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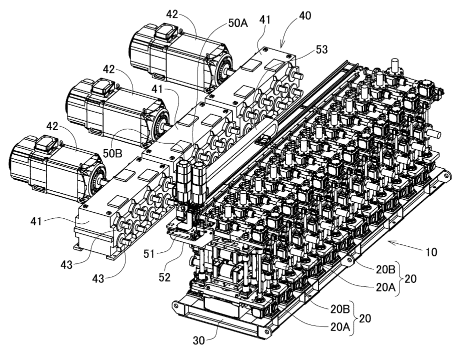
(54) METHOD AND DEVICE FOR MOLDING SQUARE TUBE

(57) [Problem to be solved] To enhance forming performance enhanced in square tube forming of forming a round tube into a square tube by passing the round tube through a plurality of roll stands arranged in a raw tube forming direction. To give a high degree of multi-usability to a square tube forming device. To suppress the entire length of a roll stand array.

[Solution] A first flat roll stand 20A and a second flat roll stand 20B of rolling directions orthogonal to each other are arranged alternately in a forming direction to form a roll stand array 10. Each of the roll stands 20A and 20B includes roll gap adjusting means by which a rolling amount is independently settable, and one of the first flat roll stand 20A and the second flat roll stand 20B adjacent to each other is driven to rotate by roll driving means 40. A forming rolling amount distribution is allocated individually as a rolling amount at each of the roll stands 20A and 20B. The forming rolling amount distribution is determined in advance for stands from a first-stage stand to a final-stage stand in response to the outer diameter, thickness, and material of a forming target raw tube and an intended dimension of a square tube as a product.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to a square tube forming method and a square tube forming device of forming a metallic round tube into a square tube, particularly, to a square tube forming method and a square tube forming device of a forming roll system using forming roll stands in a plurality of states. In this description, a square tube means a metallic square tube.

Background Art

[0002] A configuration employed as a square tube forming device of forming a round tube having a round cross-sectional shape into a square tube having a rectangular cross-sectional shape uses a forming roll stand array including a plurality of forming roll stands arranged in a forming direction. The most common configuration uses a four-direction forming roll stand for restraining the outer circumference of the same cross section of a round tube from four directions including horizontal directions and vertical directions. On the other hand, there are square tube forming devices not using such a four-direction forming roll stand. One of these devices uses a forming roll stand array in which a horizontal roll stand and a vertical roll stand are arranged alternately in a forming direction, as presented in patent literature 1 and patent literature 2.

[0003] In each of the square tube forming devices, caliber rolls are used both as a horizontal forming roll and a vertical forming roll. The caliber roll is a forming roll having an outer circumferential surface recessed more deeply in an arc-like shape from opposite end portions toward the center of the outer circumferential surface in a rotary axis direction, and the arc-like recess is a roll caliber.

[0004] In either square tube forming device, the roll caliber at each stand is basically designed to become shallower gradually from an upstream side toward a downstream side of a material traveling direction. More specifically, the roll caliber is designed in such a manner that the curvature of the roll caliber is reduced stepwise from a value close to the curvature of a round tube as a raw tube to finally become zero, which is equal to that of a linear portion held between a corner portion and a corner portion of a square tube as a product.

[0005] In the square tube forming device shown in patent literature 1, to enhance forming performance by suppressing springback of a tube member occurring between adjacent rolls, effort is made to use the forming forces of the horizontal roll stand and the vertical roll stand mutually by arranging these roll stands closely and alternately.

[0006] In the square tube forming device shown in patent literature 2, improvement is made to the roll caliber of each forming roll. The conventional four-direction forming roll stand is intended to form four corner portions at a time. This causes excessive distortion at the corner portions, so that a section between two corner portions to become a flat linear portion is prone to deformation such as undulation. This is particularly observed in a relatively thin tube. In the square tube forming device shown in patent literature 2, to form (linearize) shoulder portions adjacent to corner portions of a square tube as a product (opposite end portions of a linear portion caught between the two corner portions) before forming of other portions, the roll caliber of the forming roll is divided in a circumferential direction into a corner portion corresponding section, a shoulder portion corresponding section, and a section corresponding to a linear portion other than the shoulder portion, and these corresponding sections are given different curvatures. By doing so, a high-quality square tube having excellent forming performance is obtained.

[0007] In either square tube forming device, the roll caliber is designed in such a manner that the caliber bottom of the forming roll limitedly contacts the center of a linear portion of a square tube as a product, thereby allowing forming of tube members of different sizes using the same stand array within a certain range. However, as a range of multi-use of the device is limited, development of a square tube forming device having a wider range of roll multi-usability is expected.

[0008] Tubes including structural steel tubes have recently been requested to be accurate in curvatures of corner portions at cross sections R conforming to definitions, namely, requested to be free from thickness increase or reduction. In the square tube forming device presented in patent literature 1, however, with the intention of trying to enhance forming performance by suppressing springback, a small-diameter forming roll is employed for the purpose of narrowing a gap between a horizontal roll and a vertical roll adjacent to each other. This disables suppression of springback in a real sense due to the reason of increase in invasion resistance, etc. to make it difficult to respond to the foregoing request. By contrast, in the square tube forming device presented in patent literature 2, a relatively high degree of dimension accuracy is ensured by using the foregoing combination of a plurality of curvatures at the roll caliber. On the other hand, this increases a likelihood that the caliber roll will be used for dedicated purpose, so that roll multi-usability is unavoidably sacrificed.

[0009] In a recent round steel tube manufacturing factory, a tube manufacturing line available for use for forming in a range of several times greater in diameter ratio has been in practical use for encouraging roll multi-use. Incorporating the square tube forming device into such a tube manufacturing line has been expected to achieve manufacture of round tubes and square tubes of various diameters freely responsive to demand using the same forming line. In this case, re-forming of a round tube into a square tube involving a large amount of deformation of a cross section causes a large invasion resistance, so that ensuring stable thrust and suppressing the entire length of a stand array become important issues.

[0010] In the square tube forming devices of patent literatures 1 and 2, however, reducing a gap between adjacent roll stands results in a large amount of springback of a tube member between the adjacent roll stands to cause a considerably large resistance when a tube member passes through a stand array. For this reason, a four-direction roll stand with a combination of a horizontal roll and a vertical roll to produce large thrust becomes necessary for driving the tube member forward. In an actual case, in the square tube forming device presented in patent literature 2, four-direction roll stands are arranged at the most upstream position and the most downstream position of a forming line. In the square tube forming device presented in patent literature 1, four-direction roll stands are also actually required to be arranged in multiple stages for driving for pressing-in a raw tube, for example. Hence, increase in the entire length of the stand array along the forming line becomes unavoidable.

Prior Art Literatures

Patent Literatures

[0011]

Patent Literature 1: Japanese Patent Application Publication No. 2000-301233
Patent Literature 2: Japanese Patent Application Publication No. 2006-150377

Summary of Invention

Problem to be Solved by Invention

[0012] In view of the foregoing circumstances, it is an object of the present invention to provide a square tube forming method and a square tube forming device of excellent forming performance allowing a wide range of multi-use of a roll installable on a current tube manufacturing line, allowing suppression of the entire length of a roll stand array, and reducing a likelihood of the occurrence of thickness increase or reduction at a corner portion of a product.

Means of Solving Problem

[0013] To achieve the foregoing object, the present inventors focused on a flat roll stand with a combination of rod-like flat rolls without roll calibers, particularly, on a flat roll stand array in which a horizontal flat roll stand and a vertical flat roll stand are arranged alternately in a tube member forming direction. Unlike the caliber roll, the flat roll is not recessed in an arc-like shape at an outer circumferential surface. This makes a minimum outer diameter and a maximum outer diameter substantially equal to each other to allow reduction in a gap between the roll stands compared to that in a caliber roll stand. As a result, the entire length of the roll stand array is suppressed, and roll multi-usability is enhanced considerably compared to that of a caliber roll stand array.

[0014] Then, the flat roll stand array was analyzed repeatedly from a variety of viewpoints to find the following issues about forming performance, which is the most significant feature of a square tube forming device.

[0015] First, compared to the case of the caliber roll stand array, the alternate arrangement of the horizontal roll stand and the vertical roll stand basically achieves bending forming using two-direction rolls to prevent the occurrence of distortion at a corner portion to be caused by constriction forming using four-direction rolls. Additionally, a forming roll in each roll stand is a flat roll with a controlled maximum diameter, so that a gap between roll stands can actually be reduced. Even if a gap between the roll stands can be reduced, however, it is still impossible to suppress the springback of a tube member occurring between roll stands adjacent to each other.

[0016] Second, the performance of forming from a round tube into a square tube is affected largely by a ratio of allocation of a rolling amount to each stand in the roll stand array, namely, a rolling amount distribution, rather than the caliber shape of the caliber roll. What is particularly effective is operation of applying an extremely large rolling amount at some of the forming roll stands in the roll stand array and operation of largely changing a rolling amount distribution involving such large change in response to the dimension (outer diameter, thickness) and material of the round tube and the dimension of the square tube.

