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(71) Applicant: **MURATA MACHINERY, LTD.** [JP/JP]; 3, Minami Ochiai-cho, Kisshoin, Minami-ku, Kyoto-shi, Kyoto, 6018326 (JP).

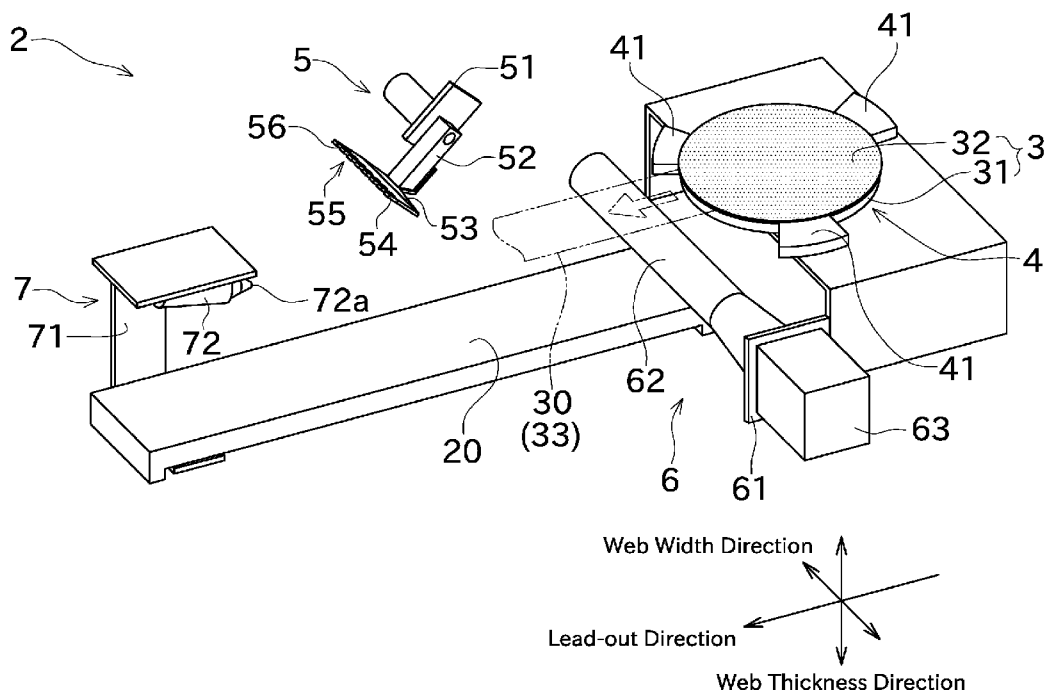
(72) Inventors: **ARAKAWA, Osamu**; c/o MURATA MACHINERY, LTD., 136, Takeda Mukaishiro-cho, Fushimi-ku, Kyoto-shi, Kyoto, 6128686 (JP). **YANO, Fumi-**

aki; c/o MURATA MACHINERY, LTD., 136, Takeda Mukaishiro-cho, Fushimi-ku, Kyoto-shi, Kyoto, 6128686 (JP). **MIYAWAKI, Yasuhito**; c/o MURATA MACHINERY, LTD., 136, Takeda Mukaishiro-cho, Fushimi-ku, Kyoto-shi, Kyoto, 6128686 (JP).

(74) Agent: **KATSURAGAWA, Naoki**; KATSURAGAWA INT'L PATENT OFFICE Wako Bldg., 2-2-17, Shibata, Kita-ku, Osaka-shi, Osaka, 5300012 (JP).

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(54) Title: CARBON NANOTUBE SUBSTRATE LEAD-OUT END PREPARATION APPARATUS, SPINNING SYSTEM, CARBON NANOTUBE SUBSTRATE LEAD-OUT END PREPARATION METHOD, AND SPINNING METHOD



(57) Abstract: A CNT substrate lead-out end preparation apparatus (2) comprises a substrate support unit (4), a scraping lead-out unit (5), a winding lead-out unit (6), and a bunching unit (7). The substrate support unit (4) supports a CNT substrate (3) on which CNTs are formed. The scraping lead-out unit (5) contacts the CNTs formed on the CNT substrate (3) and leads out a CNT web (33) from the CNT substrate (3). The winding lead-out unit (6) receives the CNT web (33) and leads out the CNT web from the CNT substrate (3). The bunching unit (7) agglomerates the CNT web (33) led out by the winding lead-out unit (6) in the web width direction of the web.



