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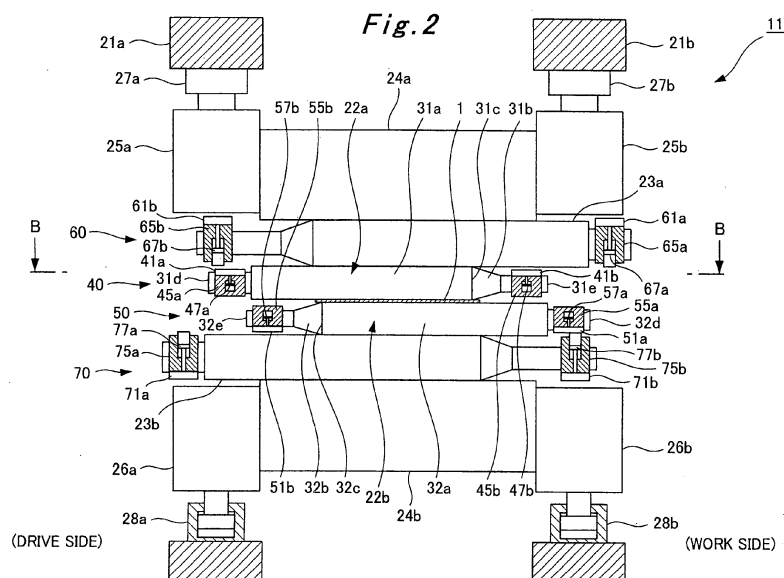
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(54) **Rolling mill having work roll shifting function**

(57) A rolling mill having a work roll shifting function comprises a rolling stand (11 to 16, 210) with a pair of upper and lower work rolls (22a, 22b; 121a, 121b) and roll shifting means (40, 50, 140) for shifting the work rolls in an axial direction thereof. The pair of upper and lower work rolls each have, at one end of a roll body portion (31a, 32a; 131a, 132a), a tapering portion (31b, 32b; 131b, 132b) having a roll diameter gradually decreasing toward a tip of the work roll. The pair of upper and lower work rolls clamp a strip (1) while having the tapering por-

tions located on opposite sides from each other in an axial direction thereof. In the work rolls, at least surfaces of the roll body portions are formed of a ceramic material or a cemented carbide and formed to have 1200 HV or more in terms of Vickers hardness. The rolling stand is a reversing rolling stand for performing multi-pass multiple rolling while inverting a transport direction of the strip. The roll shifting means are adapted to shift the work rolls stepwise every time the strip is passed.



Description

{Technical Field}

5 **[0001]** The present invention relates to a rolling mill having a work roll shifting function in which work rolls each having one end formed in a tapering shape are shifted in the axial direction thereof to control the edge drop of a strip.

{Background Art}

10 **[0002]** Generally, in the case where rolling is performed with work rolls of a rolling mill, a phenomenon referred to as so-called edge drop occurs. In the edge drop, portions near two opposite end portions of a strip become thinner than a central portion thereof in the strip thickness distribution in the width direction of the strip due to plastic flow during rolling. For the strip after rolling, desired accuracy in strip thickness is required. In particular, rolled products have increasingly become of higher quality and higher accuracy at the present time. Accordingly, demands for higher accuracy in strip thickness have become more rigorous even in the strip thickness distribution in the width direction.

15 **[0003]** Accordingly, there have heretofore been provided techniques for controlling the edge drop of widthwise opposite end portions of a strip after rolling with higher accuracy. Further, as means for controlling this edge drop, a work roll shifting method is generally employed in which work rolls each having one end formed in a tapering shape are shifted in the axial direction thereof. Such a work roll shifting method is generally applied to a tandem rolling mill.

20 **[0004]** Specifically described, as shown in Fig. 17, a tandem rolling mill 300 includes a first rolling stand 301, a second rolling stand 302, a third rolling stand 303, and a fourth rolling stand 304. Each of the rolling stands 301 to 304 rotatably supports a pair of upper and lower work rolls 310a and 310b. The work rolls 310a and 310b respectively include cylindrical roll body portions 311a and 312a and tapering portions 311b and 312b formed at one ends of these roll body portions 311a and 312a. The tapering portions 311b and 312b have roll shoulder portions 311c and 312c, which are the start positions of the tapered surfaces thereof. It should be noted that the work rolls 310a and 310b are provided such that the tapering portions 311b and 312b are located on opposite sides from each other in the axial direction of the work rolls 310a and 310b.

25 **[0005]** Further, in the case where a strip 1 is rolled using the above-described tandem rolling mill 300, the strip 1 is passed between the work rolls 310a and 310b of each of the rolling stands 301 to 304 to reduce the strip thickness thereof. Thus, in the first rolling stand 301, plastic deformation occurs even in portions located inward from widthwise opposite ends of the strip 1 having a large strip thickness. Accordingly, the shift positions of the roll shoulder portions 311c and 312c in this first rolling stand 301 are deepest positions (distance δ_1) located inward from widthwise opposite end portions of the strip 1. The shift positions in the second rolling stand 302 are positions (distance δ_2) shallower than the foregoing. The shift positions in the third rolling stand 303 are positions (distance δ_3) further shallower than the foregoing. The shift positions in the fourth rolling stand 304 are positions (distance δ_4) yet further shallower than the foregoing.

30 **[0006]** In other words, the shift positions of the roll shoulder portions 311c and 312c in the rolling stands 301 to 304 are set to change stepwise from the first rolling stand 301 on the first stage to the fourth rolling stand 304 on the last stage such that ($\delta_1 > \delta_2 > \delta_3 > \delta_4$) is satisfied, in accordance with the transition of the widthwise opposite end portions of the strip 1 which have been plastically deformed with a reduction in the thickness of the strip 1. Accordingly, the strip thicknesses of the widthwise opposite end portions of the strip 1 in each of the rolling stands 301 to 304 geometrically increase compared to the strip thickness of widthwise central portions thereof. As a result, the edge drop of the widthwise opposite end portions of the strip 1 after rolling is reduced.

35 **[0007]** On the other hand, the above-described work roll shifting method will be applied to a reversing rolling mill including a single rolling stand. As shown in Figs. 18A), 18B, and 18C, in a reversing rolling mill 350, the strip 1 is passed between the work rolls 310a and 310b back and forth plural times to be rolled plural times. Thus, the shift positions of the roll shoulder portions 311c and 312c thereof need to be changed stepwise from deepest positions located inward from the widthwise opposite end portions of the strip 1 such that ($\delta_1 > \delta_2 > \delta_3$) is satisfied, in accordance with the transition of the widthwise opposite end portions plastically deformed with a reduction in the thickness of the strip 1.

40 **[0008]** However, as shown in Fig. 18A, during the first passing, end portions of the roll body portions 311a and 312a opposite to the tapering portions 311b and 312b come in contact with the widthwise opposite end portions (edge portions) of the strip 1. As a result, heretofore, abrasion flaws R have occurred in end portions of the roll body portions 311a and 312a of the work rolls 310a and 310b formed of high-speed steel (Vickers hardness: 900 HV). Such abrasion flaws R occurs significantly particularly in the rolling of hard and medium-hard materials for which rolling force is set high and soft materials which are work-hardened by repeating passing.

45 **[0009]** Moreover, as shown in Figs. 18B and 18C, abrasion flaws R in the roll body portions 311a and 312a are shifted stepwise from the widthwise opposite end portions of the strip 1 toward portions located inward therefrom with the shifting of the roll shoulder portions 311c and 312c with every repetition of passing. This causes abrasion flaws R corresponding

to the number of times of previous passing to be transferred to surfaces of the strip 1 which is rolled by the roll body portions 311a and 312a. Thus, transfer flaws S occur.

[0010] On the other hand, there have heretofore been provided techniques intended to increase the hardnesses of roll surfaces by forming work rolls of a cemented carbide. Such work rolls are disclosed in, for example, Patent Literature 1 and 2.

{Citation List}

{Patent Literatures}

[0011]

{Patent Literature 1} Japanese Patent Application Publication No. 2009-34690

{Patent Literature 2} Japanese Patent No. 3444063

{Summary of Invention}

{Technical Problem}

[0012] However, the work rolls described in Patent Literature 1 are used in cold rolling before acid cleaning, and intended to crush and remove hot-rolling scale adhering to surfaces of a strip surface with the rolling force thereof by using a cemented carbide as the material thereof. Moreover, the work rolls described in Patent Literature 2 are provided in a tandem rolling mill, and intended to reduce the occurrence of abrasion particles of a strip during rolling and increase cleanliness on surfaces of the strip by using a cemented carbide as the material thereof. In other words, the above-described conventional work rolls have not been applied to work roll shifting method.

[0013] Accordingly, the present invention has been made to solve the above-described problem, and an object of the present invention is to provide a rolling mill having a work roll shifting function which can roll a high-quality strip having no transfer flaws on the surface thereof by reducing the occurrence of abrasion flaws in work rolls caused by widthwise opposite end portions of the strip when the work rolls each having one end formed in a tapering shape are shifted in the axial direction thereof to control the edge drop of the strip.

{Solution to Problem}

[0014] A rolling mill for solving the above problem according to the first aspect of the invention provides a rolling mill having a work roll shifting function, comprising at least one rolling stand including a pair of upper and lower work rolls and roll shifting means for shifting the work rolls in an axial direction thereof, the pair of upper and lower work rolls each having, at one end of a roll body portion thereof, a tapering portion having a roll diameter gradually decreasing toward a tip of the work roll, the pair of upper and lower work rolls clamping a strip while having the tapering portions located on opposite sides from each other in an axial direction thereof. The rolling mill is characterized in that, in the work rolls, at least surfaces of the roll body portions are formed of a ceramic material or a cemented carbide.

[0015] A rolling mill for solving the above problem according to the second aspect of the invention provides a rolling mill having a work roll shifting function, comprising at least one rolling stand including a pair of upper and lower work rolls and roll shifting means for shifting the work rolls in an axial direction thereof, the pair of upper and lower work rolls each having, at one ends of a roll body portion, a tapering portion having a roll diameter gradually decreasing toward a tip of the work roll, the pair of upper and lower work rolls clamping a strip while having the tapering portions located on opposite sides from each other in an axial direction thereof. The rolling mill characterized in that, in the work rolls, at least surfaces of the roll body portions are formed to have 1200 HV or more in terms of Vickers hardness.

[0016] A rolling mill for solving the above problem according to the third aspect of the invention provides a rolling mill having a work roll shifting function characterized in that the roll shifting means includes a double-eccentric bearing.

[0017] A rolling mill for solving the above problem according to the fourth aspect of the invention provides a rolling mill having a work roll shifting function characterized in that each of the work rolls is a small-diameter roll satisfying that a ratio of the roll diameter to a strip width of the strip is 0.03 to 0.1.

[0018] A rolling mill for solving the above problem according to the fifth aspect of the invention provides a rolling mill having a work roll shifting function including detection means for detecting strip thicknesses of widthwise opposite end portions of the strip, the detection means being provided at least on a delivery side of the rolling stand at the last stage, the rolling mill characterized in that shift positions of the tapering portions are controlled in accordance with the strip thicknesses of the strip which have been detected by the detection means.

[0019] A rolling mill for solving the above problem according to the sixth aspect of the invention provides a rolling mill

having a work roll shifting function characterized in that the rolling stand is a reversing rolling stand which performs multi-pass multiple rolling while inverting a transport direction of the strip, and the roll shifting means shifts the work rolls stepwise every time the strip is passed.

{Advantageous Effects of Invention}

[0020] Accordingly, in the rolling mill having a work roll shifting function according to the present invention, by increasing the surface hardnesses of at least the roll body portions of the work rolls, the occurrence of abrasion flaws in the roll body portions can be reduced which is caused by widthwise opposite end portions (edge portions) of a strip when the work rolls having tapering portions are shifted in the axial direction thereof to control the edge drop of the strip. Accordingly, a high-quality strip having no transfer flaws on the surface thereof can be rolled.

{Brief Description of Drawings}

[0021]

Fig. 1 is a front view of a six-high reversing rolling mill according to a first example of the present invention.

Fig. 2 is a cross-sectional view as viewed in the direction of arrows A-A of Fig. 1.

Fig. 3 is a cross-sectional view as viewed in the direction of arrows B-B of Fig. 2.

Fig. 4 is a front view of a six-high reversing rolling mill according to a second example of the present invention.

Fig. 5 is a front view of a four-high reversing rolling mill according to a third example of the present invention.

Fig. 6 is a cross-sectional view as viewed in the direction of arrows C-C of Fig. 5.

Fig. 7 is a front view of a 20-high reversing rolling mill according to a fourth example of the present invention.

Fig. 8 is a cross-sectional view as viewed in the direction of arrows D-D of Fig. 7.

Fig. 9 is a cross-sectional view as viewed in the direction of arrows E-E of Fig. 8.

Figs. 10A to 10C are views showing situations in which thrust bearings disposed on the drive side are shifted in the case where the strip width of a strip decreases from Fig. 10A to Fig. 10C.

Fig. 11 is a front view of a 20-high reversing rolling mill according to a fifth example of the present invention.

Fig. 12 is a cross-sectional view as viewed in the direction of arrows F-F of Fig. 11.

Fig. 13 is a front view of a 12-high reversing rolling mill according to a sixth example of the present invention.

Fig. 14 is a front view of a reversing rolling mill including a strip thickness measuring instrument.

Fig. 15 is a side view of the reversing rolling mill including the strip thickness measuring instrument.

Fig. 16 is a front view of a tandem rolling mill including a strip thickness measuring instrument.

Fig. 17 is an explanatory diagram of a work roll shifting method in a conventional tandem rolling mill.

Figs. 18A to 18C are explanatory diagrams of the application of a work roll shifting method to a conventional reversing rolling mill, and show the occurrence of abrasion flaws and transfer flaws during first to third passing, respectively.

{Description of Embodiments}

[0022] Hereinafter, a rolling mill having a work roll shifting function according to the present invention will be described in detail with reference to drawings.

{Example 1}

[0023] First, a first example will be described with reference to Figs. 1 to 3.

[0024] As shown in Figs. 1 and 2, a reversing rolling mill 11, which is a six-high rolling mill, includes a single rolling stand, and has a pair of left and right (drive- and work-side) housings 21a and 21b. Inside the housings 21a and 21b, pairs of upper and lower work rolls 22a and 22b, intermediate rolls 23a and 23b, backup rolls 24a and 24b are rotatably supported.