[0017] Third, the flat roll stand is considerably effective in performing these operations. The reason for this is as follows. In the case of the caliber roll with the roll caliber, an outer diameter is larger at opposite end portions than at a portion corresponding to a caliber bottom to abut on the tube member, so that a gap between rolls and change in a rolling amount are limited by a portion where the outer diameter is at maximum. By contrast, in the case of the flat roll with substantially no roll caliber, a gap between rolls changes in a wide range to allow adjustment of a rolling amount in a wide range, and this works particularly effectively in forming into the square tube.

[0018] Fourth, applying a large rolling amount at the flat roll stand increases springback, and this involves increase in passage resistance of the tube member. This causes difficulty in passing the tube member through the roll stand array, which cannot be handled even by providing a four-direction roll stand additionally such as that disclosed in patent literature 2. To solve this, strong thrust is required to be applied to the tube member passing through the flat roll stand array along its entire length by driving flat rolls to rotate at as many roll stands as possible along the entire length of the flat roll stand array. More specifically, a flat roll is driven to rotate at at least one of the horizontal roll stand and the vertical roll stand adjacent to each other.

[0019] A square tube forming method and a square tube forming device of the present invention have been developed on the basis of the foregoing findings. This square tube forming method is a square tube forming method of forming a round tube of any diameter as a forming target raw tube into a square tube of any dimension as a product by passing the round tube through a plurality of roll stands arranged in a raw tube forming direction, comprising:

using a flat roll stand array in which a first flat roll stand and a second flat roll stand of rolling directions orthogonal to each other are arranged alternately in a forming direction for a tube member and in which a rolling amount at each roll stand is independently settable;

allocating a forming rolling amount distribution individually as a rolling amount at each roll stand in the flat roll stand array, the forming rolling amount distribution being determined in advance for the stands from a first-stage stand to a final-stage stand in response to the outer diameter, thickness, and material of the forming target raw tube to be used and an intended dimension of the square tube as a product; and

forming the forming target raw tube into the square tube as a product having the intended dimension by driving at least one of the first flat roll stand and the second flat roll stand adjacent to each other.

[0020] The square tube forming device of the present invention is a square tube forming device for implementing the square tube forming method of the present invention comprising:

a flat roll stand array in which a first flat roll stand and a second flat roll stand of rolling directions orthogonal to each other are arranged alternately in a forming direction, wherein

each roll stand in the flat roll stand array includes roll gap adjusting means by which a rolling amount is independently settable, and at least one of the first flat roll stand and the second flat roll stand adjacent to each other includes roll driving means.

[0021] In the description of the present invention given below, a roll stand array means a flat roll stand array and a forming raw member means a forming target raw tube.

[0022] According to the square tube forming method and the square tube forming device of the present invention, as long as rolling directions are orthogonal to each other at the first flat roll stand and the second flat roll stand adjacent to each other, each rolling direction may be at any angle relative to a vertical line or a horizontal line. In terms of reality, however, one of the first flat roll stand and the second flat roll stand is preferably a horizontal roll stand and the other is preferably a vertical roll stand. Regarding roll driving at each roll stand, both the first flat roll stand and the second flat roll stand adjacent to each other may be driven, namely, all the rolls may be driven. Driving both the horizontal roll and the vertical roll allows forming into a square tube of different rectangular ratios. While both of these rolls can be driven only at some of the stands, driving only one of the rolls in each of all the stands is rational and desirable in terms of giving rationality to a device configuration and reducing cost of manufacturing the device.

[0023] Basically, the flat roll at each roll stand has an outer diameter constant along its entire length in a rotary axis direction. In this regard, at some of the roll stands, particularly, at one or a plurality of successive roll stands in a part of the flat roll stand array, shallow arc-like recesses having larger curvatures than an outer surface R of a roll contact surface of the tube member to pass through the one or plurality of roll stands may be formed at both of the rolls in each roll stand, regardless of whether the rolls are to be driven or not to be driven. This is also within the range of the present invention. As a result of formation of this arc-like recess at the outer circumferential surface of a driven roll in a section requiring large thrust to the tube member, for example, in an upstream section of the roll stand array, for example, large thrust is obtained. Further, formation of a similar arc-like recess at the outer circumferential surface of a non-driven roll allows the tube member to be driven forward smoothly and allows smooth forming of the tube member.

[0024] A gap adjusting motor of a roll gap adjusting mechanism for the roll stand array is preferably shared in the roll stand array. More specifically, while gap adjusting motors in a pair intended for the first flat roll stand and the second flat roll stand in a pair adjacent to each other are movable along the roll stand array, these gap adjusting motors are preferably shared between the first flat roll stands and the second flat roll stands in a plurality of pairs. This simplifies the configuration of the device and reduces the weight of the device, thereby reducing cost of manufacturing the device.

[0025] Referring to the inventions disclosed in patent literatures 1 and 2, while the horizontal roll stand and the vertical roll stand are arranged alternately, these inventions basically relate to a technique of square tube forming using the caliber roll stand array, namely, a technique of roll forming of a round tube as a raw tube gradually into a square tube as a product by reducing the curvature of the roll caliber stepwise at the stands.

[0026] According to the square tube forming using the caliber roll stand array, a total forming amount is allocated substantially uniformly to all the stages in response to the number of stands to be used. On the basis of the allocation, a caliber curvature at each stand is designed. A rolling amount at each stand is also determined by allocating a total rolling amount uniformly to the stands in response to a caliber curvature distribution.

Advantageous Effects of Invention

[0027] The square tube forming method and the square tube forming device of the present invention use the roll stand array in which the first flat roll stand and the second flat roll stand of rolling directions orthogonal to each other are arranged alternately in the forming direction to remove limitation on forming dimensions imposed by the roll caliber, thereby achieving considerably high roll multi-usability. Moreover, in addition to suppressing the entire length of the flat roll stand array by reducing a gap between flat roll stands adjacent to each other, a need for a sizing stand (four-direction roll stand) conventionally indispensable for ensuring thrust is eliminated, thereby facilitating incorporation into a current tube manufacturing line. As a result of the foregoing, it becomes possible to form a round tube of any diameter, more specifically, of any dimension (outer diameter, thickness) and any material into a square tube of any dimension.

[0028] Specifically, considerably high roll multi-usability is achieved by the use of the flat roll, a rolling amount at each stand in the stand array is independently settable to allow a rolling amount to be allocated freely, and suppressing the entire length of the roll stand array allows increase in the number of stages of the roll stands. Thus, even in the case of a large rolling amount, a forming amount at one stage of roll stand is still suppressed, thereby reducing the occurrence of winding around a roll to reduce an invasion resistance. Moreover, bending forming is performed using two-direction rolls unlike constriction forming using four rolls, and at least one of the first flat roll stand and the second flat roll stand adjacent to each other is driven to allow application of stable thrust to a tube member to pass through the stand array. As a result, even in the absence of a sizing stand (four-direction roll stand) for ensuring thrust and even with the suppressed entire length of the flat roll stand array, high tube manufacturing efficiency is still ensured stably and thickness increase or reduction is unlikely to occur at a corner portion of a product, thereby ensuring excellent forming performance.

[0029] Thus, the square tube forming method and the square tube forming device of the present invention achieve manufacture of high-quality square tubes economically.

Brief Description of Drawings

[0030]

Fig. 1 is a perspective view of a square tube forming device showing an embodiment of the present invention;

Fig. 2 is a perspective view of the square tube forming device taken from a different angle from which a roll driving mechanism is omitted;

Fig. 3 is a perspective view of a horizontal roll stand in the square tube forming device;

Fig. 4 is a perspective view of a vertical roll stand in the square tube forming device;

Fig. 5 is a perspective view showing one example of a square tube forming method of the present invention and showing a square tube forming process continuously and entirely according to this example;

Fig. 6 is an explanatory view showing the square tube forming process of forming a raw round tube into a square tube as a product in stages according to the one example by illustrating cross-sectional shapes of the tube at respective stands;

Fig. 7 is a perspective view showing a different example of the square tube forming method of the present invention and showing a square tube forming process continuously and entirely according to this example; and

Fig. 8 is an explanatory view showing the square tube forming process of forming a raw round tube into a square tube as a product in stages according to the different example by illustrating cross-sectional shapes of the tube at respective stands.

Embodiments for Carrying Out Invention

[0031] An embodiment of the present invention will be described below.

[0032] A square tube forming device of the embodiment is a device of forming a round tube as a forming raw member continuously into a square tube by passing the round tube through a plurality of forming roll stands sequentially. The square tube forming device is arranged in a round tube manufacturing line and used for forming a part of a manufactured round tube into a square tube to allow manufacture of both the round tube and the square tube.