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Description

Title of Invention: CARBON NANOTUBE SUBSTRATE LEAD-OUT END PREPARATION APPARATUS, SPINNING SYSTEM, CARBON NANOTUBE SUBSTRATE LEAD-OUT END PREPARATION METHOD, AND SPINNING METHOD

Technical Field

[0001] The present invention mainly relates to a carbon nanotube substrate lead-out end preparation apparatus for leading out a carbon nanotube fiber group from a substrate on which carbon nanotubes are formed to prepare the carbon nanotube fiber group as a lead-out end.

Background Art

[0002] In production of a carbon nanotube yarn, a well-known conventional apparatus is used to lead out a carbon nanotube fiber group from a CNT (Carbon Nanotube) substrate. PTL 1 discloses this kind of apparatus.

[0003] The apparatus of PTL 1 is configured so that a wire rod is brought into contact with an utmost end of a growing body in a lead-out direction, a part of the growing body is adhered to the wire rod by viscosity of CNTs and is led out, and the wire rod is rotated to wind the growing body therearound.

Citation List

Patent Literature

[0004] [PTL 1] JP 2017-122018 A

Summary of Invention

Problem to Be Solved by the Invention

[0005] In the configuration of PTL 1 in which the member (wire rod) adhered to the CNTs is rotated to lead out the CNTs, if the wire rod is thinned to enhance its adherence to the CNTs, a carbon nanotube web cannot be efficiently led out by rotating the wire rod.

[0006] In consideration of the above-mentioned problem, the present invention purposes to provide a carbon nanotube substrate lead-out end preparation apparatus available to surely and efficiently lead out a carbon nanotube web having a predetermined width.

Means to Solve the Problem and Effects

[0007] The foregoing description is a problem to be solved by the invention. Means to solve the problem and effects of the means will now be described.

[0008] In a first aspect of the invention, a carbon nanotube substrate lead-out end preparation apparatus having the following configuration is provided. The carbon nanotube substrate lead-out end preparation apparatus comprises a substrate support

unit, a first lead-out unit, a second lead-out unit, and an integration unit. The substrate support unit is configured to support a carbon nanotube substrate on which carbon nanotubes are formed. The first lead-out unit is configured to contact the carbon nanotubes formed on the carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate. The second lead-out unit is configured to receive the carbon nanotube web led out by the first lead-out unit and to lead out the carbon nanotube web from the carbon nanotube substrate. The integration unit is configured to agglomerate the carbon nanotube web between the carbon nanotube substrate and the second lead-out unit in the web width direction to bunch the carbon nanotube web.

[0009] Therefore, the carbon nanotube web, while being transferred via the first lead-out unit and the second lead-out unit, is surely and efficiently led out from the carbon nanotube substrate so as to be prepared to facilitate a subsequent process.

[0010] Preferably, the carbon nanotube substrate lead-out end preparation apparatus comprises an inspection unit configured to inspect the carbon nanotube web led out by the second lead-out unit so as to decide whether or not a lack portion missing a carbon nanotube exists in a predetermined width range of the carbon nanotube web.

[0011] Therefore, the carbon nanotube web is agglomerated and bunched by the integration unit after the carbon nanotube web being led out is confirmed as having the predetermined width.

[0012] Preferably, in the carbon nanotube substrate lead-out end preparation apparatus, the second lead-out unit is configured to continuously lead out the carbon nanotube web until the inspection unit decides that the lack portion does not exist in the predetermined width range.

[0013] Therefore, even if the carbon nanotube web led out at an early stage includes a lack portion missing a carbon nanotube, due to the continuous lead-out of the carbon nanotube web, the missed carbon nanotube can be newly led out by its intermolecular force so as to eliminate the lack portion, thereby improving a yield rate of the inspection.