[0025] The work rolls 22a and 22b are respectively in contact with and supported by the intermediate rolls 23a and 23b. These intermediate rolls 23a and 23b are respectively in contact with and supported by the backup rolls 24a and 24b. Moreover, roll shifting devices (roll shifting means) 40, 50, 60, and 70 are provided at the outer sides of the work rolls 22a and 22b and the intermediate rolls 23a and 23b. This will be described in detail later. Further, in the reversing rolling mill 11, a strip 1 is passed back and forth plural times between the work rolls 22a and 22b driven and rotated (forward and reverse rotation) by an unillustrated drive unit so that the strip 1 is rolled to a predetermined strip thickness and strip width.

[0026] The work rolls 22a and 22b respectively include cylindrical roll body portions 31a and 32a, tapering portions 31b and 32b in tapered shapes respectively formed at one ends of the roll body portions 31a and 32a, roll neck portions

31d and 32d formed at the other ends of the roll body portions 31a and 32a, and roll neck portions 31e and 32e formed at tips of the tapering portions 31b and 32b. Moreover, the tapering portions 31b and 32b have roll shoulder portions 31c and 32c, which are the start positions (origins) of the tapered surfaces thereof. It should be noted that the work rolls 22a and 22b are disposed such that the tapering portions 31b and 32b are located on opposite sides from each other in the axial direction of the work rolls 22a and 22b.

[0027] Here, the surfaces of the roll body portions 31a and 32a and the tapering portions 31b and 32b are used to roll the strip 1. In the work rolls 22a and 22b, at least the surfaces (surface layers) of the roll body portions 31a and 32a are formed of a ceramic material or a cemented carbide (e.g., WC-Co system), which is a high hardness material. Moreover, the surface hardnesses thereof are 1200 HV or more in terms of Vickers hardness, preferably approximately 1600 HV. It should be noted that the surfaces of the tapering portions 31b and 32b may also be formed of a ceramic material or a cemented carbide, and the surface hardnesses thereof may be 1200 HV or more in terms of Vickers hardness.

[0028] Specifically, the work rolls 22a and 22b are composite rolls whose surface layer portions are formed of a ceramic material or a cemented carbide and whose internal layer (core) portions are formed of high-speed steel or the like. It should be noted that the work rolls 22a and 22b may be thermally-sprayed-surface rolls in which a ceramic material is thermally sprayed on surfaces thereof.

[0029] By the roll shifting device 40, the work roll 22a is rotatably supported to be shiftable in the axial direction thereof. Specifically, the roll shifting device 40 includes a pair of left and right bearing boxes 41a and 41b. Inside these bearing boxes 41a and 41b, the roll neck portions 31d and 31e of the work roll 22a are rotatably supported, respectively. Of these, as shown in Fig. 3, the bearing box 41a on the drive side has a shifting frame 43 detachably attached thereto through a detachable hook 42. Further, shifting cylinders 44a and 44b are interposed between the shifting frame 43 and the housing 21a.

[0030] On opposite sides of each of the bearing boxes 41a and 41b, pairs of front and rear shifting blocks 45a and 45b are provided. These opposing shifting blocks 45a and 45b are connected by a stay 46, and are respectively supported between side walls of the housings 21a and 21b to be slidable in the axial direction of the work roll 22a. Further, bending cylinders 47a and 47b are housed in the shifting blocks 45a and 45b, respectively. These bending cylinders 47a and 47b can press lower surfaces of the bearing boxes 41a and 41b. Thus, bending force is applied to the work roll 22a.

[0031] Accordingly, in the roll shifting device 40, the work roll 22a can be shifted in the axial direction thereof by actuating the shifting cylinders 44a and 44b. Further, since the shifting blocks 45a and 45b are also shifted with the shifting of the bearing boxes 41a and 41b, even if the bearing boxes 41a and 41b are located at any shift positions, the bending cylinders 47a and 47b can apply bending force, and strip shape control in the width direction of the strip 1 can be performed.

[0032] Similarly, by the roll shifting device 50, the work roll 22b is rotatably supported to be shiftable in the axial direction thereof. Specifically, the roll shifting device 50 includes a pair of left and right bearing boxes 51a and 51b. Inside these bearing boxes 51a and 51b, the roll neck portions 32d and 32e of the work roll 22b are rotatably supported, respectively.

[0033] The bearing boxes 51a and 51b have the same supporting structures as those of the bearing boxes 41a and 41b shown in Fig. 3. On two opposite sides of each of the bearing boxes 51a and 51b, pairs of front and rear shifting blocks 55a and 55b are provided. The shifting blocks 55a and 55b are respectively provided between side walls of the housings 21a and 21b to be slidable in the axial direction of the work roll 22b. Further, bending cylinders 57a and 57b are housed in the shifting blocks 55a and 55b, respectively. These bending cylinders 57a and 57b can press lower surfaces of the bearing boxes 51a and 51b. Thus, bending force is applied to the work roll 22a. Accordingly, the roll shifting device 50 can also perform shifting operation, bending operation, and strip shape control similar to those of the roll shifting device 40.

[0034] Moreover, by the roll shifting device 60, the intermediate roll 23a in a tapering shape is supported which has the same shape as those of the work rolls 22a and 22b. Specifically, the intermediate roll 23a is rotatably supported in bearing boxes 61a and 61b, and supported between side walls of the housings 21a and 21b to be slidable in the axial direction thereof. Further, bending cylinders 67a and 67b respectively in shifting blocks 65a and 65b apply bending force to the intermediate roll 23a.

[0035] Similarly, by the roll shifting device 70, the intermediate roll 23b in a tapering shape is supported which has the same shape as those of the work rolls 22a and 22b. Specifically, the intermediate roll 23b is rotatably supported in bearing boxes 71a and 71b, and supported between side walls of the housings 21a and 21b to be slidable in the axial direction thereof. Further, bending cylinders 77a and 77b respectively in shifting blocks 75a and 75b apply bending force to the intermediate roll 23b.

[0036] Accordingly, concurrently with the shifting operation of the intermediate rolls 23a and 23b, bending force can be applied to these intermediate rolls 23a and 23b. Thus, strip shape control in the width direction of the strip 1 can be performed with higher accuracy.

[0037] Furthermore, the backup roll 24a is rotatably supported in bearing boxes 25a and 25b. These bearing boxes 25a and 25b are respectively supported by the housings 21a and 21b through a pair of left and right pass-line adjustment devices 27a and 27b including worm jacks and the like. In other words, by actuating the pass-line adjustment devices

27a and 27b, the pass-line of the strip 1 can be adjusted in the vertical direction.

[0038] On the other hand, the backup roll 24b is rotatably supported in bearing boxes 26a and 26b. These bearing boxes 26a and 26b are respectively supported by the housings 21a and 21b through a pair of left and right roll gap control oil-hydraulic cylinders 28a and 28b. In other words, by actuating the roll gap control oil-hydraulic cylinders 28a and 28b, the rolling force thereof is transmitted from the work rolls 22a and 22b through the intermediate rolls 23a and 23b or directly from the work rolls 22a and 22b to the strip 1.

[0039] Accordingly, when the strip 1 is rolled using the reversing rolling mill 11, the strip 1 is passed between the work rolls 22a and 22b back and forth plural times. Further, during this multiple rolling in which the strip 1 is passed multiple times while the transport direction thereof is inverted, the work rolls 22a and 22b are gradually shifted for every pass. The shift positions of the roll shoulder portions 31c and 32c are controlled stepwise from deepest positions located inward from two opposite end portions of the strip 1, in accordance with the transition of the two opposite end portions plastically deformed with a reduction in the thickness of the strip 1. This can reduce the edge drop of the strip 1.

[0040] At this time, the end portions of the roll body portions 31a and 32a opposite to the tapering portions 31b and 32b come respectively in contact with widthwise opposite end portions (edge portions) of the strip 1. However, since the surface hardnesses of the roll body portions 31a and 32a are high, in spite of the fact that the roll shoulder portions 31c and 32c are shifted with every repetition of passing in accordance with the transition of the widthwise opposite end portions of the strip 1 which have been plastically deformed, the occurrence of abrasion flaws R (see Figs. 18A to 18C) in the roll body portions 31a and 32a can be reduced. Thus, the high-quality strip 1 having no transfer flaws S (see Figs. 18A to 18C) on the surface thereof can be rolled.

[0041] Here, for the work rolls 22a and 22b, a test result indicating the following was obtained: the depth of wear of a ceramic material or a cemented carbide having a Vickers hardness of 1600 HV, which is 1.8 times harder than high-speed steel having a Vickers hardness of 900 HV, is 1/25 of that of the high-speed steel. Thus, based on this test result, in the case of a material having a Vickers hardness of 1200 HV, which is 1.3 times harder than high-speed steel having a Vickers hardness of 900 HV, the depth of wear thereof can be set to 1/4 of that of the high-speed steel. Accordingly, the surfaces of the roll body portions 31a and 32a of the work rolls 22a and 22b are formed of a ceramic material or a cemented carbide, which is a high hardness material, and the surface hardnesses thereof are 1200 HV or more in terms of Vickers hardness. Further, by specifying the surface materials and surface hardnesses of the roll body portions 31a and 32a as described above, the occurrence of abrasion flaws R can be reduced even during the rolling particularly of hard materials such as magnetic steel, stainless steel, and ultra-high tensile strength steel strip for which rolling force is set high; medium-hard materials; and soft materials such as copper alloy steel strip which are work-hardened by rolling.

{Example 2}

[0042] Next, a second example will be described with reference to Fig. 4.

[0043] As shown in Fig. 4, in a reversing rolling mill 12, the intermediate-diameter work rolls 22a and 22b are rotatably supported. On the entry and delivery sides of these work rolls 22a and 22b, support rolls 81a and 81b facing the work roll 22a and support rolls 91a and 91b facing the work roll 22b are rotatably supported.

[0044] The roll body portion 31a (see Fig. 2) of the work roll 22a is supported by the support rolls 81a and 81b. These support rolls 81a and 81b are rotatably supported by split bearings 82a and 82b, respectively. On the other hand, the roll body portion 32a (see Fig. 2) of the work roll 22b is supported by the support rolls 91a and 91b. These support rolls 91a and 91b are rotatably supported by split bearings 92a and 92b, respectively. It should be noted that the support rolls 81a, 81b, 91a, and 91b may be provided on one of the entry and delivery sides.

[0045] Further, since the support stiffness of the work rolls 22a and 22b can be improved by providing the support rolls 81a, 81b, 91a, and 91b, the deflection thereof in a horizontal direction (transport direction of the strip 1) can be reduced. Thus, the work rolls 22a and 22b can be formed to have intermediate diameters in accordance with the improvement of support stiffness. Here, in the work rolls 22a and 22b as intermediate-diameter rolls, the ratios of the roll diameters thereof to the strip width of the strip 1 are 0.08 to 0.25.

[0046] Accordingly, by increasing the surface hardnesses of the roll body portions 31a and 32a of the work rolls 22a and 22b, abrasion flaws R in the roll body portions 31a and 32a caused by the widthwise opposite end portions of the strip 1 can be reduced even when the work rolls 22a and 22b formed to have intermediate diameters are shifted in the axial direction thereof to reduce the edge drop of the strip 1. Thus, the high-quality strip 1 having no transfer flaws S on the surface thereof can be rolled.

{Example 3}

[0047] Next, a third example will be described with reference to Figs. 5 and 6.

[0048] As shown in Figs. 5 and 6, a reversing rolling mill 13 is a four-high rolling mill obtained by removing the intermediate rolls 23a and 23b and the roll shifting devices 60 and 70 for shifting the same from the reversing rolling mill

11 described in the first example.

[0049] Accordingly, in the reversing rolling mill 13 having a simplified configuration, again, by increasing the surface hardnesses of the roll body portions 31a and 32a of the work rolls 22a and 22b, abrasion flaws R in the roll body portions 31a and 32a caused by the widthwise opposite end portions of the strip 1 can be reduced when the work rolls 22a and 22b having the tapering portions 31b and 32b are shifted in the axial direction thereof to reduce the edge drop of the strip 1. Thus, the high-quality strip 1 having no transfer flaws S on the surface thereof can be rolled.

{Example 4}

[0050] Next, a fourth example will be described with reference to Figs. 7 to 10.

[0051] As shown in Figs. 7 and 8, a reversing rolling mill 14, which is a 20-high rolling mill, includes a single rolling stand, and has a pair of left and right (drive- and work-side) outer housings 111a and 111b. Inside these outer housings 111a and 111b, a pair of upper and lower work rolls 121a and 121b, two pairs of upper and lower first intermediate rolls 122a and 122b, three pairs of upper and lower second intermediate rolls 123a and 123b, and four pairs of upper and lower backing bearing spindles 124a and 124b are rotatably supported.

[0052] The work rolls 121a and 121b are respectively in contact with and supported by the first intermediate rolls 122a and 122b. These first intermediate rolls 122a and 122b are respectively in contact with and supported by the second intermediate rolls 123a and 123b. Moreover, the second intermediate rolls 123a and 123b are in contact with and supported by backing bearings 125a and 125b by which the backing bearing spindles 124a and 124b are rotatably supported. Furthermore, the backing bearing spindles 124a and 124b are rotatably supported in four pairs of upper and lower saddles 126a and 126b, respectively. These saddles 126a and 126b are supported by a pair of upper and lower inner housings 112a and 112b, respectively. Further, in the reversing rolling mill 14, the strip 1 is passed back and forth plural times between the work rolls 121a and 121b which co-rotate with each other to roll the strip 1 to a predetermined strip thickness and strip width.

[0053] The upper inner housing 112a is supported by the outer housings 111a and 111b through two pairs of left and right pass-line adjustment devices 113a and 113b including worm jacks and the like. In other words, by actuating the pass-line adjustment devices 113a and 113b, the pass-line of the strip 1 can be adjusted in the vertical direction.

[0054] On the other hand, the lower inner housing 112b is supported by the outer housings 111a and 111b through a pair of left and right roll gap control oil-hydraulic cylinders 114a and 114b. In other words, by actuating the roll gap control oil-hydraulic cylinders 114a and 114b, the rolling force is transmitted to the strip 1 through the second intermediate rolls 123a and 123b, the first intermediate rolls 122a and 122b, and the work rolls 121a and 121b.

[0055] The work rolls 121a and 121b respectively include cylindrical roll body portions 131a and 132a, and tapering portions 131b and 132b in tapered shapes respectively formed at one ends of the roll body portions 131a and 132a. Moreover, the tapering portions 131b and 132b have roll shoulder portions 131c and 132c, which are the start positions (origins) of the tapered surfaces thereof. It should be noted that the work rolls 121a and 121b are disposed such that the tapering portions 131b and 132b are located on opposite sides in the axial direction of the work rolls 121a and 121b.