[0033] As shown in Figs. 1 and 2, this square tube forming device includes a roll stand array 10 of a square tubular shape extending long in a tube member forming direction. The square tubular roll stand array 10 has a configuration in which a horizontal roll stand 20A of a square frame-like shape having a small thickness in the tube member forming direction and a vertical roll stand 20B of a square frame-like shape also having a small thickness in the tube member forming direction are arranged alternately on a stand base 30 in the tube member forming direction. A round tube as a forming raw member passes through the roll stand array 10 from a front side toward a back side of Fig. 1. Namely, the front side of Fig. 1 is an upstream side of the roll stand array 10, and the back side of Fig. 1 is a downstream side of the roll stand array 10.

[0034] As shown in Fig. 3, the horizontal roll stand 20A includes: upper and lower horizontal fixed bases 22A, 22A coupled by a total of four vertical rods 21A arranged two on the right and two on the left; upper and lower horizontal movable bases 23A, 23A supported to be vertically movable by the right and left vertical rods 21A between the upper and lower horizontal fixed bases 22A, 22A; and upper and lower horizontal rolls 24A, 24A attached to respective surfaces of the movable bases 23A, 23A facing each other.

[0035] Each of the upper and lower horizontal rolls 24A is a flat roll having an outer diameter substantially constant along its entire length in a center axis direction. A horizontal support shaft supporting the horizontal roll 24A is rotatably supported by brackets 25A, 25A provided in bearings on the opposite sides of the horizontal roll 24A. One end portion of this support shaft projects as an input shaft 24A' toward one side of the roll stand array 10 and is coupled to a roll driving mechanism 40 as roll driving means arranged on the one side, thereby driving the horizontal roll 24A to rotate (see Fig. 1).

[0036] A roll gap between the upper and lower horizontal rolls 24A, 24A in a pair is adjusted by a mechanical upper jack 26A attached in a downward-pointing position to the upper surface of the upper horizontal fixed base 22A at the center and by a mechanical lower jack 26A attached in an upward-pointing position to the lower surface of the lower horizontal fixed base 22A at the center.

[0037] Specifically, the downward-pointing upper jack 26A has a tip portion coupled to the upper surface of the upper movable base 23A while penetrating the upper horizontal fixed base 22A, and is driven by a horizontal roll gap adjusting motor 50A (see Figs. 1 and 2) arranged on the one side of the roll stand array 10 through a horizontal input shaft 27A. The upward-pointing lower jack 26A has a tip portion coupled to the lower surface of the lower movable base 23A while penetrating the lower horizontal fixed base 22A, and is driven symmetrically to and synchronously with the upper jack 26A as driving force of the horizontal roll gap adjusting motor 50A (see Figs. 1 and 2) is transmitted to the lower jack 26A through a gear box 28A attached to a lateral upper surface of the upper horizontal fixed base 22A on the other side, a vertical power transmission shaft 29A, and a gear box 28A attached to a lateral lower surface of the lower horizontal fixed base 22A on the other side.

[0038] The symmetric and synchronous driving using the upper and lower jacks 26A, 26A described above drives the upper and lower movable bases 23A, 23A to move up and down symmetrically, thereby adjusting a roll gap between the upper and lower horizontal rolls 24A, 24A. Namely, a gap adjusting mechanism for the upper and lower horizontal rolls 24A, 24A is configured using the upper and lower jacks 26A, 26A, the horizontal roll gap adjusting motor 50A, and a power transmission mechanism including the input shaft 27A, the upper and lower gear boxes 28A, 28A, and the power transmission shaft 29A.

[0039] As shown in Fig. 4, the vertical roll stand 20B includes: right and left vertical fixed bases 21B, 21B in a pair; two upper and lower horizontal rods 22B, 22B coupling the right and left vertical fixed bases 21B, 21B; right and left movable bases 23B, 23B supported to be horizontally movable by the two upper and lower horizontal rods 22B, 22B between the right and left vertical fixed bases 21B, 21B; and right and left vertical rolls 24B, 24B rotatably supported by the right and left movable bases 23B, 23B respectively.

[0040] The right and left vertical fixed bases 21B, 21B are provided in standing positions symmetrically to each other on opposite end portions of the lower horizontal fixed base 22A of the horizontal roll stand 20A described above (see Fig. 3). Namely, the foregoing lower horizontal fixed base 22A of the horizontal roll stand 20A extends toward the downstream side of the roll stand array 10, and the vertical fixed bases 21B, 21B are attached to this extending portion. In this way, the horizontal roll stand 20A and the vertical roll stand 20B in a pair adjacent to each other form a horizontal and vertical stand pair 20 integrated by the common horizontal fixed base 22A.

[0041] Each of the right and left movable bases 23B includes upper and lower sliders slidably supported by the upper and lower horizontal rods 22B, 22B, and a roll support frame 25B attached between the upper and lower sides. The roll support frame 25B, which further functions as a coupling member between the upper and lower sliders, has a configuration opened inwardly formed by a combination of upper and lower horizontal members and an outer vertical member. The foregoing right and left vertical rolls 24B, 24B are rotatably supported between these upper and lower horizontal members. A roll gap between the right and left vertical rolls 24B, 24B is adjusted by right and left jacks 26B, 26B attached to outer side surfaces of the right and left vertical fixed bases 22B, 22B respectively with the inner sides thereof pointing toward the respective outer side surfaces.

[0042] Specifically, the jack 26B on the one side has a tip portion coupled to the outer side surface of the outer vertical member of the movable base 23B on the one side while penetrating the vertical fixed base 22B on the one side, and is driven by a vertical roll gap adjusting motor 50B (see Figs. 1 and 2) arranged on the one side of the roll stand array 10 through a vertical input shaft 27B. The jack 26B on the other side has a tip portion coupled to the outer side surface of the outer vertical member of the movable base 24B on the other side while penetrating the vertical fixed base 22B on the other side, and is driven symmetrically to and synchronously with the jack 26B on the one side as driving force of the vertical roll gap adjusting motor 50B (see Figs. 1 and 2) is transmitted to the jack 26B on the other side through a gear box 28B attached to a lateral portion of the stand base 30 on the one side, a horizontal power transmission shaft 29B, and a gear box 28B attached to a lateral portion of the stand base 30 on the other side.

[0043] The symmetric and synchronous driving using the right and left jacks 26B, 26B described above moves the right and left movable bases 23B, 23B horizontally and symmetrically to each other, thereby adjusting a gap between the right and left vertical rolls 24B, 24B. Namely, a gap adjusting mechanism for the right and left vertical rolls 24B, 24B is configured using the right and left jacks

26B, 26B, the vertical roll gap adjusting motor 50B, and a power transmission mechanism including the input shaft 27B, the right and left gear boxes 28B, 28B, and the power transmission shaft 29B.

[0044] With the horizontal roll stand 20A and the vertical roll stand 20B in a pair having the foregoing configurations defined as the horizontal and vertical stand pair 20, a plurality of such pairs is arranged on the stand base 30 in the tube member forming direction to form the roll stand array 10 of the square tube forming device. More specifically, the roll stand array 10 is composed of 11 stand pairs 20 (23 roll stands in total including the horizontal roll stand 20A in a final stage).

[0045] As described above, in this square tube forming device, a gap between the horizontal rolls 24A, 24A in the horizontal roll stand 20A is adjusted by the horizontal roll gap adjusting motor 50A, and a gap between the vertical rolls 24B, 24B in the vertical roll stand 20B is adjusted by the vertical roll gap adjusting motor 50B. The horizontal roll gap adjusting motor 50A and the vertical roll gap adjusting motor 50B are provided only in one pair for one horizontal and vertical stand pair 20, and the horizontal roll gap adjusting motor 50A and the vertical roll gap adjusting motor 50B in one pair moves along the roll stand array 10 (here, in a self-propelled manner) to adjust gaps between the horizontal rolls 24A, 24A and gaps between the vertical rolls 24B, 24B of the 12 horizontal and vertical stand pairs 20 sequentially.

[0046] Specifically, as shown in Figs. 1 and 2, particularly in Fig. 2, a support table 51 is provided on the one side of the roll stand array 10, particularly at the top thereof while extending along the entire length of the roll stand array 10. The support table 51 is supported horizontally by a stay 52, etc. extending from the top of the stand pair 20 toward the one side. The horizontal roll gap adjusting motor 50A and the vertical roll gap adjusting motor 50B in a pair are coupled to each other and in this state, are movable on the support table 51 along the roll stand array 10. The horizontal roll gap adjusting motor 50A and the vertical roll gap adjusting motor 50B in a pair stop at positions corresponding to the 12 horizontal and vertical stand pairs 20 and are coupled to the horizontal input shaft 27A in the horizontal roll stand 20A and to the vertical input shaft 27A in the vertical roll stand 20B at each of the stopping positions, thereby adjusting a gap between the horizontal rolls 24A, 24A in the horizontal roll stand 20A and a gap between the vertical rolls 24B, 24B in the vertical roll stand 20B.