[0014] Preferably, in the carbon nanotube substrate lead-out end preparation apparatus, the first lead-out unit includes a lead-out member adapted to contact the carbon nanotubes.

[0015] Therefore, the lead-out member facilitates catching of the carbon nanotubes which are formed on the carbon nanotube substrate to be led out as the carbon nanotube web.

[0016] In the carbon nanotube substrate lead-out end preparation apparatus, the lead-out member may be a comb-toothed member.

[0017] Therefore, in this case, carbon nanotubes can be easily caught to be led out.

[0018] Alternatively, in the carbon nanotube substrate lead-out end preparation apparatus, the lead-out member may include a tip adapted to contact the carbon nanotubes. The

tip is formed linear continuously from one end to another end in a width required to lead out the carbon nanotube web.

[0019] Therefore, in this case, the lead-out member can be easily formed.

[0020] Preferably, in the carbon nanotube substrate lead-out end preparation apparatus, the second lead-out unit includes a roller for winding the carbon nanotube web.

[0021] Therefore, the winding of the carbon nanotube web onto the roller facilitates leading out of the carbon nanotube web in a large length.

[0022] Preferably, in the carbon nanotube substrate lead-out end preparation apparatus, the integration unit includes a sucking device for sucking the carbon nanotube web.

[0023] Therefore, a sucking flow facilitates bunching of the carbon nanotube web tightly in the width direction.

[0024] In a second aspect of the invention, a spinning system having the following configuration is provided. The spinning system comprises the carbon nanotube substrate lead-out end preparation apparatus and a yarn forming apparatus. The yarn forming apparatus is configured to agglomerate the carbon nanotube web so as to form a yarn.

[0025] Therefore, the lead-out end is prepared by the carbon nanotube substrate lead-out end preparation apparatus, thereby facilitating forming of a yarn.

[0026] Preferably, in the spinning system, the yarn forming apparatus is configured to form the yarn by twisting the carbon nanotube web.

[0027] Therefore, the carbon nanotube web can be easily agglomerated into a yarn-form.

[0028] Preferably, in the spinning system, the twisting of the carbon nanotube web is false-twisting.

[0029] Therefore, due to such a simple configuration, the carbon nanotube web can be agglomerated into a yarn-form.

[0030] In a third aspect of the invention, a carbon nanotube substrate lead-out end preparation method as follows is provided. The carbon nanotube substrate lead-out preparation method comprises a first lead-out process, a second lead-out process, and an integration process. The first lead-out process is operating of a first member to contact carbon nanotubes formed on a carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate. The second lead-out process is operating of a second member to receive the carbon nanotube web led out by the first process and to lead out the carbon nanotube web from the carbon nanotube substrate. The integration process is agglomerating the carbon nanotube web led out by the second lead-out process in a web width direction to bunch the carbon nanotube web.

[0031] Therefore, the carbon nanotube web, while being transferred via the first lead-out unit and the second lead-out unit, is surely and efficiently led out from the carbon nanotube substrate so as to be prepared to facilitate a subsequent process.

[0032] In a fourth aspect of the invention, a spinning method comprises a first lead-out process, a second lead-out process, an integration process and a yarn forming process. The first lead-out process is operating of a first member to contact carbon nanotubes formed on a carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate. The second lead-out process is operating of a second member to receive the carbon nanotube web led out by the first process and to lead out the carbon nanotube web from the carbon nanotube substrate. The integration process is agglomerating the carbon nanotube web led out by the second lead-out process in a web width direction to bunch the carbon nanotube web. The yarn forming process is using of the lead-out end bunched by the integration process to lead out the carbon nanotube web from the carbon nanotube substrate and to form a yarn by twisting the carbon nanotube web.

[0033] Therefore, the lead-out end is prepared by the carbon nanotube substrate lead-out end preparation method, thereby facilitating forming of a yarn.

Brief Description of Drawings

[0034] [fig.1]A schematic view of a configuration of a yarn spinning apparatus.

[fig.2]A perspective view of a CNT substrate prepared by a CNT substrate lead-out end preparation apparatus according to an embodiment of the invention.

[fig.3]A perspective view of a configuration of the CNT substrate lead-out end preparation apparatus.