[0056] Here, the surfaces of the roll body portions 131a and 132a and the tapering portions 131b and 132b are used to roll the strip 1. In the work rolls 121a and 121b, at least the surfaces (surface layers) of the roll body portions 131a and 132a are formed of a ceramic material or a cemented carbide (e.g., WC-Co system), which is a high hardness material. Moreover, the surface hardnesses thereof are 1200 HV or more in terms of Vickers hardness, preferably approximately 1600 HV. It should be noted that the surfaces of the tapering portions 131b and 132b may also be formed of a ceramic material or a cemented carbide, and the surface hardnesses thereof may be 1200 HV or more in terms of Vickers hardness.

[0057] Specifically, the work rolls 121a and 121b are composite rolls whose surface layer portions are formed of a ceramic material or a cemented carbide and whose internal layer (core) portions are formed of high-speed steel or the like. It should be noted that the work rolls 121a and 121b may be thermally-sprayed-surface rolls in which a ceramic material is thermally sprayed on surfaces thereof.

[0058] Moreover, a roll shifting device (roll shifting means) 140 is provided at the outer sides of the work rolls 121a and 121b. This roll shifting device 140 includes double-eccentric thrust bearings 141a, 141b, 141c, and 141d, shift drive units 142a, 142b, 142c, and 142d, and brackets 143a and 143b.

[0059] The thrust bearings 141a and 141b are respectively in contact with end faces of the roll body portion 131a and the tapering portion 131b of the work roll 121a, and supported by the brackets 143a and 143b to be rotatable about a vertical axis and shiftable in the axial direction of the work roll 121a. Further, on upper surfaces of the brackets 143a and 143b, the shift drive units 142a and 142b are provided, respectively. These shift drive units 142a and 142b are connected to the thrust bearings 141a and 141b, respectively. This will be described in detail later.

[0060] Similarly, the thrust bearings 141c and 141d are respectively in contact with end faces of the roll body portion 132a and the tapering portion 132b of the work roll 121b, and supported by the brackets 143a and 143b to be rotatable about a vertical axis and shiftable in the axial direction of the work roll 121b. Further, under lower surfaces of the brackets

143a and 143b, the shift drive units 142c and 142d are provided, respectively. These shift drive units 142c and 142d are connected to the thrust bearings 141c and 141d, respectively. This will be described in detail later.

[0061] It should be noted that since the thrust bearings 141a to 141d and the shift drive units 142a to 142d have the same configurations, respectively, the thrust bearing 141a and the shift drive unit 142a, which are disposed in an upper portion on the drive side, will be described below as representative of the thrust bearings 141a to 141d and the shift drive units 142a to 142d with reference to Figs. 9 and 10.

[0062] As shown in Figs. 9, 10(a), 10(b), and 10(c), the thrust bearing 141a includes a spindle 161 rotatably supported by a bracket 143a. Outside the spindle 161 in the diameter direction thereof, an inner eccentric ring 162, an outer eccentric ring 163, a bearing inner ring 164, a plurality of rollers 165, and a bearing outer ring 166 are disposed in that order, and all of these are rotatably supported. Furthermore, the bearing outer ring 166 is rotatably supported by the spindle 161 through the inner eccentric ring 162 and the outer eccentric ring 163, and rotatably supported by the spindle 161 through the bearing inner ring 164 and the rollers 165. It should be noted that the spindle 161, the inner eccentric ring 162, and the outer eccentric ring 163 can be disposed such that the central axes thereof are deviated from each other.

[0063] The spindle 161 and the inner eccentric ring 162 are coupled to each other by an inner key 167. Above the inner key 167, a small-diameter pinion 168 is provided. This small-diameter pinion 168 is rotatably supported to be coaxial with the central axis of the spindle 161. Moreover, in the outer eccentric ring 163, a long opening 163a is formed which extends in the diameter direction of the outer eccentric ring 163. An outer key 169 is slidably fitted into this long opening 163a. Above the outer key 169, a large-diameter pinion 170 is provided. This large-diameter pinion 170 is rotatably supported to be coaxial with the central axis of the spindle 161.

[0064] On the other hand, the shift drive unit 142a includes a pair of front and rear shifting oil-hydraulic cylinders 181 and 182. The shifting oil-hydraulic cylinders 181 and 182 respectively include cylinder portions 181a and 182a, rods 181b and 182b slidably supported in the cylinder portions 181a and 182a, and racks 181c and 182c provided at tips of the rods 181b and 182b. Further, the rack 181c is in mesh with the small-diameter pinion 168, and the rack 182c is in mesh with the large-diameter pinion 170.

[0065] Accordingly, by contracting or expanding the shifting oil-hydraulic cylinders 181 and 182 at the same time, the inner eccentric ring 162 and the outer eccentric ring 163 can be rotated in opposite directions by the same angle of rotation. As a result, the bearing outer ring 166 is not decentered but can be shifted only in the axial direction of the work roll 121a.

[0066] In other words, by actuating the shift drive units 142a and 142b to rotate and shift the thrust bearings 141a and 141b, the work roll 121a interposed therebetween can be shifted in the axial direction thereof. Moreover, by actuating the shift drive units 142c and 142d to rotate the thrust bearings 141c and 141d, the work roll 121b interposed therebetween can be shifted in the axial direction thereof.

[0067] It should be noted that the shift states of the thrust bearings 141a and 141c shown in Fig. 10A correspond to the case where the strip width of the strip 1 is relatively large, and that the shift states of the thrust bearings 141a and 141c shown in Fig. 10C correspond to the case where the strip width of the strip 1 is relatively small.

[0068] Furthermore, at the outer sides of the first intermediate rolls 122a and 122b, an unillustrated roll shifting device (roll shifting means) is provided. In other words, the first intermediate rolls 122a and 122b are rotatably supported by the roll shifting device to be shiftable in the axial direction thereof.

[0069] Accordingly, when the strip 1 is rolled using the reversing rolling mill 14, the strip 1 is passed between the work rolls 121a and 121b back and forth plural times. Further, during this multiple rolling in which the strip 1 is passed multiple times while the transport direction thereof is inverted, the work rolls 121a and 121b are gradually shifted for every pass. The shift positions of the roll shoulder portions 131c and 132c of the work rolls 121a and 121b are controlled stepwise from deepest positions located inward from two opposite end portions of the strip 1, in accordance with the transition of the two opposite end portions plastically deformed with a reduction in the thickness of the strip 1. This can reduce the edge drop of the strip 1.

[0070] At this time, the end portions of the roll body portions 131a and 132a opposite to the tapering portions 131b and 132b come respectively in contact with the widthwise opposite end portions (edge portions) of the strip 1. However, since the surface hardnesses of the roll body portion 131a and 132b are high, in spite of the fact that the roll shoulder portions 131c and 132c are shifted with every repetition of passing in accordance with the transition of the widthwise opposite end portions of the strip 1 which have been plastically deformed, the occurrence of abrasion flaws R (see Figs. 18A to 18C) in the roll body portions 131a and 132a can be reduced. Thus, the high-quality strip 1 having no transfer flaws S (see Fig. 18A to 18C) on the surface thereof can be rolled.

[0071] Here, for the work rolls 121a and 121b, a test result indicating the following was obtained: the depth of wear of a ceramic material or a cemented carbide having a Vickers hardness of 1600 HV, which is 1.8 times harder than high-speed steel having a Vickers hardness of 900 HV, is 1/25 of that of the high-speed steel. Thus, based on this test result, in the case of a material having a Vickers hardness of 1200 HV, which is 1.3 times harder than high-speed steel having a Vickers hardness of 900 HV, the depth of wear thereof can be set to 1/4 of that of the high-speed steel. Accordingly, the surfaces of the roll body portions 131a and 132a of the work rolls 121a and 121b are formed of a ceramic material

or a cemented carbide, which is a high hardness material, and the surface hardnesses thereof are 1200 HV or more in terms of Vickers hardness. Further, by specifying the surface materials and surface hardnesses of the roll body portions 131a and 132a as described above, the occurrence of abrasion flaws R can be reduced during the rolling particularly of hard materials such as magnetic steel and stainless steel strip for which rolling force is set high.

[0072] Moreover, in the reversing rolling mill 14, since the rolls 121a, 121b, 122a, 122b, 123a, and 123b and the backing bearing spindles 124a and 124b are disposed in a 20-high cluster arrangement, the work rolls 121a and 121b can be formed to have small diameters in accordance with the improvement of the support stiffness of the work rolls 121a and 121b. Further, in spite of the fact that the work rolls 121a and 121b have small diameters and therefore roll neck portions cannot be formed, the provision of the double-eccentric thrust bearings 141a to 141d makes it possible to shift the work rolls 121a and 121b in the axial direction thereof with a simple configuration in a space-saving manner. Here, in the work rolls 121a and 121b as small-diameter rolls, the ratios of the roll diameters thereof to the strip width of the strip 1 are 0.03 to 0.10.

[0073] Furthermore, since a vertically divided configuration is employed in which the inner housings 112a and 112b are divided in the vertical direction, the gap between the work rolls 121a and 121b can be increased. This can improve the ease of cobble removal work at the time of cutting the strip 1.

{Example 5}

[0074] Next, a fifth example will be described with reference to Figs. 11 and 12.

[0075] As shown in Figs. 11 and 12, a reversing rolling mill 15, which is a 20-high rolling mill, includes a monoblock housing 191 having a unitary structure in which upper and lower portions are integrated with each other. Of the upper backing bearings 125a, the backing bearings 125a disposed on both outer sides are supported by the monoblock housing 191 through pass-line adjustment saddles 192b, and the centrally disposed backing bearings 125a are supported by the monoblock housing 191 through roll gap control saddles 192a. Since the monoblock housing 191 has a unitary structure in which upper and lower portions are integrated with each other as described above, the reversing rolling mill 15 can be simplified and miniaturized.

[0076] Accordingly, in the reversing rolling mill 15 thus simplified and miniaturized, again, by increasing the surface hardnesses of the roll body portions 131a and 132a of the work rolls 121a and 121b, abrasion flaws R in the roll body portions 131a and 132a caused by the widthwise opposite end portions of the strip 1 can be reduced when the work rolls 121a and 121b having the tapering portions 131b and 132b are shifted in the axial direction thereof to reduce the edge drop of the strip 1. Thus, the high-quality strip 1 having no transfer flaws S on the surface thereof can be rolled.

{Example 6}

[0077] Next, a sixth example will be described with reference to Fig. 13.

[0078] As shown in Fig. 13, a reversing rolling mill 16 is a 12-high rolling mill obtained by removing the second intermediate rolls 123a and 123b from the reversing rolling mill 14 or 15 described in the fourth or fifth example. It should be noted that the number of pairs of upper and lower the backing bearing spindles 124a and 124b and the number of pairs of upper and lower the backing bearings 125a and 125b are three. Since the rolls 121a, 121b, 122a, and 122b and the backing bearing spindles 124a and 124b are disposed in a 12-high cluster arrangement as described above, the reversing rolling mill 16 can be simplified and miniaturized.

[0079] Accordingly, in the reversing rolling mill 16 thus simplified and miniaturized, again, by increasing the surface hardnesses of the roll body portions 131a and 132a of the work rolls 121a and 121b, abrasion flaws R in the roll body portions 131a and 132a caused by the widthwise opposite end portions of the strip 1 can be reduced when the work rolls 121a and 121b having the tapering portions 131b and 132b are shifted in the axial direction thereof to reduce the edge drop of the strip 1. Thus, the high-quality strip 1 having no transfer flaws S on the surface thereof can be rolled.

[0080] Here, as shown in Fig. 14, on the delivery side of the work rolls 22a and 22b or 121a and 121b (rolling stand) of each of the reversing rolling mills 11 to 16 of the above-described first to sixth examples, a strip thickness measuring instrument (detection means) 200 is disposed. This strip thickness measuring instrument 200 is intended to measure strip thickness at one or more points in each of the widthwise opposite end portions (edge portions) of the strip 1.

[0081] Next, an edge drop reduction method will be described with reference to Fig. 15 by taking as representative the case where the work rolls 22a and 22b are used. It should be noted that as shown in Fig. 15, the distances from the roll shoulder portions 31c and 32c of the work rolls 22a and 22b to the widthwise opposite end portions of the strip 1 are denoted by δd and δw on the drive and work sides, respectively.

[0082] Further, in the case where the strip thickness of the operation-side end portion of the strip 1 which has been measured by the strip thickness measuring instrument 200 is smaller than a predetermined thickness, the work roll 22a is shifted in the axial direction thereof such that the roll shoulder portion 31c moves toward a widthwise central portion of the strip 1. In other words, the work roll 22a is shifted such that the distance δw increases. Similarly, in the case where

the work roll 121a is shifted in the axial direction thereof, the thrust bearing 141a is set to the shift state shown in Fig. 10C.

[0083] On the other hand, in the case where the strip thickness of the operation-side end portion of the strip 1 which has been measured by the strip thickness measuring instrument 200 is larger than the predetermined thickness, the work roll 22a is shifted in the axial direction thereof such that the roll shoulder portion 31c moves outward in the width direction of the strip 1. In other words, the work roll 22a is shifted such that the distance δw decreases. Similarly, in the case where the work roll 121a is shifted in the axial direction thereof, the thrust bearing 141a is set to the shift state shown in Fig. 10A.

[0084] Moreover, in the case where the strip thickness of the drive-side end portion of the strip 1 which has been measured by the strip thickness measuring instrument 200 is smaller than the predetermined thickness, the work roll 22b is shifted in the axial direction thereof such that the roll shoulder portion 32c moves toward a widthwise central portion of the strip 1. In other words, the work roll 22b is shifted such that the distance δd increases. Similarly, in the case where the work roll 121b is shifted in the axial direction thereof, the thrust bearing 141c is set to the shift state shown in Fig. 10C.

[0085] On the other hand, in the case where the strip thickness of the drive-side end portion of the strip 1 which has been measured by the strip thickness measuring instrument 200 is larger than the predetermined thickness, the work roll 22b is shifted in the axial direction thereof such that the roll shoulder portion 32c moves outward in the width direction of the strip 1. In other words, the work roll 22a is shifted such that the distance δd decreases. Similarly, in the case where the work roll 121b is shifted in the axial direction thereof, the thrust bearing 141c facing the work roll 22a is set to the shift state shown in Fig. 10A.