[0047] This operation is performed on each of all the horizontal and vertical stand pairs 20 to adjust the gaps between the horizontal rolls 24A, 24A and the gaps between the vertical rolls 24B, 24B in all the respective horizontal and vertical stand pairs 20 independently of each other. Here, 53 is a flexible cable for feeding electricity to the movable horizontal roll gap adjusting motor 50A and vertical roll gap adjusting motor 50B.

[0048] As described above, in this square tube forming device, the horizontal rolls 24A, 24A in the horizontal roll stand 20A are driven to rotate by the roll driving mechanism 40 arranged on the one side of the roll stand array 10. The roll driving mechanism 40 mentioned herein is divided into three driving units 41. Each of the driving units 41 is coupled to four horizontal roll stands 20A in four stand pairs 20 adjacent to each other in the roll stand array 10, thereby driving the upper and lower horizontal rolls 24A, 24A in each of the four horizontal roll stands 20A to rotate.

[0049] Specifically, the roll driving mechanism 40 includes a driving motor 42 for driving each driving unit 41, and includes upper and lower output shafts 43, 43 corresponding to each of the four horizontal roll stands 20A and coupled to the input shafts 24A', 24A' of the upper and lower horizontal rolls 24A, 24A in each of the four horizontal roll stands 20A. By doing so, with the four horizontal roll stands 20A defined as one set, the upper and lower horizontal rolls 24A, 24A in each of the horizontal roll stands 20A are driven to rotate.

[0050] In the square tube forming device of the embodiment, in some of the roll stands in the roll stand array 10, here, some of the roll stands on the upstream side, more specifically, two horizontal and vertical stand pairs 20, namely, two horizontal roll stands 20A and two vertical roll stands 20B viewed from the most upstream position, extremely shallow arc-like recesses having larger curvatures than an outer surface R of the tube member to pass through between rolls are formed at the outer circumferential surfaces of the horizontal rolls 24A, 24A in each horizontal roll stand 20A and at the outer circumferential surfaces of the vertical rolls 24B, 24B in each vertical roll stand 20B.

[0051] A method of forming a round tube into a square tube using the square tube forming device of the embodiment will be described next as a square tube forming method of the embodiment.

[0052] In response to the dimension (outer diameter, thickness) and material of the round tube as a forming raw member, the dimension of the square tube as a product, etc., in a plurality of (here, 12) horizontal and vertical stand pairs 20 (namely, combinations of the horizontal roll stands 20A and the vertical roll stands 20B) in the roll stand array 10, a gap between the upper and lower horizontal rolls 24A, 24A in the horizontal roll stand 20A and a gap between the right and left vertical rolls 24B, 24B in the vertical roll stand 20B are adjusted for each stand pair 20 in order from the upstream side toward the downstream side of the roll stand array 10, for example. As described above, this adjustment is made using the movable horizontal roll gap adjusting motor 50A and vertical roll gap adjusting motor 50B in combination.

[0053] After the gap between the horizontal rolls 24A, 24A in the horizontal roll stand 20A and the gap between the vertical rolls 24B, 24B in the vertical roll stand 20B are adjusted in each of all the stand pairs 20, the roll driving mechanism 40 drives only the horizontal rolls 24A, 24A in the horizontal roll stand 20A in each of all the stand pairs 20 to rotate.

[0054] In this state, the round tube as a forming raw member is passed through the roll stand array 10. This tube member is passed through the stand pairs 20 in the roll stand array 10 (namely, combinations of the horizontal roll stands 20A and the vertical roll stands 20B) sequentially to be formed from the round tube into the square tube.

[0055] The roll stand array 10 is configured using the horizontal roll stand 20A and the vertical roll stand 20B arranged alternately. Further, the horizontal rolls 24A, 24A in the horizontal roll stand 20A and the vertical rolls 24B, 24B in the vertical roll stand 20B are both flat rolls having outer diameters substantially constant along their entire lengths in the center axis direction. These realize not only reduction in a distance between adjacent stands but also ease of avoidance of interference between rolls in the adjacent stands. This makes a roll gap in each stand independently adjustable in a wide range. Moreover, even with a reduced gap between the adjacent stands, it is still possible to use a flat roll of a relatively large diameter to avoid winding of the tube member around the roll and avoid increase in invasion resistance to be cause by such winding.

[0056] As a result, it becomes possible to increase a rolling amount at a particular position in the roll stand array 10 such as a position corresponding to some of stands on the upstream side, and to reduce a rolling amount gradually in the other positions, for example. In such a way, a rolling amount distribution oriented to forming performance can be set in consideration of a springback amount to be changed by the outer diameter, material, or thickness of a forming raw member, for example.

[0057] Additionally, a tube member invasion resistance is inherently controlled low in the roll stand array 10, and the horizontal rolls 24A, 24A are driven to rotate in each of all the horizontal roll stands 20A to apply thrust to the entire length of a tube member to pass through the roll stand array 10. Thus, even if a rolling amount at a particular position in the roll stand array 10 is increased to cause large springback correspondingly, the tube member is still passed smoothly through the roll stand array 10.

[0058] In particular, in the square tube forming device of the embodiment, in some of stands on the upstream side (while these stands are two horizontal and vertical stand pairs 20, the number of such pairs may be greater), the extremely shallow arc-like recesses having larger curvatures than the roll contact surface R of the tube member to pass through between rolls are formed at the outer circumferential surfaces of the horizontal rolls 24A, 24A in each horizontal roll stand 20A and at the outer circumferential surfaces of the vertical rolls 24B, 24B in each vertical roll stand 20B. As a result, particularly large thrust is applied to the tube member while the tube member passes through the stands.

[0059] As a result of the provision of the foregoing arc-like recesses at the horizontal rolls 24A, 24A in the horizontal roll stand 20A and at the vertical rolls 24B, 24B in the vertical roll stand 20B on the upstream side of the roll stand array 10, force of pulling the tube member into the roll stand array 10 is increased to allow smoother passage of the tube member.

[0060] The tube member to pass through the roll stand array 10 is subjected to bending forming applied from two directions using the flat horizontal rolls 24A, 24A and the flat vertical rolls 24B, 24B to form a corner portion. This functions, in addition to the smooth passage of the tube member, to enhance forming performance, thereby manufacturing a high-quality square tube. More specifically, the square tube having a predetermined sectional curvature is manufactured in the absence of a thickness reduction at the corner portion. The absence of thickness reduction at the corner portion eliminates a need to assume the occurrence of thickness reduction in the dimension of a forming raw tube, thereby achieving the effect of reducing the diameter of a base tube or the effect of giving substantially equal thicknesses to a round tube and a square tube to be manufactured.

[0061] Additionally, in the square tube forming device of the embodiment, the horizontal roll stand 20A and the vertical roll stand 20B are arranged alternately to suppress interference between rolls in adjacent stands. Further, only the horizontal rolls 24A, 24A in the horizontal roll stand 20A are driven to rotate while the vertical rolls 24B, 24B in the vertical roll stand 20B are free rollers. Thus, interference between members in the adjacent stands is suppressed to a greater extent. As a result, the entire length of the roll stand array 10 is controlled to a short length to facilitate retention of space for arrangement of the device in a tube manufacturing factory. Moreover, the weight of the device is reduced to encourage reduction in manufacturing cost.

[0062] Further, a gap between rolls in the horizontal roll stand 20A and a gap between rolls in the vertical roll stand 20B are adjusted for each horizontal and vertical stand pair 20 using a pair of the movable horizontal roll gap adjusting motor 50A and vertical roll gap adjusting motor 50B in combination. Namely, the horizontal roll gap adjusting motor 50A and the vertical roll gap adjusting motor 50B are shared between a plurality of the horizontal and vertical stand pairs 20. This simplifies the configuration of the square tube forming device, resulting in reduction in the weight of the device and further reduction in cost of manufacturing the device.

Examples

[0063] Finally, by referring to Figs. 5 to 8, analysis result about two square tube forming examples will be described in detail as examples of the present invention. Analysis software used for obtaining the analysis result is 3D elastic-plastic deformation finite analysis software developed by the present inventors having accuracy sufficient for reproducing actual forming. These drawings are schematic drawings generated on the basis of result output from this software.

[0064] According to square tube forming examples 1 and 2, the same flat roll stand array is used. Fig. 5 continuously and entirely shows a square tube forming process implemented in the flat roll stand array according to the square tube forming example 1, and Fig. 6 shows change in a tube cross-sectional shape from a round tube as a forming raw member to a square tube as a product in stages of respective stands according to the square tube forming example 1. Likewise, Fig. 7 continuously and entirely shows a square tube forming process implemented in the flat roll stand array according to the square tube forming example 2, and Fig. 8 shows change in a tube cross-sectional shape from a round tube as a forming raw member to a square tube as a product in stages of respective stands according to the square tube forming example 2. The roll outer diameters are shown at the same ratio in Figs. 5 and 7 to facilitate comparison between the sizes of the outer diameters of the raw tubes.