[fig.4]An enlarged view of a configuration of a comb-toothed member.

[fig.5]A side view of a scraping lead-out unit leading out a CNT web from the CNT substrate.

[fig.6]A side view of a winding lead-out unit receiving the CNT web led out by the scraping lead-out unit.

[fig.7]A side view of the winding lead-out unit further leading out the CNT web from the CNT substrate.

[fig.8]A side view of an inspection unit detecting a width of the CNT web.

[fig.9]A side view of the CNT web led out by the winding lead-out unit when it is loosened.

[fig.10]A side view of a bunching unit sucking the CNT web to form a thread-shaped CNT portion.

[fig.11]A side view of a prepared lead-out end of the CNT substrate, including the thread-shaped CNT portion led out from an air sucker of the integration unit.

Description of Embodiments

[0035] Embodiments of the present invention will now be described with reference to drawings.

- [0036] A yarn spinning apparatus (a yarn forming apparatus) 1 shown in FIG. 1 leads out CNTs from a CNT substrate 3a, forms the CNTs into a CNT yarn 10, and winds the CNT yarn 10.
- [0037] The CNT substrate 3a supplies CNTs as materials to be spun. Many CNTs are aligned on a surface of the CNT substrate 3a at one side in its thickness direction so as to form a CNT array 32. Each CNT is oriented substantially perpendicular to the surface of the CNT substrate 3a.
- [0038] The CNTs are led out from the CNT substrate 3a while forming a fiber group (CNT fiber group 30) as an aggregate. The direction of leading out the CNT fiber group 30 from the CNT substrate 3a is substantially parallel to the surface of the CNT substrate. The CNT fiber group 30 having a predetermined width is led out from the CNT substrate 3a so as to be entirely formed as a thin sheet. In the CNT fiber group 30, the CNTs are aligned in large numbers in their width direction. Further, in the CNT fiber group 3, each of the CNTs is oriented substantially parallel to its led-out direction, and they are connected to one another in their length direction while being led out one after another. In some parts of the following description, the CNT fiber group 30 is referred to as a CNT web 33.
- [0039] The yarn spinning apparatus 1 mainly includes a substrate fixture unit 11, a spinning unit 12 and a winding unit 13.
- [0040] Terms “upstream” and “downstream” used in the following description of the yarn spinning apparatus 1 mean upstream and downstream in a traveling direction of the CNT fiber group 30 and the CNT yarn 10 in a process of spinning and winding the CNT yarn 10 by the yarn spinning apparatus 1.
- [0041] The substrate fixture unit 11 is adapted to have the CNT substrate 3a attachable/removable thereto and therefrom. When the CNT web 33 is led out from the CNT substrate 3a, the substrate fixture unit 11 holds the set CNT substrate 3a immovably.
- [0042] A predetermined preparation work is applied to the CNT substrate 3a before it is set on the substrate fixture unit 11. Accordingly, the CNT substrate 3a is formed with a lead-out end 35 as shown in FIG. 2. The lead-out end 35 includes the CNT web 33 and a thread-shaped CNT portion 34. The CNT web 33 is led out from the CNT array 32 formed on the CNT substrate 3a. The thread-shaped CNT portion 34 is formed on an utmost end of the CNT web 33 in a lead-out direction.
- [0043] The CNT web 33 is a web-shaped aggregate consisting of the aligned CNTs. It is joined to the CNT array 32.
- [0044] The thread-shaped CNT portion 34 is formed linear by bunching the utmost end of the CNT web 33 tightly in its width direction. In this regard, the CNTs are of a character that they are easily agglomerated by their intermolecular forces and their agglomeration is irreversible. Therefore, even if a binder or the like is not used, the web-

shaped CNT portion 34 is kept from loosening. With regard to the present invention, the agglomeration means a coupling phenomenon that occurs when coordinatively unsaturated atoms on surfaces of the CNTs are coordinated to adjoin one another so as to obtain stabilization energy by van der Waals force.