[0086] Furthermore, as shown in Fig. 16, the above-described work rolls 22a and 22b, intermediate rolls 23a and 23b, and backup rolls 24a and 24b may be applied to first to fifth rolling stands 211, 212, 213, 214, and 215 of a tandem rolling mill 210. In this case, on the delivery side of the fifth rolling stand 215 which is the last rolling stand, the strip thickness measuring instrument 200 is provided. This makes it possible to reduce the occurrence of abrasion flaws R in the surfaces of the roll body portions 31a and 32a of the work rolls 22a and 22b during rolling. Accordingly, rolling can be performed without limitations on the strip width of the strip 1 which is to be rolled.

[0087] In other words, in the case where rolling is performed using work rolls formed of high-speed steel or the like as heretofore, since abrasion flaws R occur on surfaces of roll body portion thereof, rolling needs to be performed in the order from a strip having a large strip width to a strip having a smaller strip width. On the other hand, abrasion flaws R in the roll body portion 31a and 32a caused by the widthwise opposite end portions of the strip 1 can be reduced by increasing the surface hardnesses of the roll body portions 31a and 32a of the work rolls 22a and 22b, and therefore rolling can be performed without limitations on the strip width of the strip 1. Thus, flexibility in rolling operation can be increased.

{Industrial Applicability}

[0088] The present invention can be applied to a rolling mill having a work roll shifting function for shifting work rolls in the axial direction thereof to perform strip shape control in the width direction of a strip.

{Reference Signs List}

[0089]

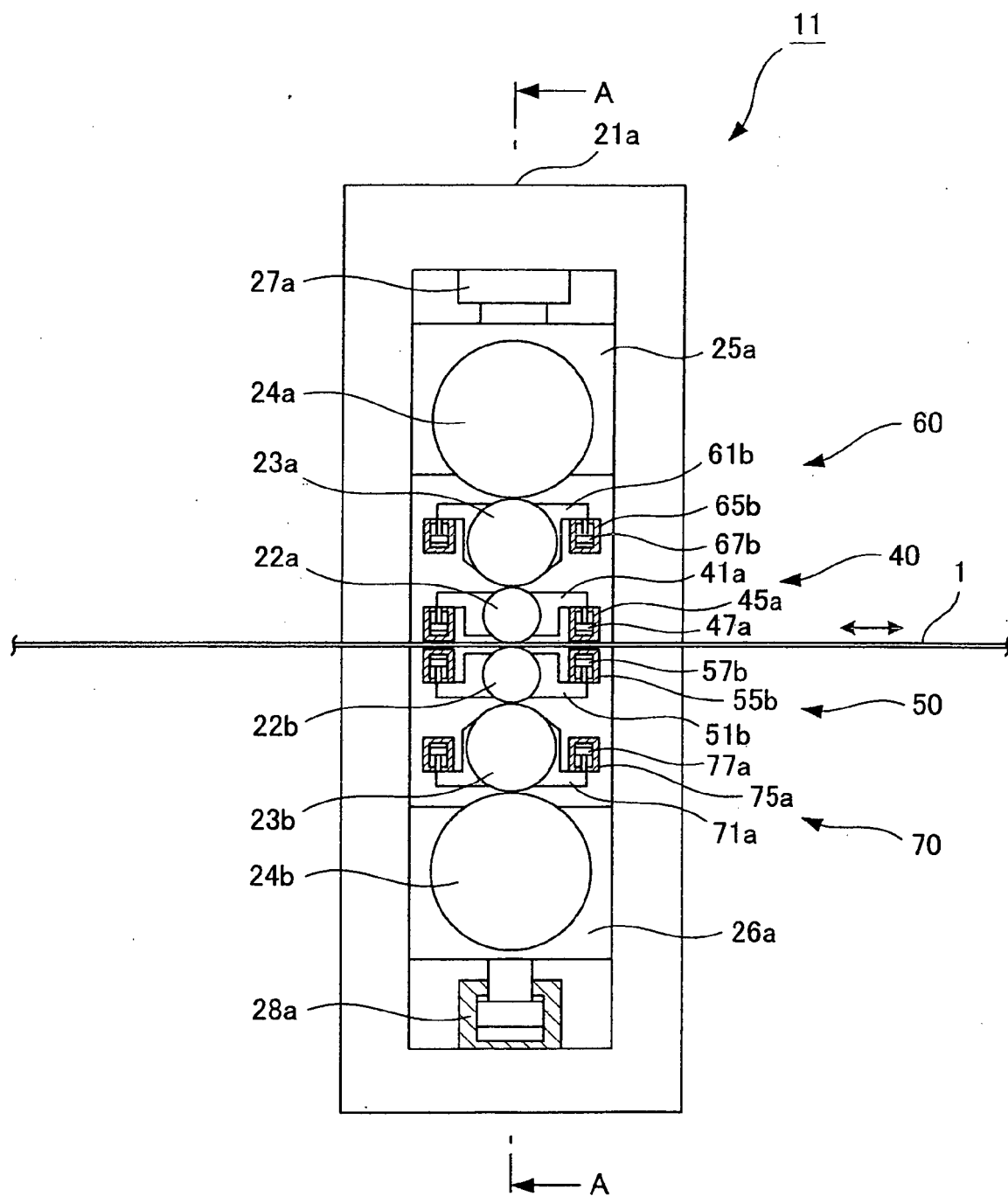
11 to 16	REVERSING ROLLING MILL
22a, 22b, 121a, 121b	WORK ROLL
31a, 32a, 131a, 132a	ROLL BODY PORTION
31b, 32b, 131b, 132b	TAPERING PORTION
31c, 32c, 131c, 132c	ROLL SHOULDER PORTION
31d, 31e, 32d, 32e	ROLL NECK PORTION
40, 50, 140	ROLL SHIFTING DEVICE
41a, 41b, 51a, 51b	BEARING BOX
42	DETACHABLE HOOK
43	SHIFTING FRAME
44a, 44b	SHIFTING CYLINDER
45a, 45b, 55a, 55b	SHIFTING BLOCK
46	STAY
47a, 47b, 57a, 57b	BENDING CYLINDER
141a to 141d	THRUST BEARING
142a to 142d	SHIFT DRIVE UNIT

143a, 143b	BRACKET
161	SPINDLE
162	INNER ECCENTRIC RING
163	OUTER ECCENTRIC RING
5 164	BEARING INNER RING
165	ROLLER
166	BEARING OUTER RING
167	INNER KEY
168	SMALL-DIAMETER PINION
10 169	OUTER KEY
170	LARGE-DIAMETER PINION
181, 182	SHIFTING OIL-HYDRAULIC CYLINDER
200	STRIP THICKNESS MEASURING INSTRUMENT
210	TANDEM ROLLING MILL
15	

Claims

1. A rolling mill having a work roll shifting function, comprising at least one rolling stand (11 to 16, 210) including a pair of upper and lower work rolls (22a, 22b; 121a, 121b) and roll shifting means (40, 50, 140) for shifting the work rolls in an axial direction thereof, the pair of upper and lower work rolls each having, at one end of a roll body portion (31a, 32a; 131a, 132a), a tapering portion (31b, 32b; 131b, 132b) having a roll diameter gradually decreasing toward a tip of the work roll, the pair of upper and lower work rolls clamping a strip (1) while having the tapering portions located on opposite sides from each other in an axial direction thereof,
characterized in that
in the work rolls, at least surfaces of the roll body portions are formed of a ceramic material or a cemented carbide and formed to have 1200 HV or more in terms of Vickers hardness,
the rolling stand is a reversing rolling stand for performing multi-pass multiple rolling while inverting a transport direction of the strip, and
the roll shifting means are adapted to shift the work rolls stepwise every time the strip is passed.
2. The rolling mill according to claim 1,
wherein the roll shifting means (40, 50, 140) include a double-eccentric bearing (141a, 141b, 141c, 141d).
3. The rolling mill according to claim 1 or 2,
wherein each of the work rolls (121a, 121b) is a roll satisfying that a ratio of the roll diameter to a strip width of the strip (1) is 0.03 to 0.1.
4. The rolling mill according to any one of claims 1 to 3, further comprising:
detection means (200) for detecting strip thicknesses of widthwise opposite end portions of the strip (1), the detection means (200) being provided at least on a delivery side of the rolling stand at the last stage (11, 12, 13, 15, 16),
wherein shift positions of the tapering portions (31b, 32b, 131b, 132b) are controlled in accordance with the strip thicknesses of the strip (1) which have been detected by the detection means (200).