[0065] The flat roll stand array used in the square tube forming examples 1 and 2 has a configuration conforming to the square tube forming device shown in Figs. 1 to 4. With a vertical roll stand and a horizontal roll stand defined as one pair, this roll stand array includes 24 rolls with 12 pairs of vertical roll stands and horizontal roll stands in total arranged alternately. A roll diameter in each roll stand is 150 mm, and the roll stand array has an entire length of 4660 mm. While a rolling amount is individually settable for each of the 24 roll stands, the 12 pairs of roll stands each including a vertical roll stand and a horizontal roll stand in one pair were divided into three groups with one group including four pairs, and an individual rolling amount was set for each of these groups.

[0066] In the first group at the most upstream position, for ensuring thrust, a shallow arc-like recess having a larger curvature than an outer surface R of a roll contact surface of a tube member to pass through each roll stand is formed at each roll.

[0067] In the square tube forming example 1 shown in Figs. 5 and 6, a raw round tube of a relatively small diameter made of common steel (Ys = 360 Mpa) and having an outer diameter of 44.45 mm and a thickness of 3.6 mm is to be formed into a square tube as a product having a regular square cross section with one side of 38 mm and a thickness of 3.6 mm. According to a rolling amount distribution employed for this raw tube made of common steel, a ratio of 9:3:1 was set for the first group, for the second group, and for the third group respectively.

[0068] Specifically, with a rolling amount required for forming the cross-sectional shape of the raw round tube entirely into the cross-sectional shape of the square tube as a product set at 13, the rolling amount distribution was determined in such a manner as to perform forming of a rolling amount of 9/13 (about 69.3%) in the first group, to perform forming of a rolling amount of 3/13 (about 23%) in the second group, and to perform forming of a rolling amount of 1/13 (about 7.7%) in the third group. For forming from the round tube into the regular square cross section, the same rolling amount is set for a vertical roll and a horizontal roll in a pair, and as a result of planarization of side sections, four corners of the regular square cross section are formed.

[0069] As a result, about 69% forming of a total forming amount is finished at a final stand RB8 in the first group, about 92% forming is finished at a final stand RB16 in the second group, and 100% forming both in length and width is finished at a final stand RB24 in the third group.

[0070] In the square tube forming example 2 shown in Figs. 7 and 8, a raw round tube of a relatively large diameter made of the same common steel (Ys = 360 Mpa) and having an outer diameter of 119.67 mm and a thickness of 7 mm is to be formed into a square tube as a product having a flat rectangular shape with a length of 50 mm, a width of 150 mm, and a thickness of 7 mm. In this example, a rolling amount distribution was also set to provide a ratio of 9:3:1 for the first group, for the second group, and for the third group respectively. For forming from the round tube into the rectangular cross section, a position to become a corner can be set by determining a rolling amount for a vertical roll and a horizontal roll in a pair in such a manner as to be larger on the vertical side and to be smaller on the horizontal side. As a result of planarization of side sections, four corners of the rectangular cross section are formed.

[0071] As a result, about 69% forming of a total forming amount is finished at the final stand RB8 in the first group, about 92% forming is finished at the final stand RB16 in the second group, and 100% forming both in length and width is finished at the final stand RB24 in the third group.

[0072] As comprehensibly shown particularly in Fig. 8, a rolling amount is distributed in the foregoing manner for reason of employing a forming process of performing planarization of side sections readily in the first group on the upstream side for corner forming, continuously performing the planarization of the side sections gently in the second group on the midstream side for the corner forming, and obtaining intended dimensions in the third group on the downstream side. In the two cases of square tube forming, such a rolling amount distribution is employed by giving consideration to intended dimensions of a product. Allowing employment of a forming process responsive to such product specifications according to circumstances forms the characteristic of the present invention. A range of roll multi-use defined by a model for analysis is such that an outer diameter ratio is up to three times and an aspect ratio is up to three times. Result obtained from the analysis shows that manufacturing an actual machine and actually operating the machine produces the same effect.

[0073] While roll stands in a flat roll stand array are divided into three groups with one group including one pair × 4 (eight stands), these roll stands may alternatively be divided into four groups with one group including one pair × 3 (six stands), into six groups with one group including one pair × 2 (four stands), or into 12 groups with one group including one pair × 1 (two stands). By choosing a method of defining groups in various ways together with a rolling amount distribution in response to a difference in forming specifications (the material, outer diameter, and thickness of a raw round tube, and dimensions of a square tube as a product), it becomes possible to perform a wide range of square tube forming.

Reference Signs List

[0074]

10	Roll stand array
20	Horizontal and vertical stand pair
20A	Horizontal roll stand (first flat roll stand)
21A	Vertical rod
22A	Horizontal fixed base
23A	Movable base
24A	Horizontal roll
25A	Bracket
26A	Jack
27A	Input shaft
28A	Gear box
29A	Power transmission shaft
20B	Vertical roll stand (second flat roll stand)
21B	Vertical fixed base
22B	Horizontal rod
23B	Movable base
24B	Vertical roll
25B	Roll support frame
26B	Jack
27B	Input shaft
28B	Gear box
29B	Power transmission shaft
30	Stand base
40	Roll driving mechanism (roll driving means)
41	Driving unit
42	Driving motor
50A	Horizontal roll gap adjusting motor
50B	Vertical roll gap adjusting motor
51	Support table
52	Stay
53	Cable

Claims

1. A square tube forming method of forming a round tube of any diameter as a forming target raw tube into a square tube of any dimension as a product by passing the round tube through a plurality of roll stands arranged in a raw tube forming direction, comprising:

    using a flat roll stand array in which a first flat roll stand and a second flat roll stand of rolling directions orthogonal to each other are arranged alternately in a forming direction for a tube member and in which a rolling amount at each roll stand is independently settable;

    allocating a forming rolling amount distribution individually as a rolling amount at each roll stand in the flat roll stand array, the forming rolling amount distribution being determined in advance for the stands from a first-stage stand to a final-stage stand in response to the outer diameter, thickness, and material of the forming target raw tube to be used and an intended dimension of the square tube as a product; and

    forming the forming target raw tube into the square tube as a product having the intended dimension by driving at least one of the first flat roll stand and the second flat roll stand adjacent to each other.

2. The square tube forming method according to claim 1, wherein
at one or a plurality of roll stands in a part of the flat roll stand array, thrust is applied to the tube member by forming an arc-like recess at a flat roll, the recess having a larger curvature than a roll contact surface R of the tube member to pass through the one or plurality of roll stands.

3. The square tube forming method according to claim 1, wherein
gap adjusting motors in a pair intended for the first flat roll stand and the second flat roll stand in a pair adjacent to each other are arranged to be movable along the flat roll stand array, and are shared between the first flat roll stands and the second flat roll stands in a plurality of pairs in the flat roll stand array.

4. A square tube forming device for implementing the square tube forming method described in any one of claims 1 to 3, comprising:

    a flat roll stand array in which a first flat roll stand and a second flat roll stand of rolling directions orthogonal to each other are arranged alternately in a forming direction, wherein
    each roll stand in the flat roll stand array includes roll gap adjusting means by which a rolling amount is independently settable, and at least one of the first flat roll stand and the second flat roll stand adjacent to each other includes roll driving means.

5. The square tube forming device according to claim 4, wherein
at one or a plurality of roll stands in a part of the flat roll stand array, an arc-like recess having a larger curvature than a roll contact surface R of a tube member to pass through the one or plurality of flat roll stands is formed at a flat roll.

6. The square tube forming device according to claim 4, wherein

gap adjusting motors in a pair intended for the first flat roll stand and the second flat roll stand in a pair adjacent to each other are arranged to be movable along the flat roll stand array, and are shared between the first flat roll stands and the second flat roll stands in a plurality of pairs in the flat roll stand array.