- [0045] Since the CNT substrate 3a is previously formed with the lead-out end 35 (thread-shaped CNT portion 34) as mentioned above, the yarn spinning apparatus 1 can lead out the CNT fiber group 30 formed as the CNT web 33 from the CNT substrate 3a only by supplying the lead-out end 35 of the CNT substrate 3a to the spinning unit 12, so that the yarn spinning apparatus 1 can start its spinning work smoothly.
- [0046] The preparation work applied to the CNT substrate 3a is carried out by a CNT substrate lead-out end preparation apparatus 2 shown in FIG. 3. The yarn spinning apparatus 1 and the CNT substrate lead-out end preparation apparatus 2 constitute a spinning system according to the present embodiment. A concrete configuration of the CNT substrate lead-out end preparation apparatus 2 will be described later.
- [0047] In the spinning unit 12 of FIG. 1, the CNT fiber group 30 led out from the CNT substrate 3a is false-twisted with swirl airflow so as to be formed into the CNT yarn 10. The swirl airflow for the false twisting can be generated by supplying the spinning unit 12 with compressed air.
- [0048] In the winding unit 13, the CNT yarn 10 formed by the spinning unit 12 is wound around an unillustrated winding tube so as to form a package.
- [0049] An intermediate conveying unit 14 is disposed between the spinning unit 12 and the winding unit 13. Referring to FIG. 1, the intermediate conveying unit 14 includes a pair of rollers 14a and 14b to convey the CNT yarn 10 formed by the spinning unit 12 to the winding unit 13. The rollers 14a and 14b are disposed so as to sandwich the CNT yarn 10 therebetween, and are rotated at preset rotational speeds. Therefore, a predetermined tension is given to the CNT yarn 10 so that the CNT yarn 10 can be led out from the spinning unit 12.
- [0050] The CNT substrate lead-out end preparation apparatus 2 will now be described with reference to FIG. 3. The CNT substrate lead-out end preparation apparatus 2 mainly includes a base member 20, a substrate support unit 4, a scraping lead-out (a first lead-out) unit 5, a winding lead-out (a second lead-out) unit 6, and a bunching unit (an integration unit) 7.
- [0051] In the following description of the CNT substrate lead-out end preparation apparatus 2, a term “lead-out direction” means a direction of the CNT fiber group 30 (CNT web 33) led out from a CNT substrate 3 by the scraping lead-out unit 5 and the winding lead-out unit 6.
- [0052] The base member 20 is configured as a linearly thin plate-shaped member. The base

member 20 is longitudinally disposed parallel to the direction of the CNT web 33 led out from the CNT substrate 3 (the lead-out direction).

[0053] The substrate support unit 4 is attached to an end portion of the base member 20 at one side in the longitudinal direction of the base member 20. The substrate support unit 4 is attachable/removable to and from the CNT substrate 3. When the scraping lead-out unit 5 or the winding lead-out unit 6 leads out the CNT fiber group 30 or in another case, the substrate support unit 4 holds the set CNT substrate 3 so that the CNT substrate 3 becomes unmovable. Various configurations of the substrate support unit 4 are conceivable. For example, a plurality of holding members 41 may be made to contact an outer peripheral surface of a later-discussed substrate 31 in such a way as shown in FIG. 3 so as to hold the substrate 31.

[0054] The CNT substrate 3 includes the substrate 31 serving as a base material, and includes the CNT array 32 formed on a surface of the substrate 31 at one side in the thickness direction of the substrate 31, the CNT array 32 including many CNTs erected and aligned in parallel thereon. For example, a member made from glass, silicon or metal is used as the substrate 3. The CNT array 32 is formed on the substrate 31 by a chemical vapor deposition, for example. Each of the CNTs constituting the CNT array 32 has a length of 1 millimeter, for example, and is directed substantially perpendicular to the surface of the substrate 31.

[0055] The CNT substrate 3 is set on the substrate support unit 4 horizontally so as to have the CNT array 32 on its upper surface. The CNT substrate 3 of the present embodiment is circular. However, it is not limited to this structure. The CNT substrate 3 may have another shape.

[0056] The CNT substrate lead-out end preparation apparatus 2 leads out the CNT web 33 in a web-like shape from the set CNT substrate 3. In the following description, a term “web width direction” means a width direction of the led-out CNT web 33, and a term “web thickness direction” means a thickness direction of the led-out CNT web 33. In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the web width direction is horizontal (parallel to the surface of the CNT substrate 3), and the web thickness direction is vertical.

