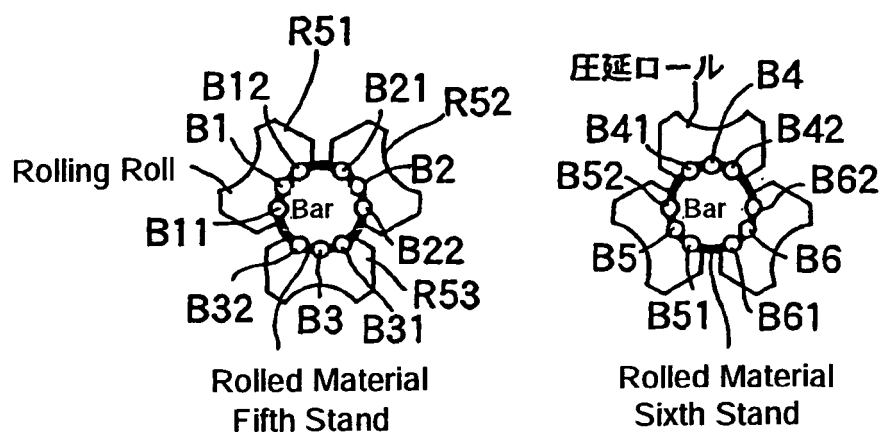
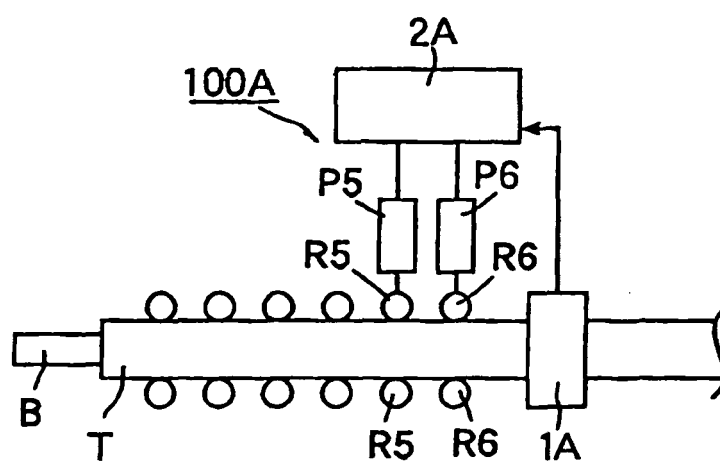


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/014718

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ B21B17/02, 37/78

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)
Int.Cl⁷ B21B17/00-25/06, 37/00-37/78

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2004
Kokai Jitsuyo Shinan Koho 1971-2004 Jitsuyo Shinan Toroku Koho 1996-2004

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 <u>A</u>	JP 2001-293503 A (Sumitomo Metal Industries, Ltd.), 23 October, 2001 (23.10.01), Par. Nos. [0080] to [0088]; Figs. 4, 7 (Family: none)	1, 4 <u>2, 3, 5, 6</u>

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
04 January, 2005 (04.01.05)

Date of mailing of the international search report
18 January, 2005 (18.01.05)

Name and mailing address of the ISA/
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