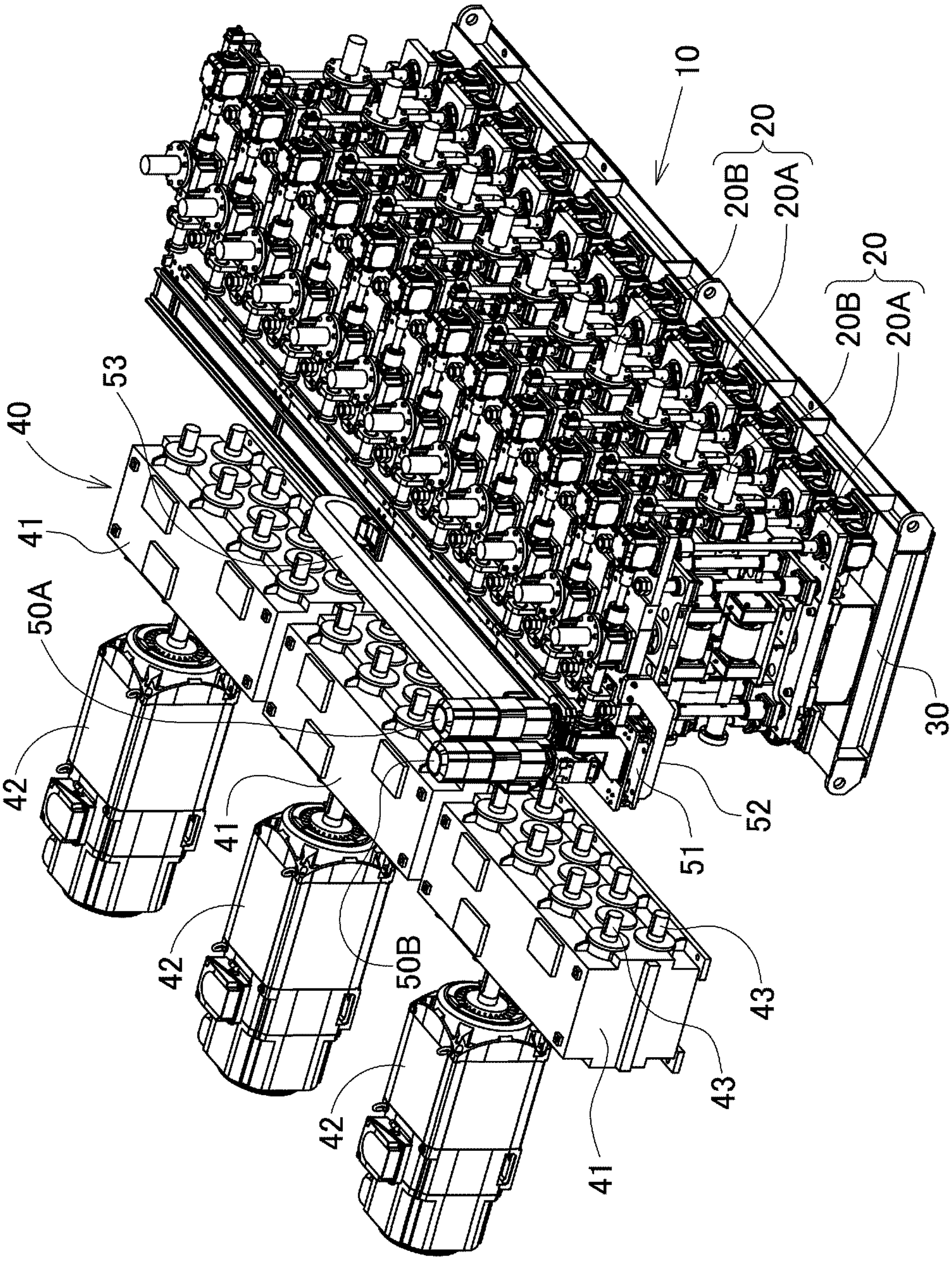
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Fig. 1

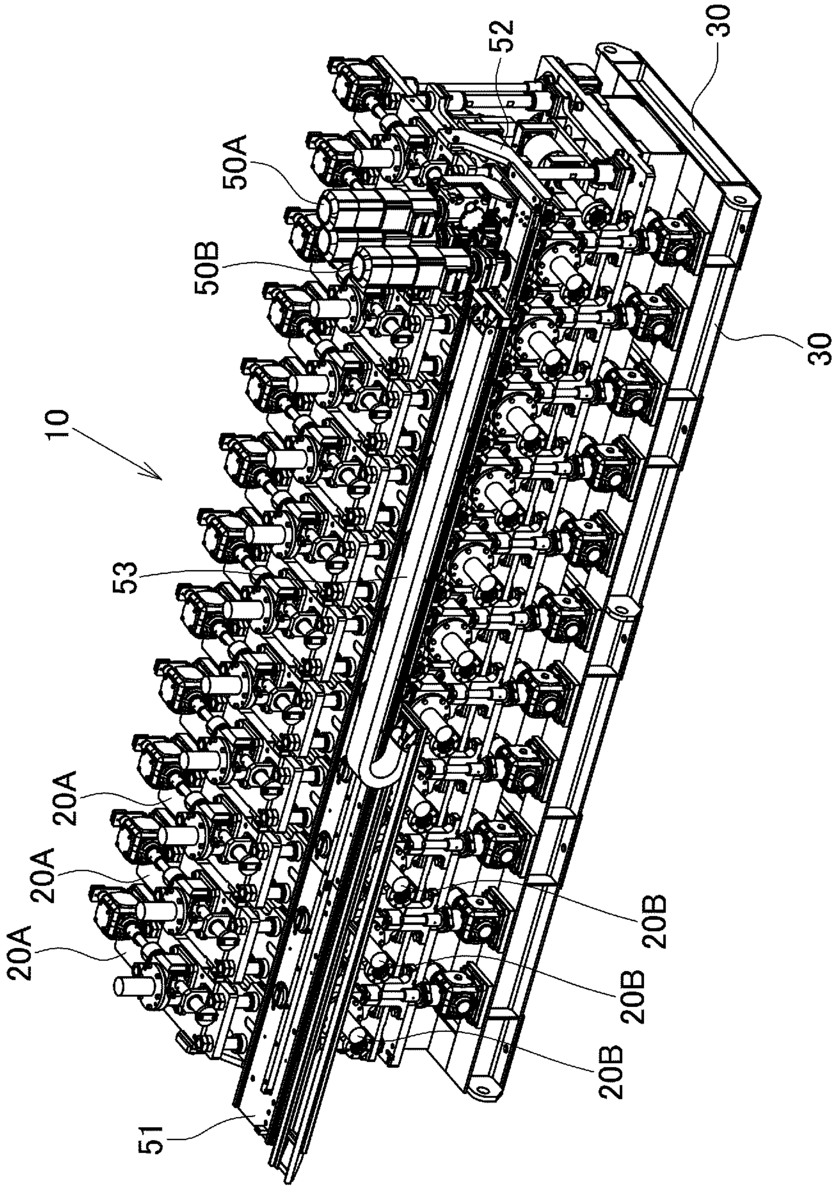

Fig. 2

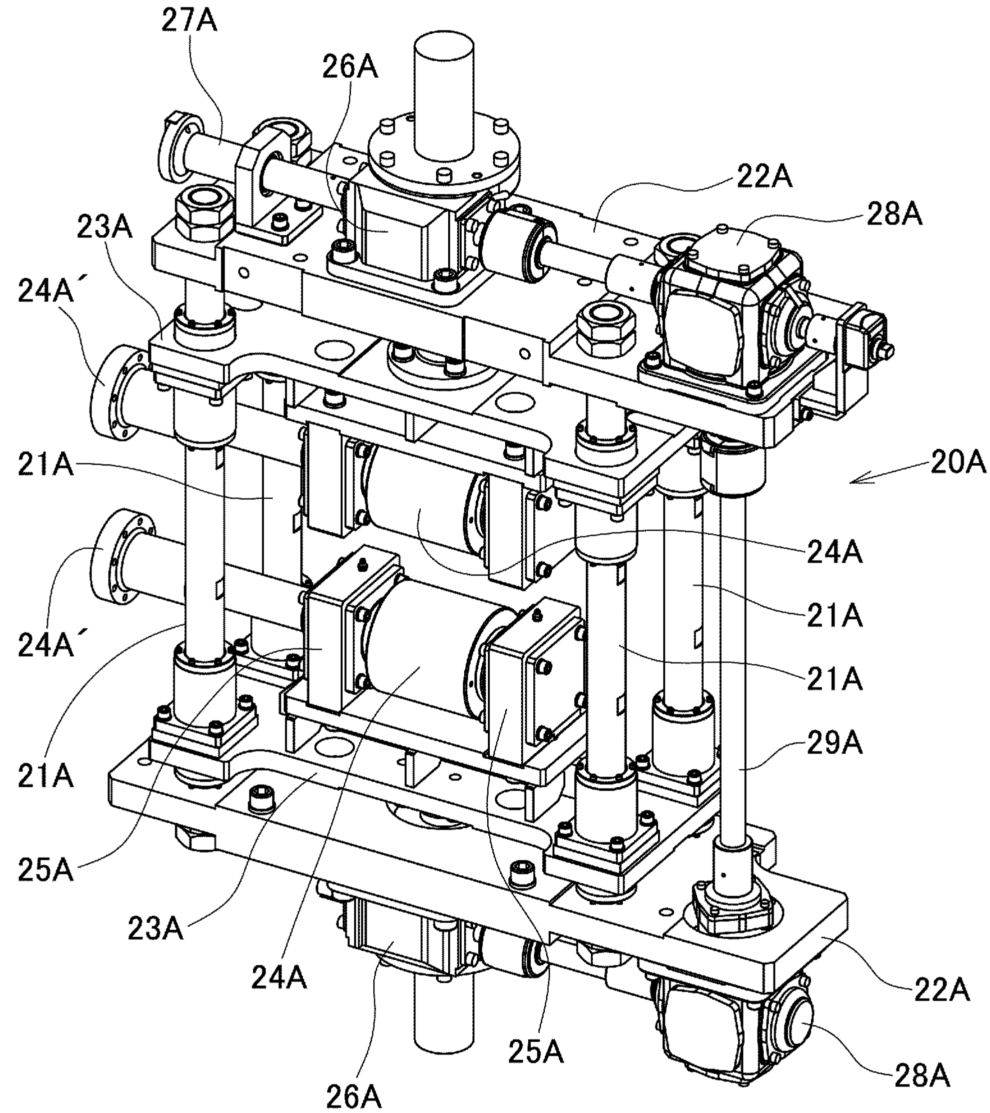
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Fig. 3