[0057] Referring to FIG. 3, the scraping lead-out unit 5 includes a base 51, a scraping arm 52, and a comb-toothed member (a lead-out member, a first member) 53.

[0058] The base 51 is disposed downstream of the substrate support unit 4 in the lead-out direction. The base 51 is provided with an unillustrated sliding mechanism so that the base 51 is slidably movable in a direction parallel to the longitudinal direction of the base member 20. An appropriate actuator (a scraping slide driver), including an electric motor or so on, is provided to slide the base 51, although the actuator is not illustrated. Therefore, the scraping lead-out unit 5 is movable closer to or away from the substrate

support unit 4.

[0059] The base 51 is provided with an unillustrated rotating mechanism so that the base 51 is rotatable around an unillustrated axis parallel to the web width direction. Due to an unillustrated appropriate actuator, the base 51 is movable between an activation position close to the substrate support unit 4 and a retraction position upwardly slantwise away from the substrate support unit 4. In FIG. 3, the base 51 is illustrated as being located at the retraction position.

[0060] The scraping arm 52 is rotatably supported by the base 51. Due to an unillustrated appropriate actuator, the scraping arm 52 is rotatable in a predetermined angle stroke.

[0061] The comb-toothed member 53 is fixed to a tip of the scraping arm 52. The comb-toothed member 53 is made of a plate-shaped metal member. Referring to FIG. 4, the comb-toothed member 53 is formed with a tooth row portion 55 opposite to the side thereof fixed to the scraping arm 52. The tooth row portion 55 includes teeth 54 having a common shape and aligned repeatedly and linearly. The alignment direction of teeth 54 is parallel to the web width direction.

[0062] Due to the above-mentioned configuration, when the scraping arm 52 is rotated in a state where the base 51 slides to approach the substrate support unit 4 and is positioned at the activation position, a tip (the tooth row portion 55) of the comb-toothed member 53 comes to abut against the CNT array 32 formed on the CNT substrate 3, as shown in FIG. 5. In this state, when the base 51 slides away from the substrate support unit 4, the CNTs are scraped from the CNT array 32 by the comb-toothed member 53 so that the CNT web 33 is led out from the CNT substrate 3.

[0063] On the other hand, when the base 51 is positioned at the retraction position as shown in FIG. 3, the scraping lead-out unit 5 is kept from interfering with motion of the winding lead-out unit 6 and the bunching unit 7.

[0064] Referring to FIG. 4, the shape of the comb-toothed member 53 will be described in detail. In the tooth row portion 55, each pair of adjoining teeth 54 are formed therebetween with a notch 56. The notch 56 is formed to have predetermined width W and depth D.

[0065] In the CNT array 32, the coordinated adjoining CNTs pull each other by their intermolecular forces. Therefore, the CNT array 32 has an appropriate viscosity. The width W of the notch 56 is predetermined so that the CNT disposed in the notch 56 can be pulled by another CNT scraped by the teeth 54 so as to be led out therefrom well. In the comb-toothed member 53, for example, a width of each of the teeth 54 is 0.5 mm, the width W of the notch 56 is 0.5 mm, and the depth D of the notch 56 (in other words, length of teeth 54) is 2 mm. However, they are not limited to this structure.

[0066] The depth D of the notch 56 is larger than the length of the CNT extending perpendicular to the surface of the substrate 31. Therefore, the CNT disposed in the notch

56 is prevented from abutting against the comb-toothed member 53 to be crushed in the longitudinal direction of the CNT. As a result, the CNTs are protected so that all of them can face the same lead-out direction in a self-organizing manner, thereby ensuring the continuity of the CNTs.