Fig. 1



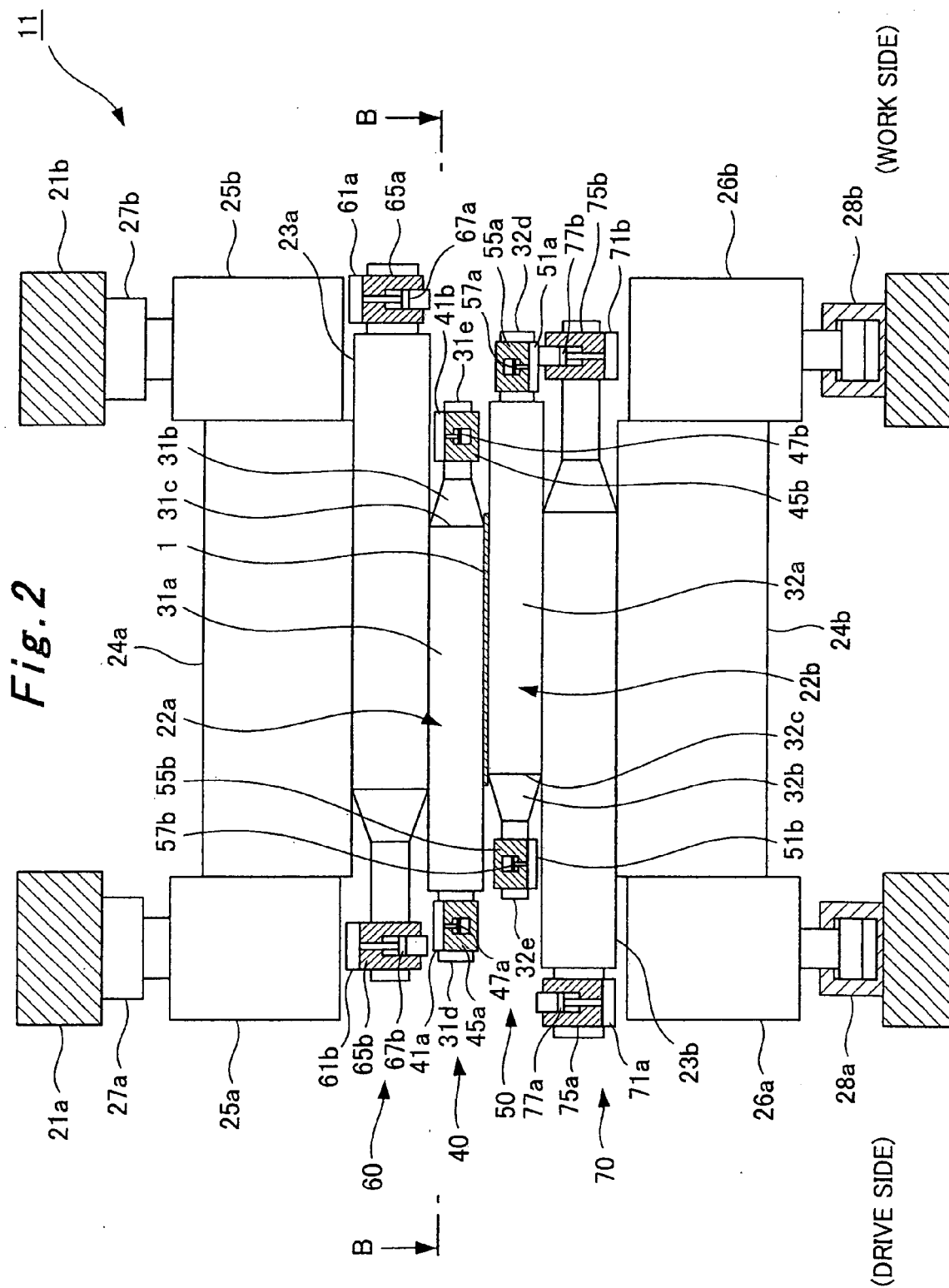


Fig. 3

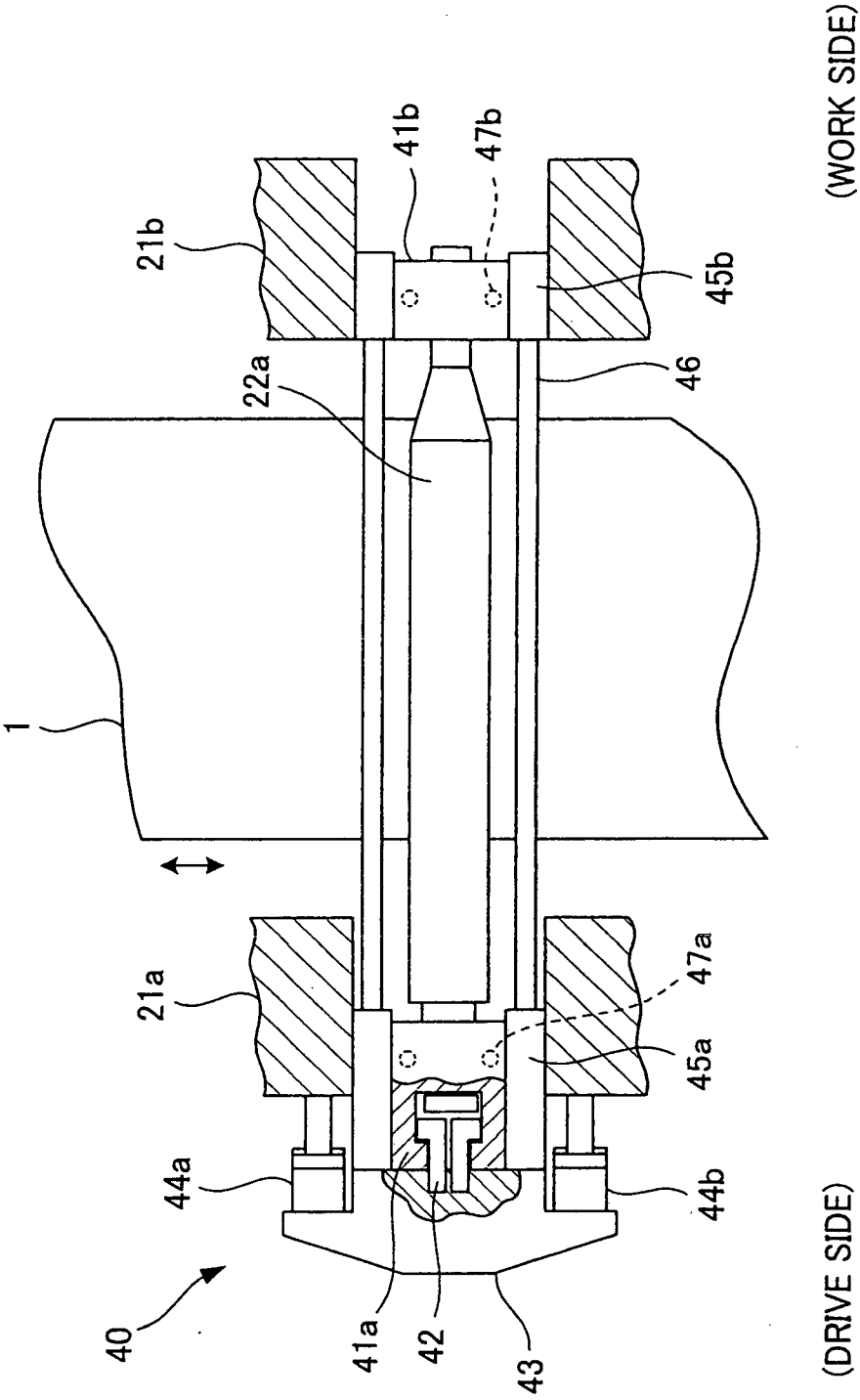


Fig. 4

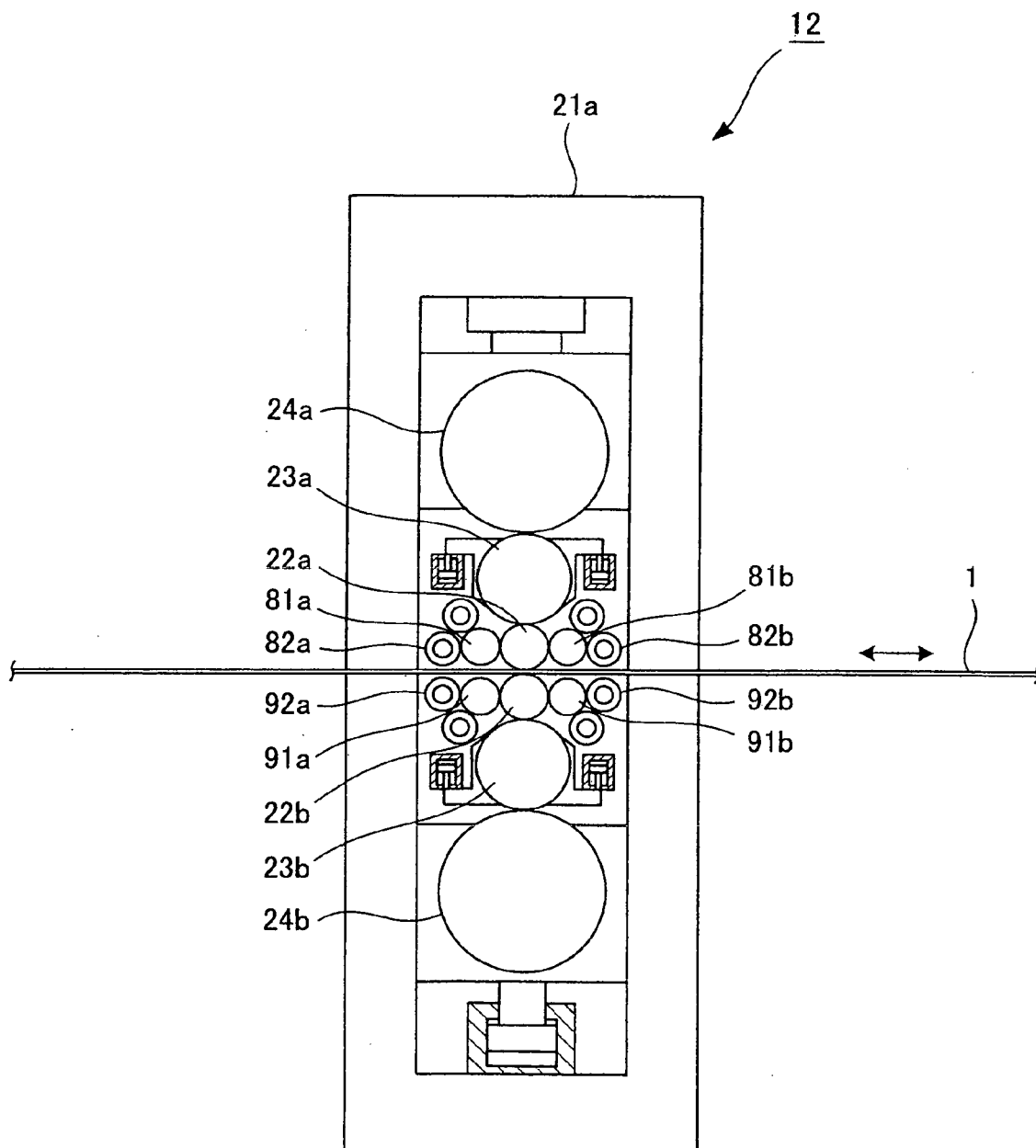


Fig. 5

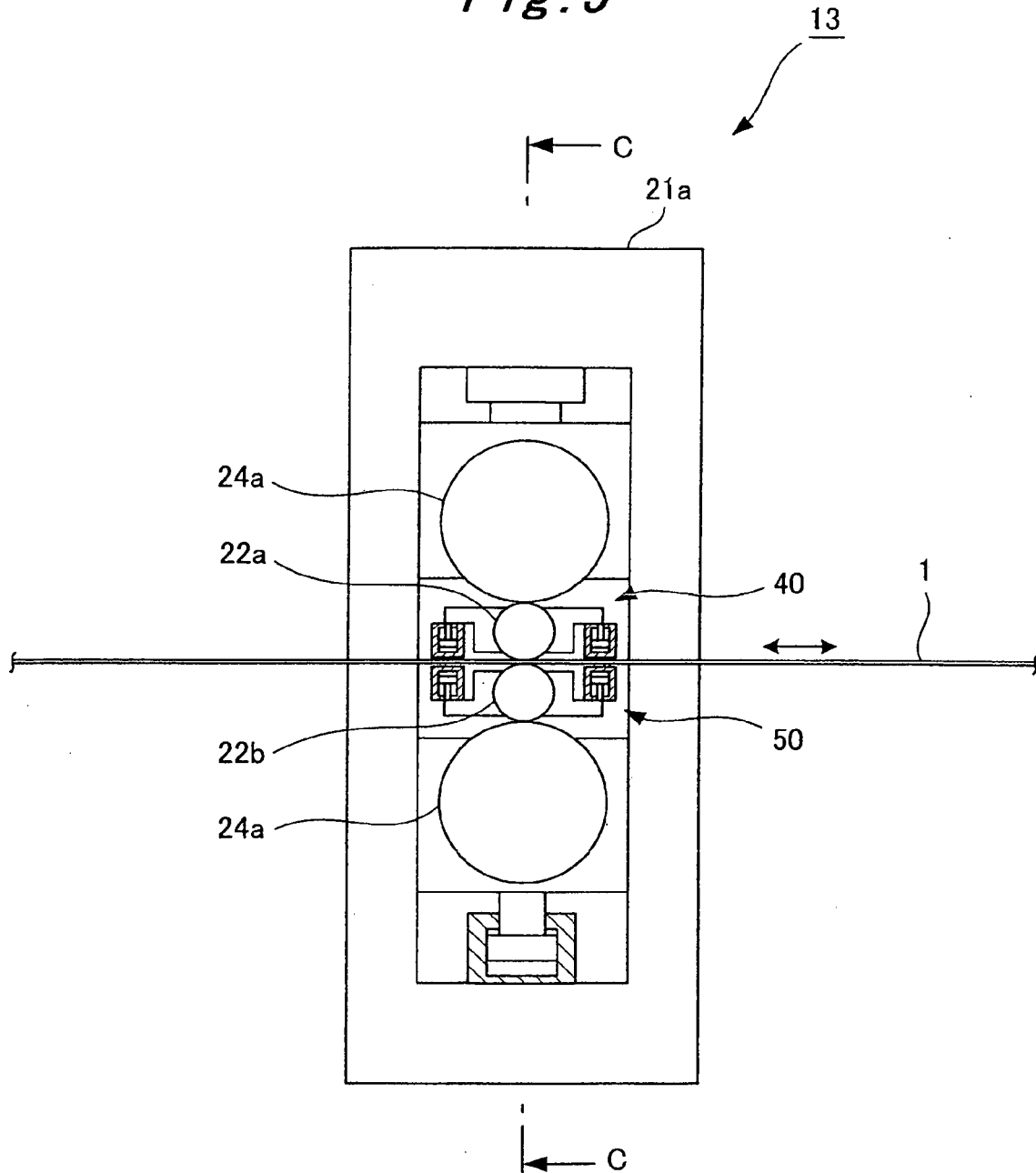


Fig. 6

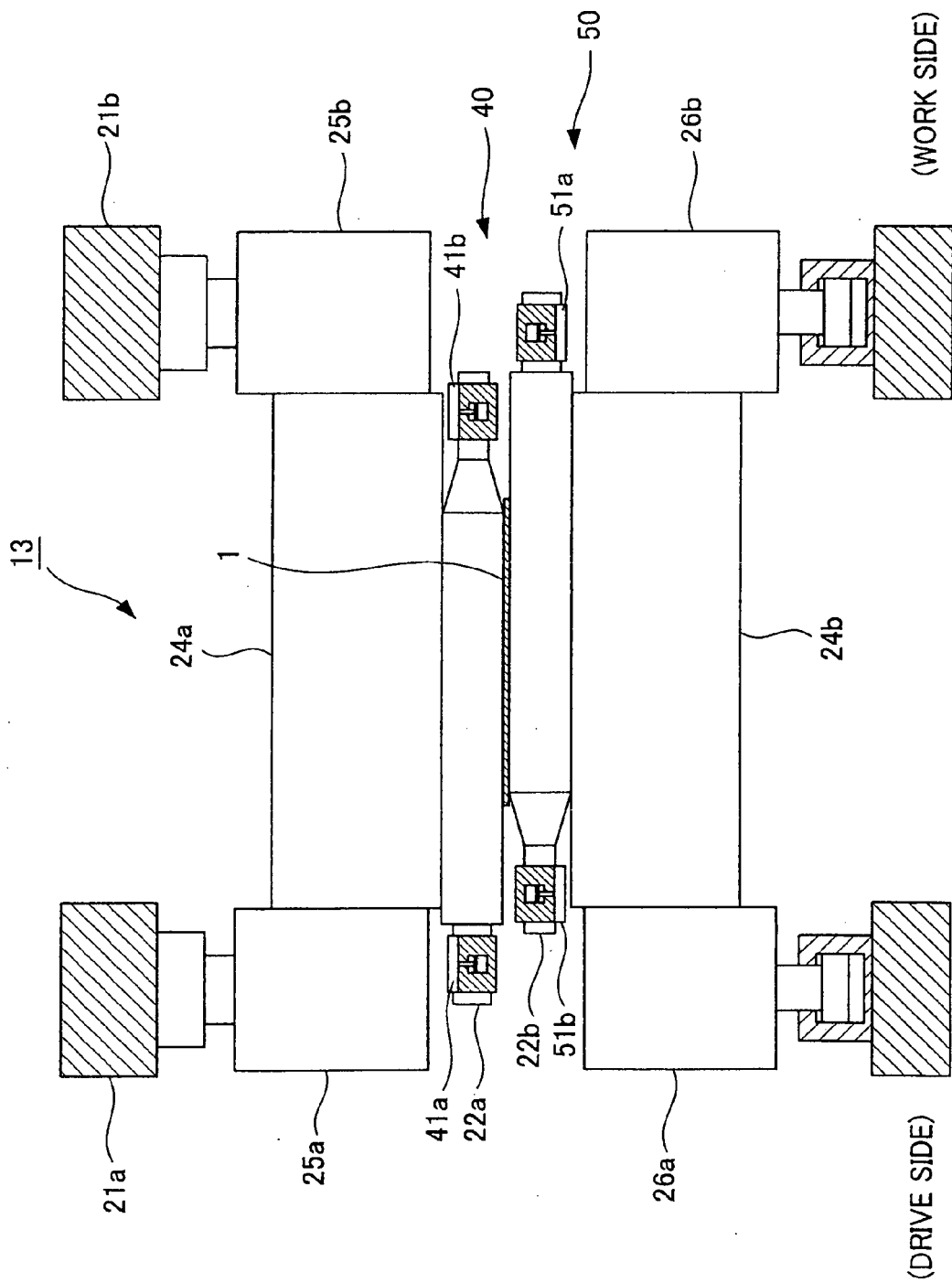


Fig. 7

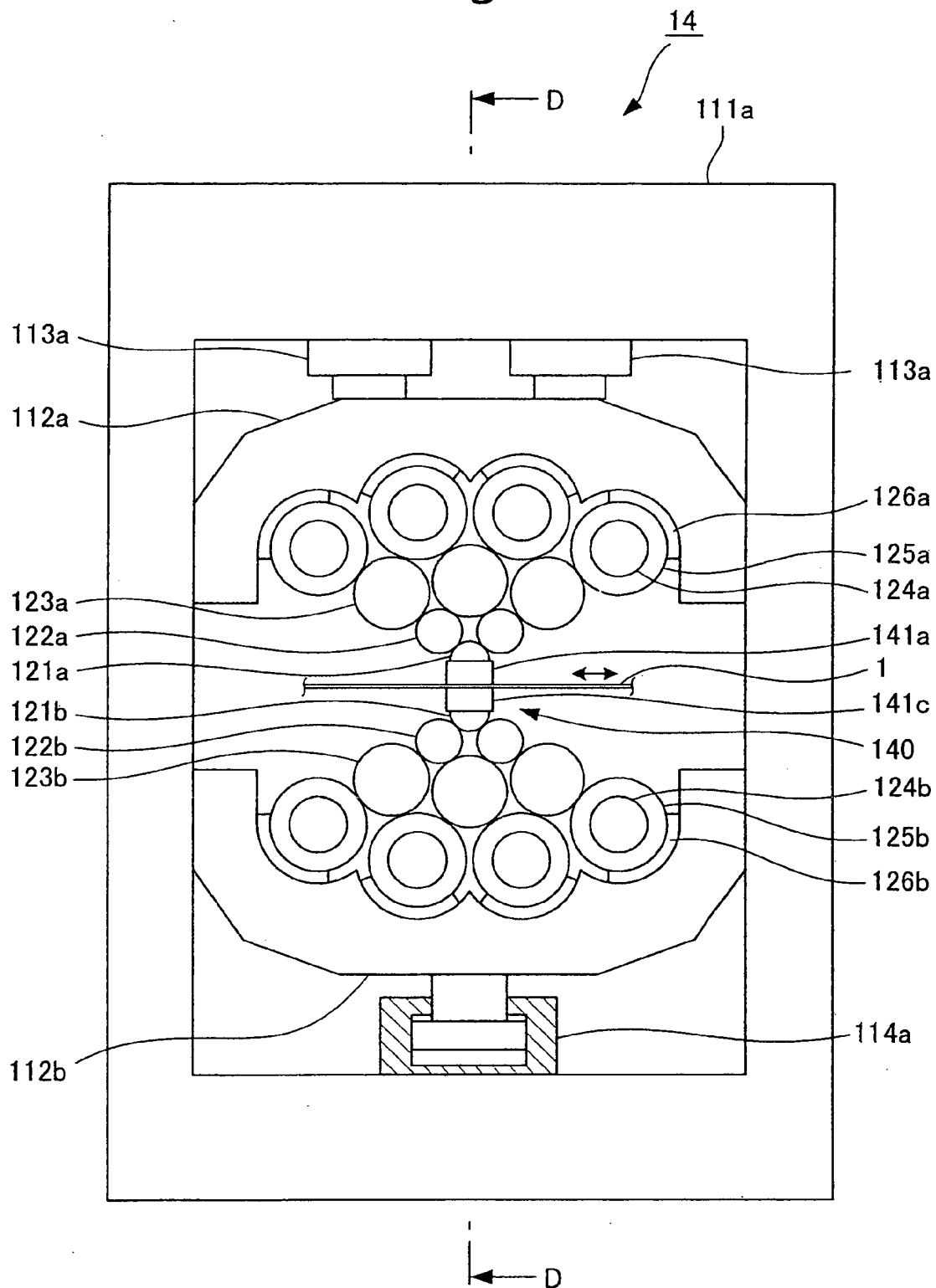


Fig. 8

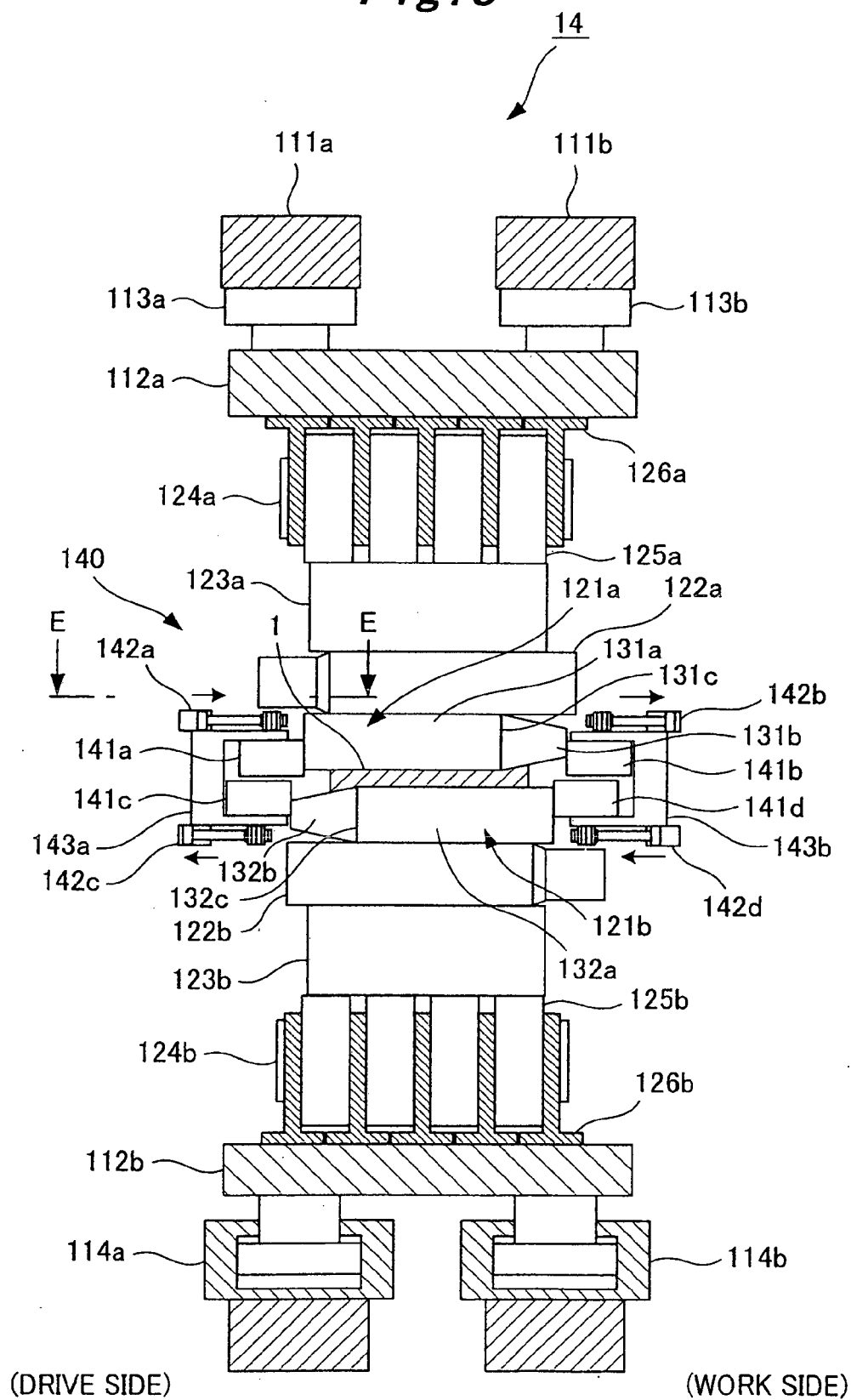


Fig. 9

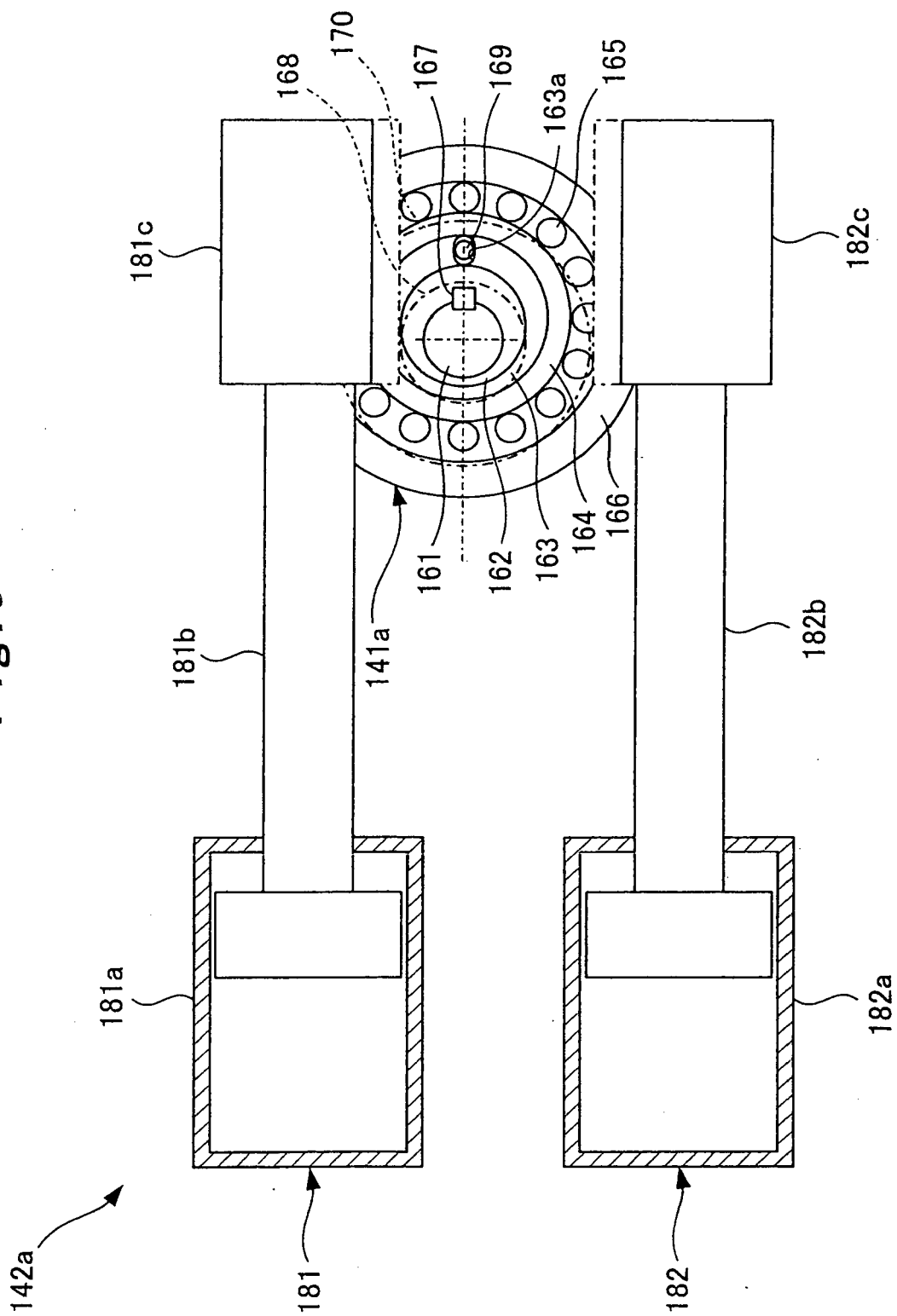