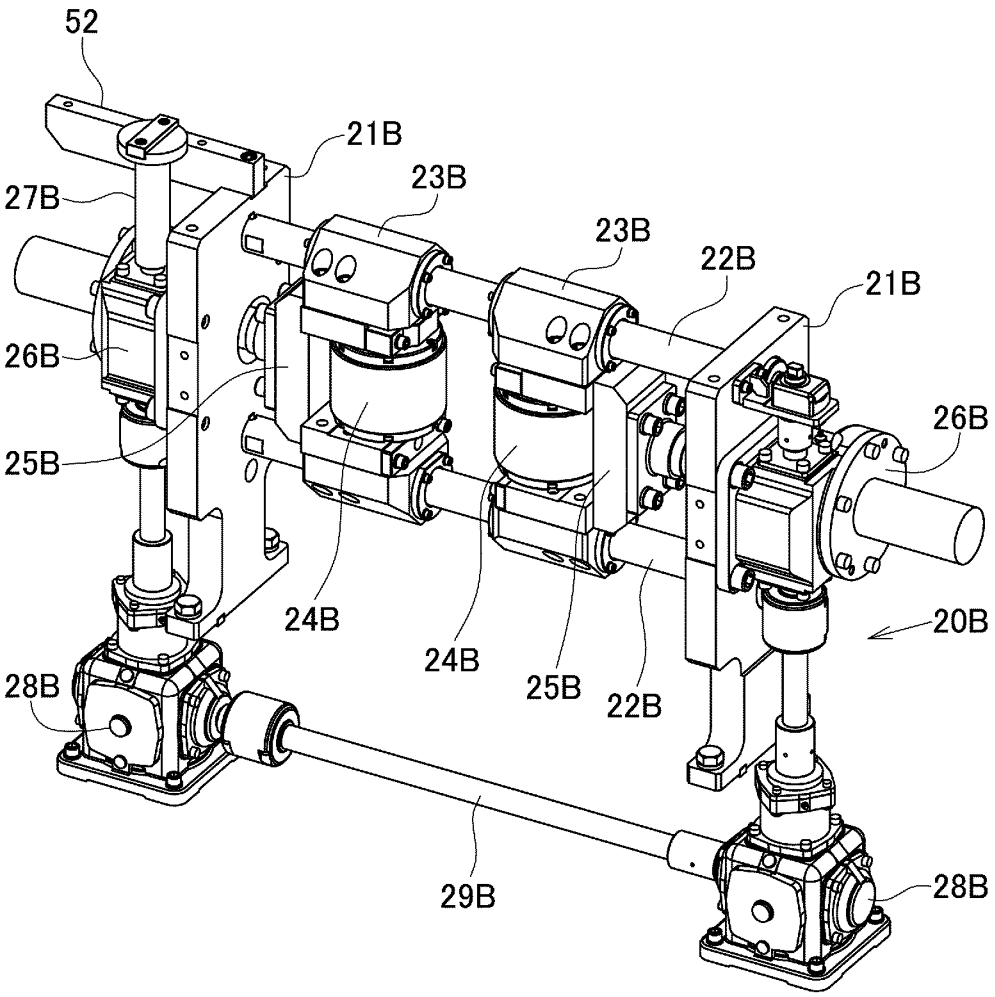
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Fig. 4

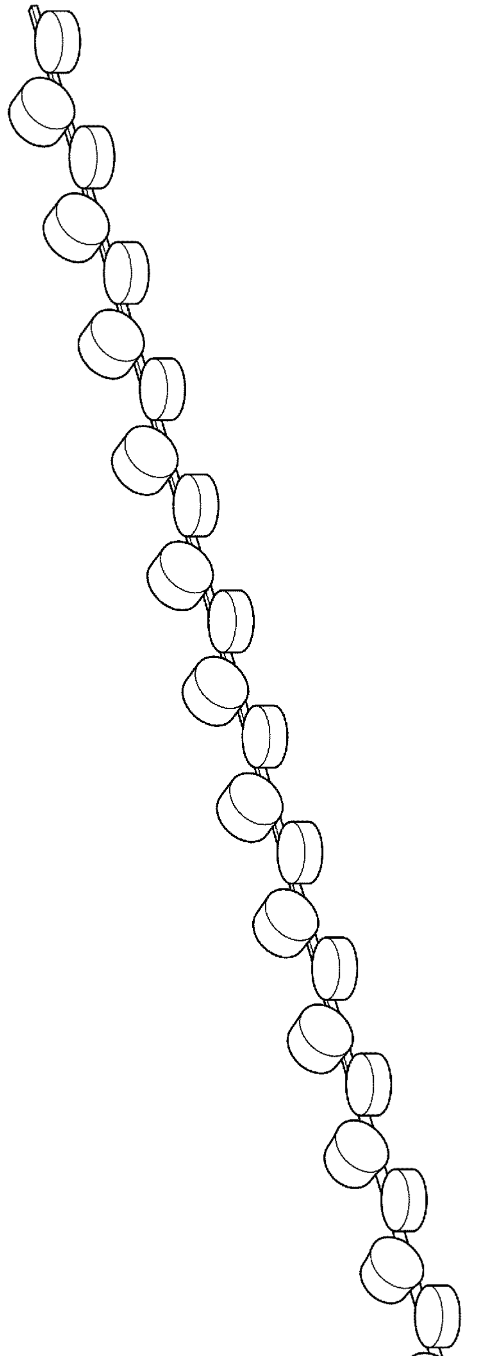
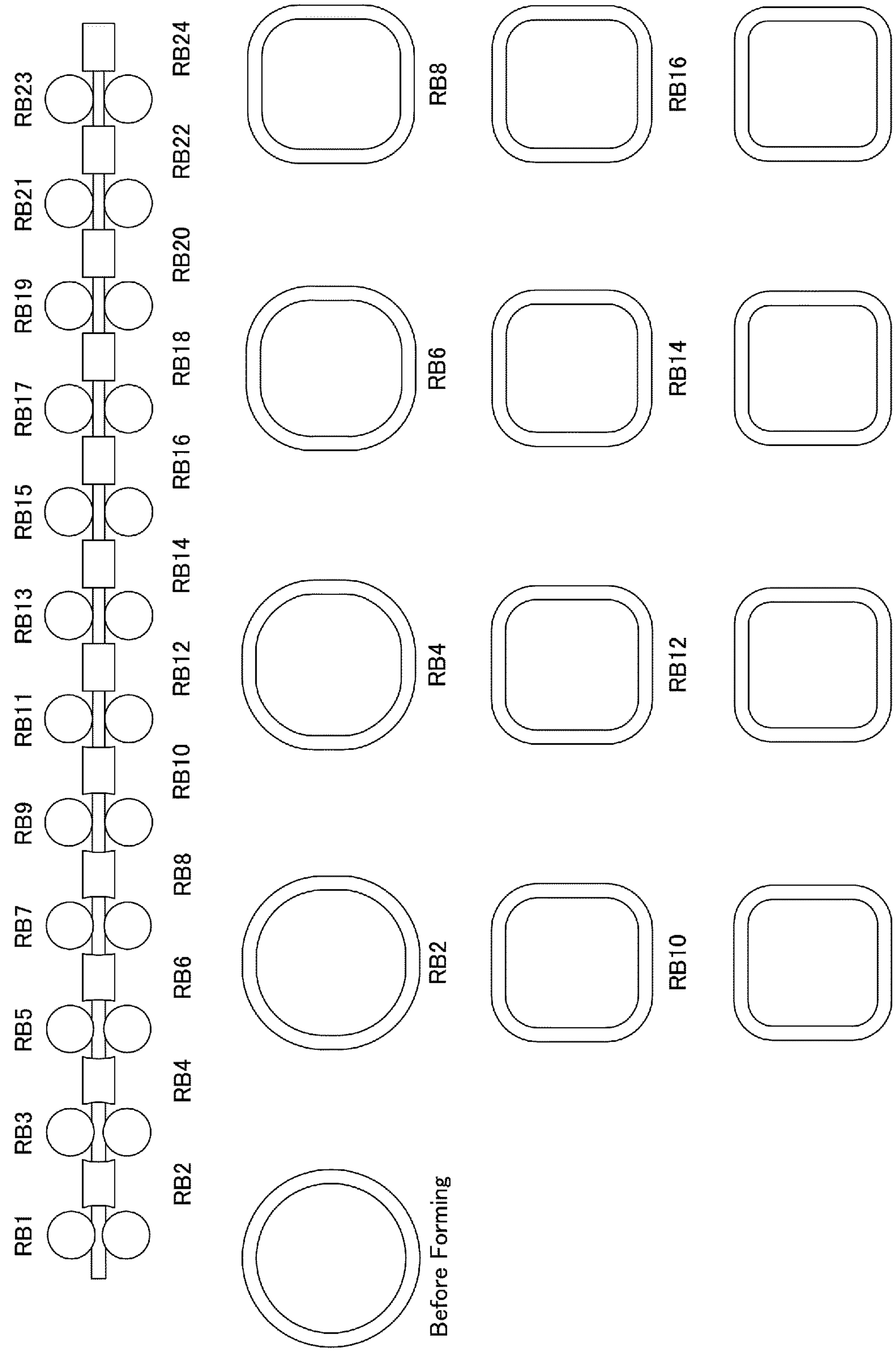


Fig. 5

Fig. 6



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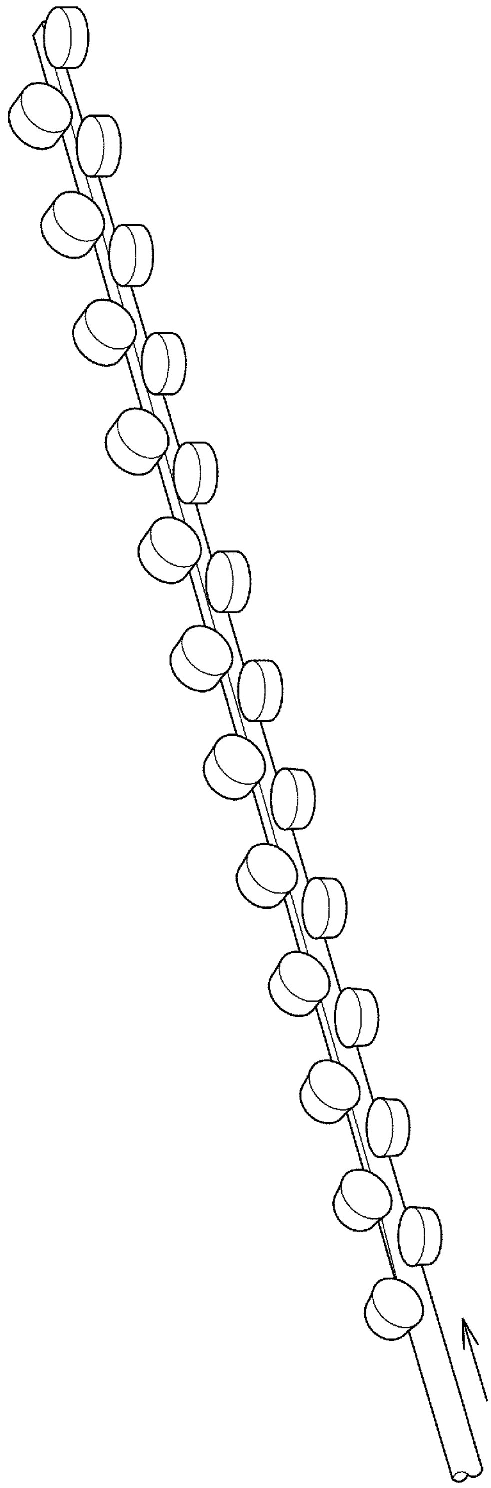
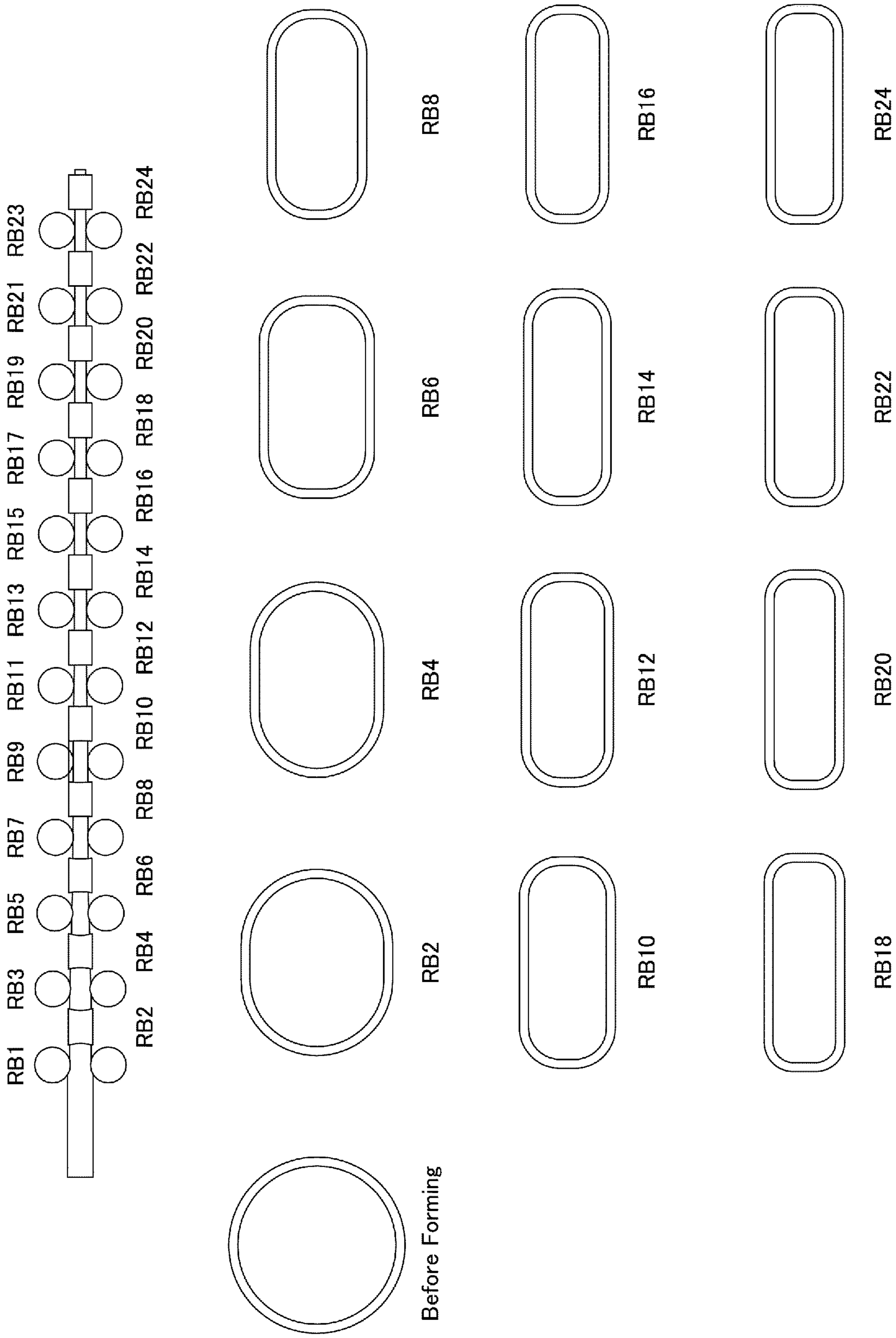


Fig. 7

Fig. 8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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/015917

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. B21D5/12(2006.01)i, B21C37/15(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. B21D5/12, B21C37/15

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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.
Y	JP 2000-301233 A (KIUCHI, Manabu) 31 October 2000, paragraphs [0004]-[0010], fig. 1-5 & WO 2000/064606 A1, page 6, line 6 to page 11, line 19 & EP 1169150 B1	1-6
Y	JP 10-258311 A (DAI ICHI HIGH FREQUENCY CO., LTD.) 29 September 1998, paragraph [0014], fig. 1-4 (Family: none)	1-6
Y A	JP 5520542 B2 (TAKASHIMA, Masayuki) 11 June 2014, paragraphs [0012], [0025], [0026], fig. 4, 5 (Family: none)	2, 3, 5, 6 1, 4

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26.04.2019	14.05.2019

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/015917

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2004-243367 A (AISIN SEIKI CO., LTD.) 02 September 2004, paragraphs [0029]-[0056], fig. 1-5, 9 (Family: none)	3, 6 1-2, 4-5
A	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 76857/1992 (Laid-open No. 34810/1994) (SUMITOMO HEAVY INDUSTRIES, LTD.) 10 May 1994, paragraphs [0010]-[0016], fig. 1-7 (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2000301233 A **[0011]**
- JP 2006150377 A **[0011]**