Fig. 10C

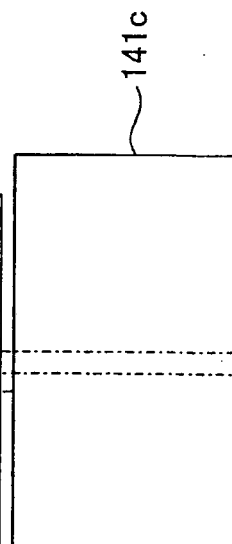
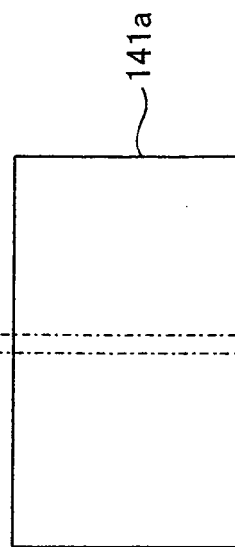
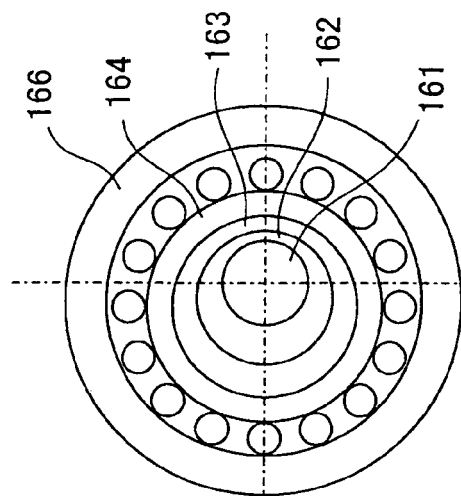


Fig. 10B

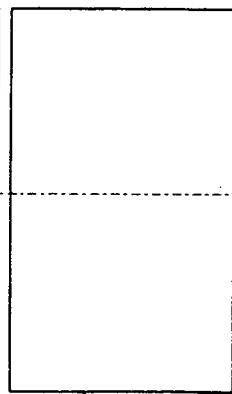
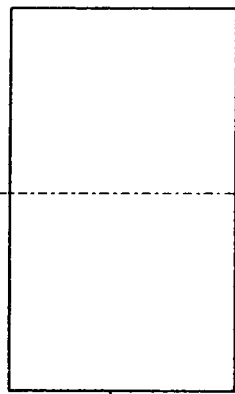
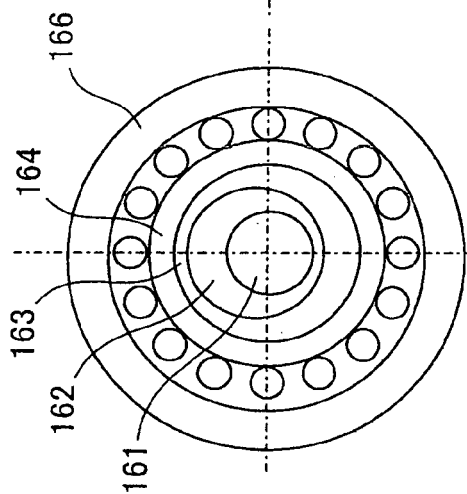


Fig. 10A

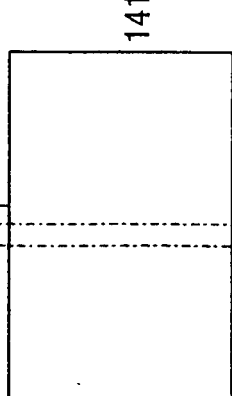
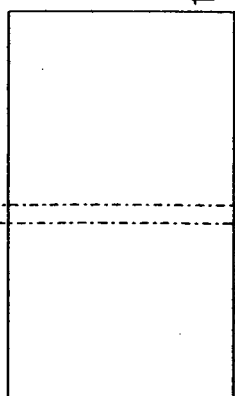
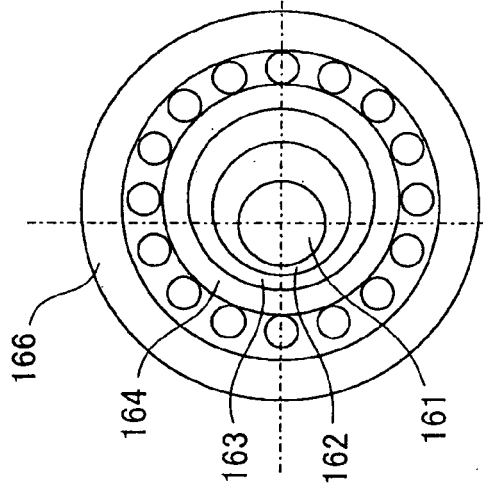


Fig. 11

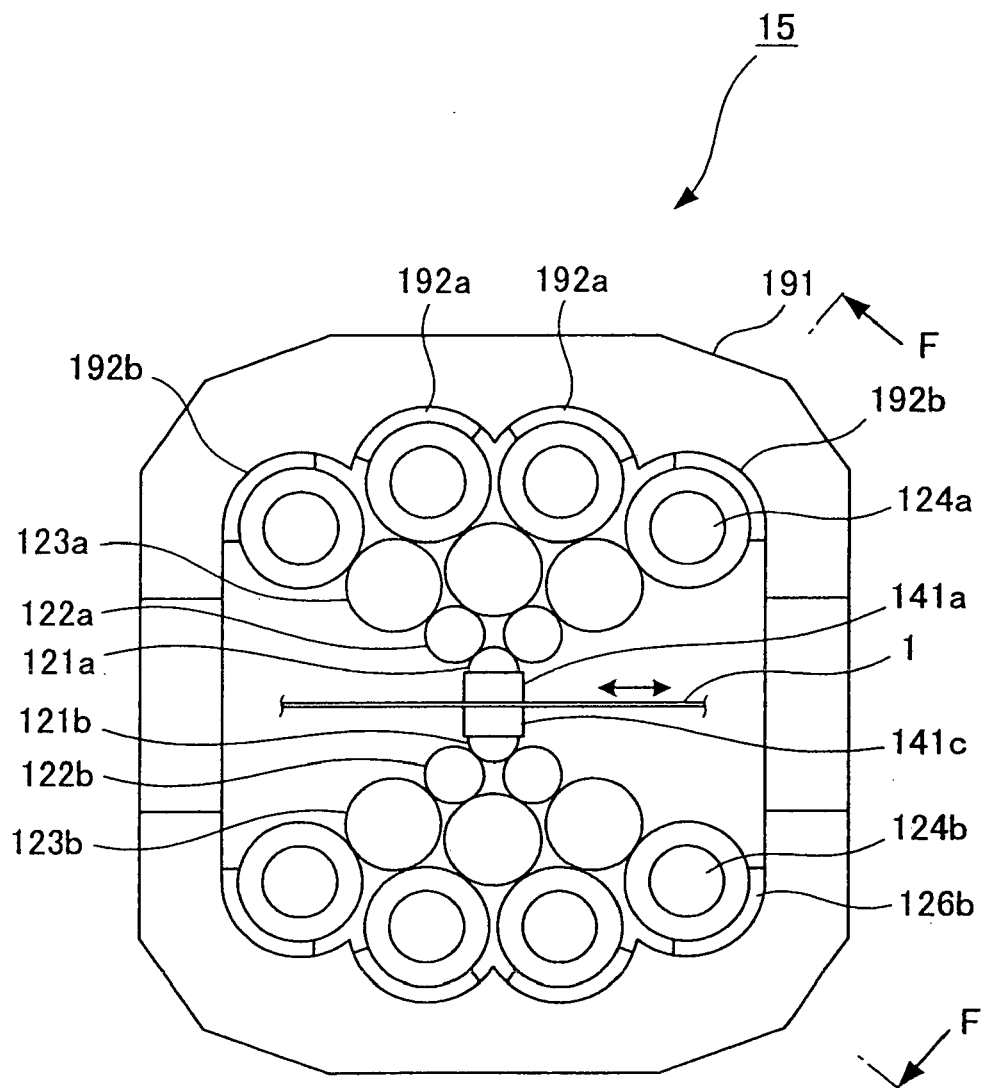


Fig. 12

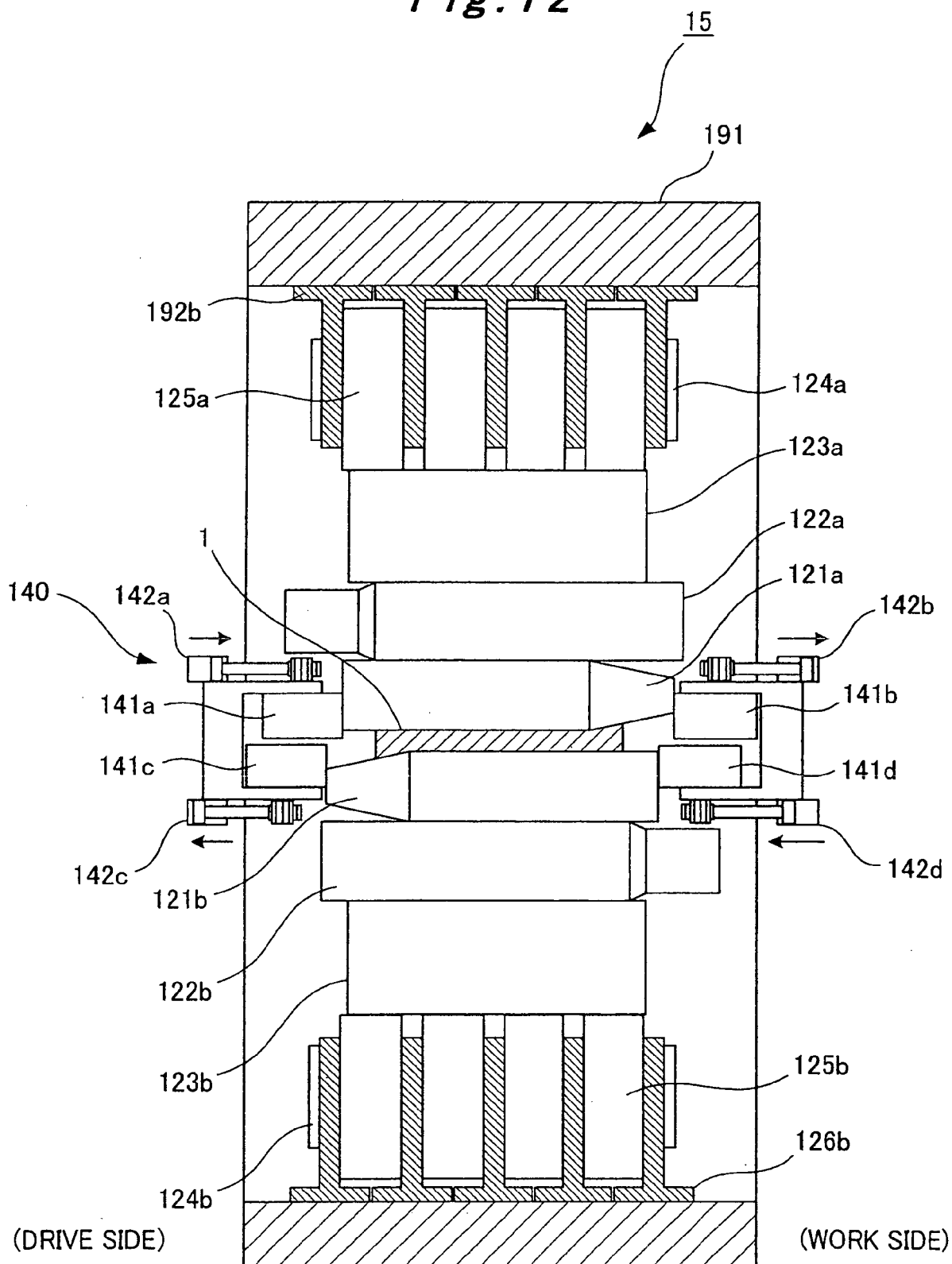


Fig. 13

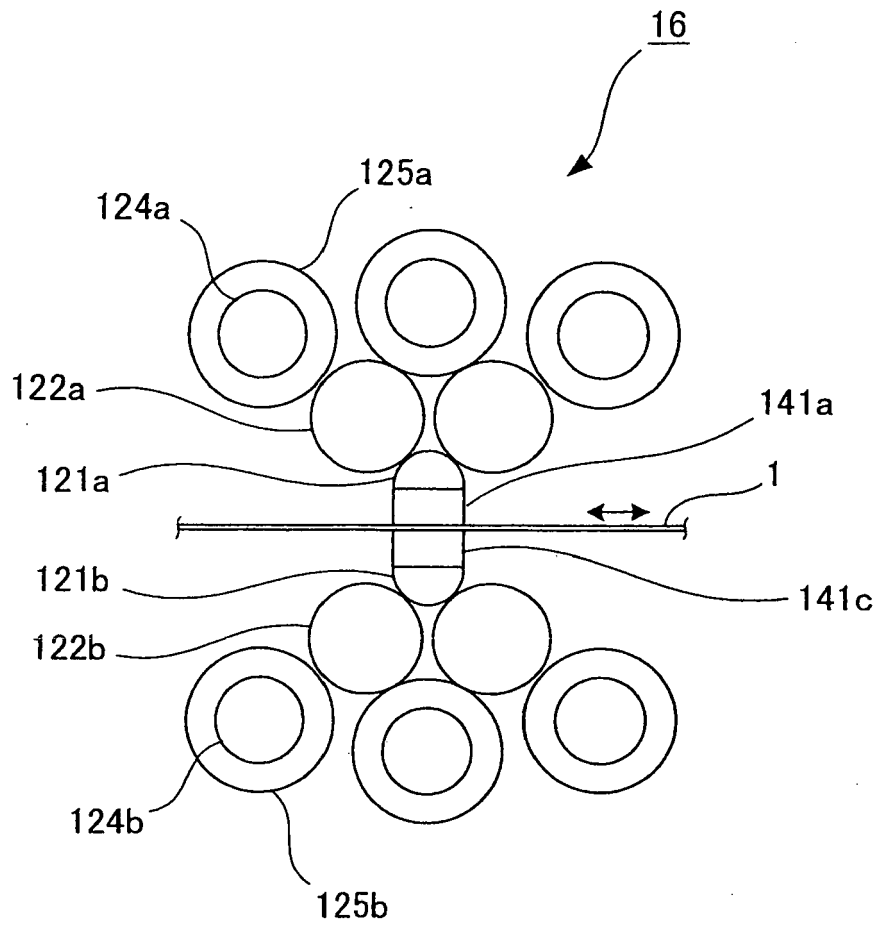


Fig. 14

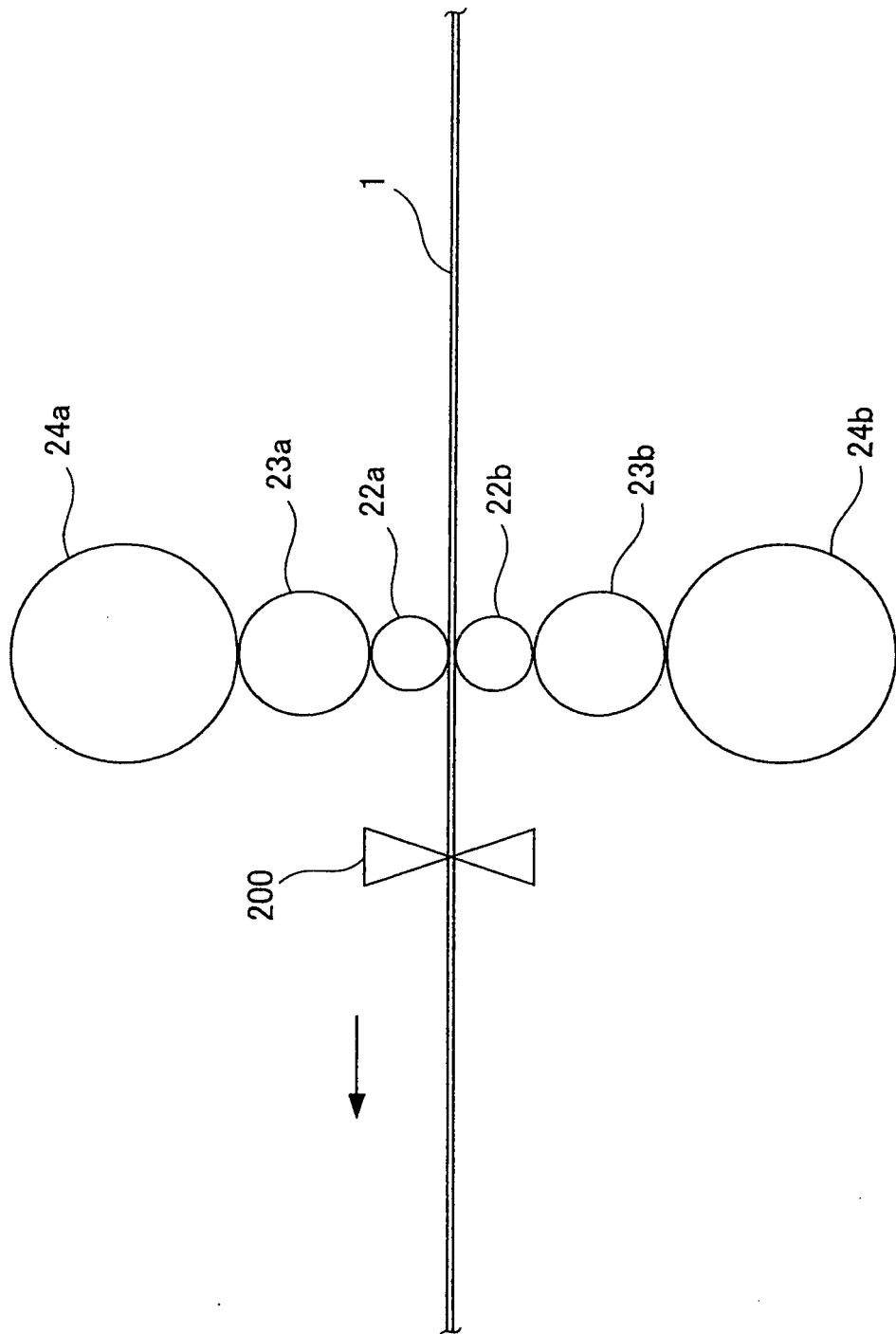


Fig. 15

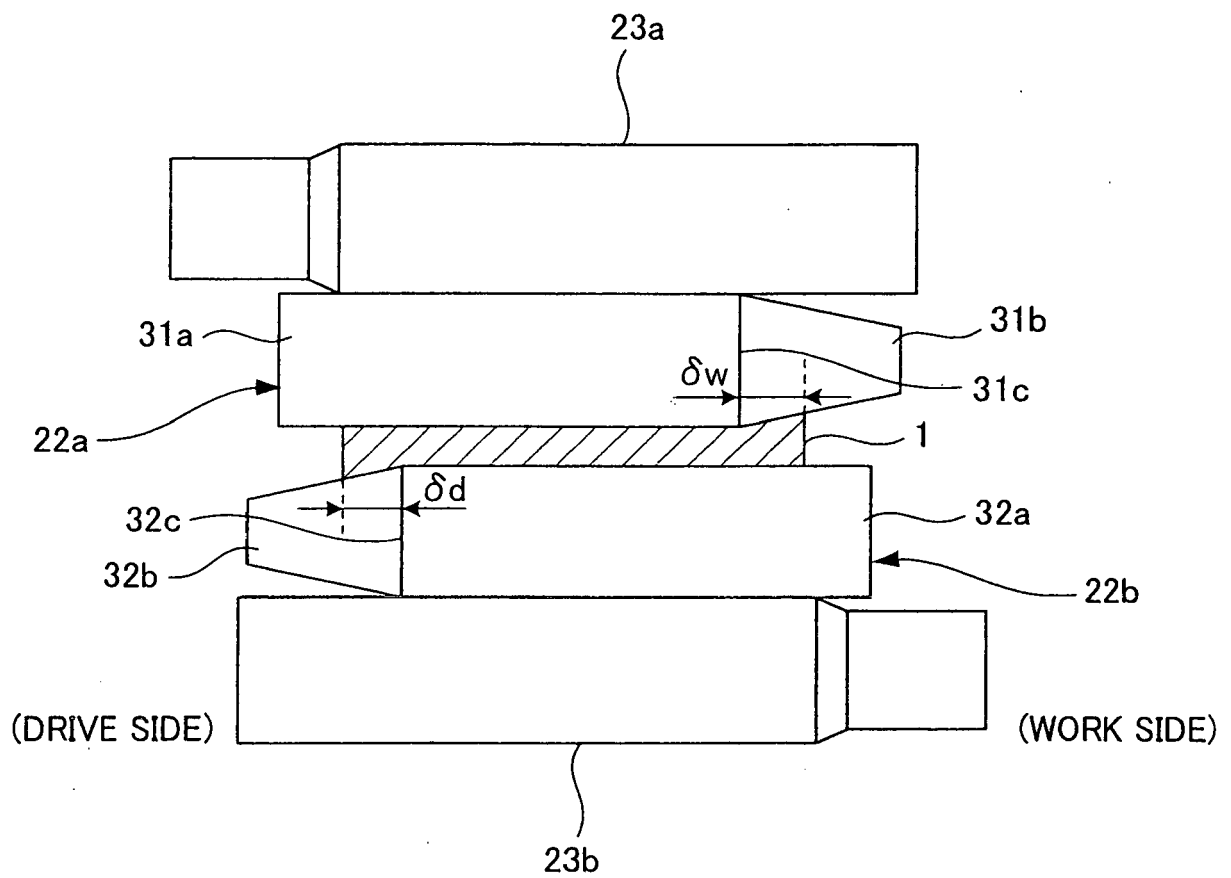
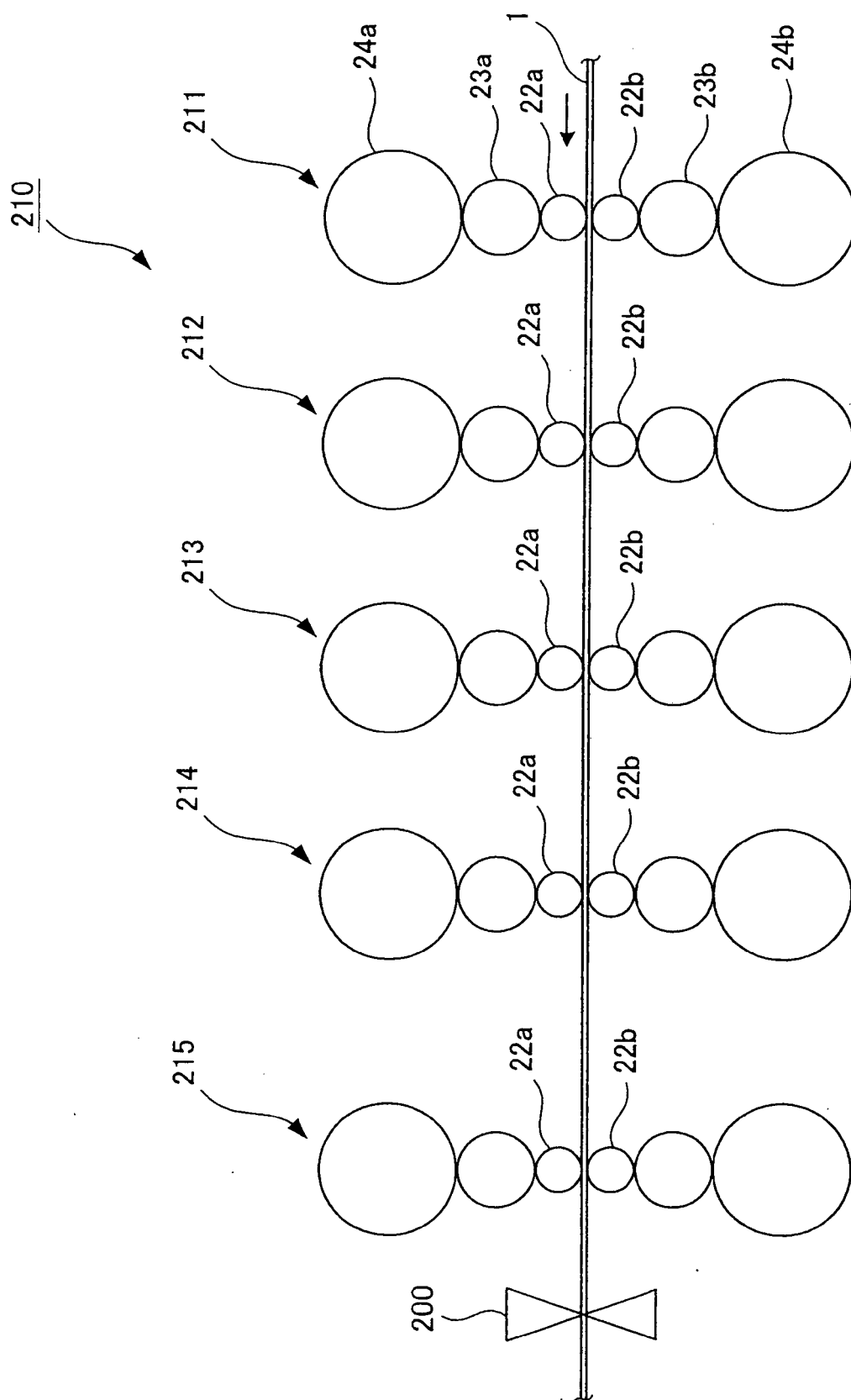


Fig. 16



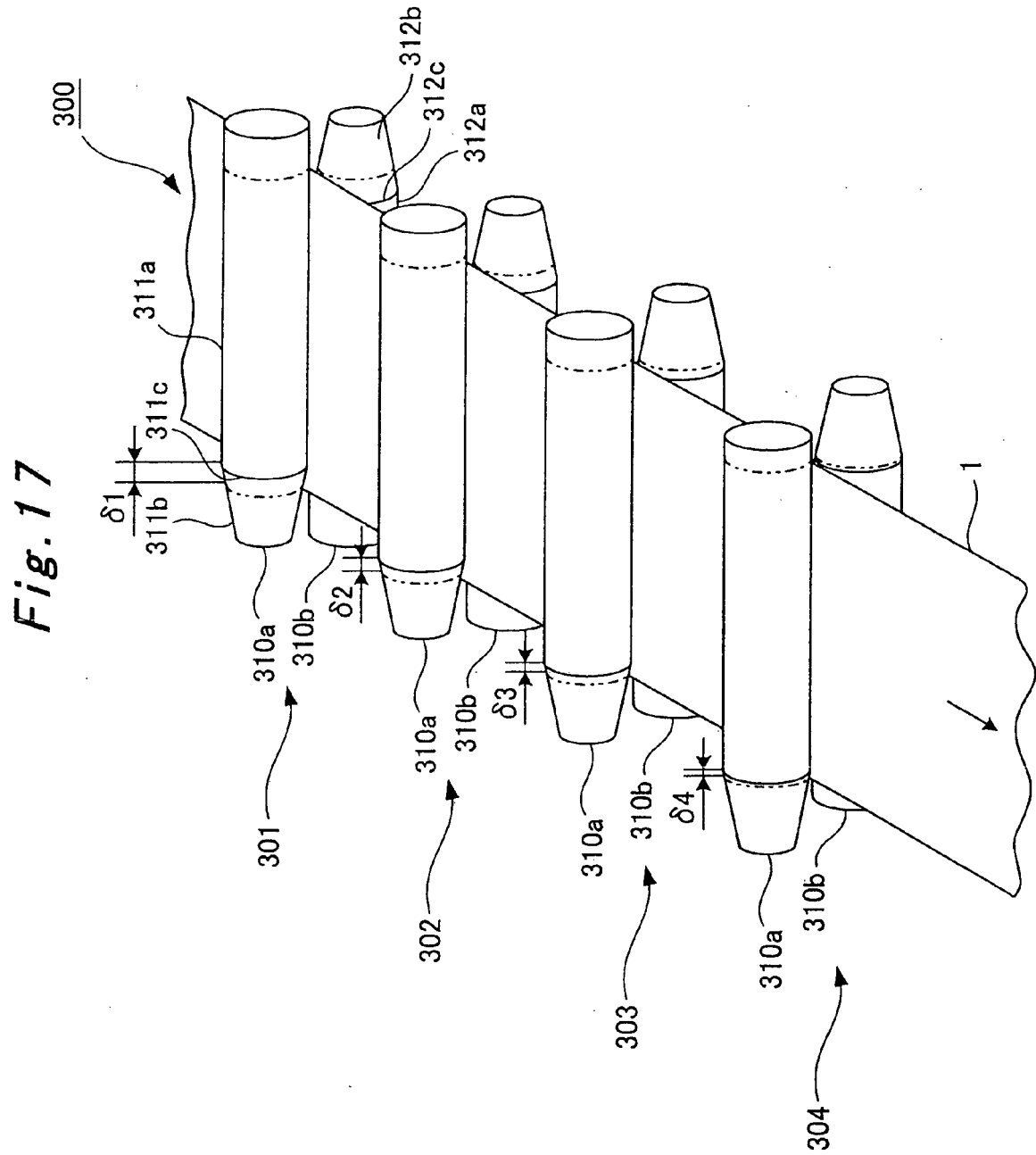


Fig. 18A

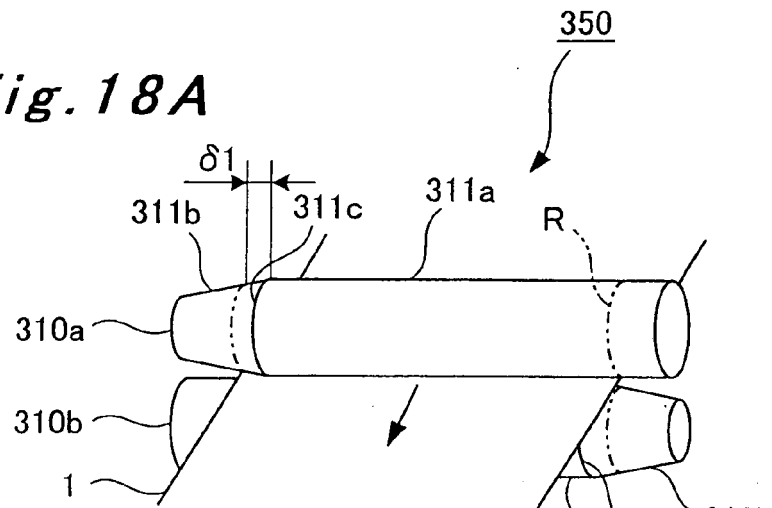


Fig. 18B

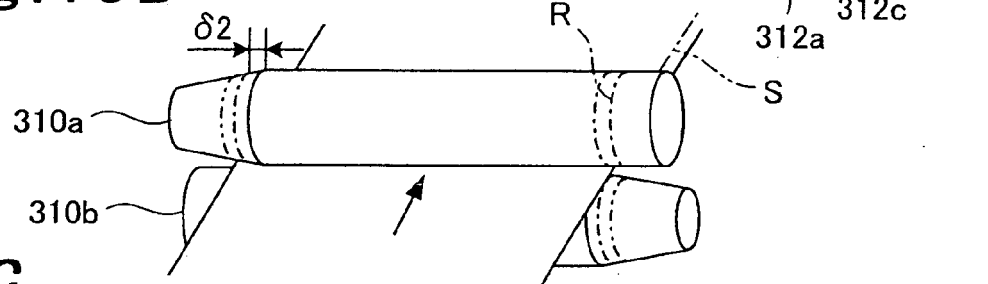
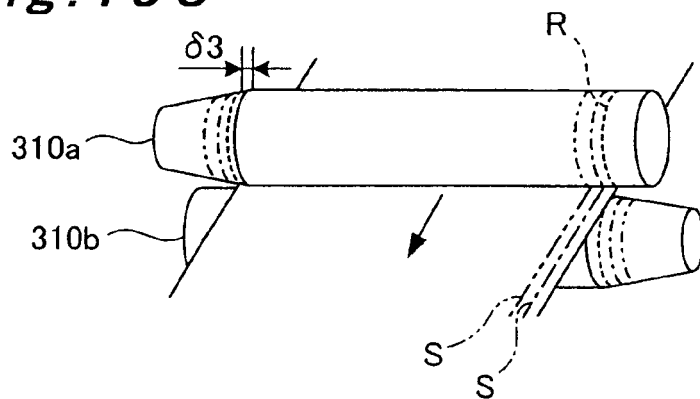


Fig. 18C





EUROPEAN SEARCH REPORT

Application Number
EP 14 00 1890

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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Y	US 2 674 140 A (EGGER OSCAR A) 6 April 1954 (1954-04-06) * column 3, line 65 - column 4, line 10 *	2	
Y	DE 102 08 389 A1 (HITACHI LTD [JP]) 26 June 2003 (2003-06-26) * claims 1-2 *	3	
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			B21B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 24 July 2014	Examiner Forciniti, Marco
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 14 00 1890

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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