- [0067] In this way, the CNTs on the CNT substrate 3 are led out through the notches 56 in the tooth row portion 55. In the comb-toothed member 53, the notches 56 and the teeth 54 are alternately aligned in the web width direction, so that the CNT web 33 led out by the scraping lead-out unit 5 is formed with small gaps corresponding to the respective teeth 54 in the web width direction. In other words, many CNT missing portions (partial lacks) are arranged in the web width direction locally in the CNT web 33 led out by the scraping lead-out unit 5.
- [0068] The winding lead-out unit 6 includes a winding slider 61 and a winding roller (a roller, a second member) 62, as shown in FIG. 3.
- [0069] The winding slider 61 is provided with an unillustrated sliding mechanism so that the winding slider 61 is slidably movable in a direction parallel to the longitudinal direction of the base member 20. An appropriate actuator (a winding slide driver), including an electric motor or so on, is provided to slide the winding slider 61, although the actuator is not illustrated. Therefore, the winding lead-out unit 6 is movable closer to or away from the substrate support unit 4.
- [0070] The winding slider 61 is disposed at one side in the web width direction with respect to a route of the CNT web 33 led out from the substrate support unit 4. The winding slider 61 is disposed downstream of the substrate support unit 4 in the lead-out direction.
- [0071] The winding slider 61 is provided with an unillustrated lifting mechanism so that a height of the winding slider 61 is changeable. Therefore, the winding lead-out unit 6 can be retracted to a low position so as to be prevented from interfering with motion of the scraping lead-out unit 5 and the bunching unit 7.
- [0072] The winding roller 62 is formed in a circularly columnar shape, and is rotatably supported by the winding slider 61. The winding roller 62 is disposed so as to have its axis parallel to the web width direction. An axial length of the winding roller 62 is predetermined so as to encompass the length of the tooth row portion 55 of the comb-toothed member 53. Therefore, the CNT web 33 led out by the comb-toothed member 53 is appropriately delivered to the winding roller 62.
- [0073] An electric motor (a winding driver) 63 for rotating the winding roller 62 is attached to the winding slider 61. The electric motor 63 is rotatable forwardly and reversely. The CNT web 33 can be led out from the winding roller 62 by rotating the winding roller 62 with the electric motor 63 when the CNT web 33 is wound on an outer circumferential surface of the winding roller 62.

- [0074] The bunching unit 7 includes a sucking slider 71 and an air sucker (sucking device) 72.
- [0075] The sucking slider 71 is provided with an unillustrated sliding mechanism so that the sucking slider 71 is slidably movable in a direction parallel to the longitudinal direction of the base member 20. An appropriate actuator (sucking slide drive portion), including an electric motor or so on, is provided to slide the sucking slider 71, although the actuator is not illustrated. Therefore, the bunching unit 7 is movable closer to or away from the substrate support unit 4.
- [0076] The air sucker 72 is substantially as high as the CNT substrate 3 supported by the substrate support unit 4, and is fixed at an appropriate position in the sucking slider 71. The air sucker 72 is formed with a sucking hole 72a. The sucking hole 72a is disposed so that, when the air sucker 72 together with the sucking slider 71 approaches the substrate support unit 4, the sucking hole 72a comes close to a center of the CNT web 33 in the web width direction, the CNT web 33 being led out from the substrate support unit 4 by the winding lead-out unit 6.
- [0077] The air sucker 72 generates a negative pressure by using an appropriate manner (for example, supply of compressed air to an ejector), thereby generating a sucking flow in the sucking hole 72a. Due to the sucking flow generated in the sucking hole 72a, the CNT web 33 led out from the substrate support unit 4 by the winding lead-out unit 6 is sucked into an internal portion of the air sucker 72, so that the CNT web 33 can be bunched tightly in its width direction so as to form the thread-shaped CNT portion 34. The sucking flow generated by the air sucker 72 may include a swirling component.
- [0078] A lead-out end preparation action of the CNT substrate lead-out preparation apparatus 2 will now be described with reference to the drawings.
- [0079] After the CNT substrate 3 serving as an object to be prepared is held by the substrate support unit 4, the scraping lead-out unit 5 slides the base 51 toward the substrate support unit 4 and locates the base 51 at the activation position where the base 51 is not retracted upward, and in this state, the scraping lead-out unit 5 rotates the scraping arm 52 so as to sink the tip of the comb-toothed member 53 from the upside into the CNT array 32 on the surface of the substrate support unit 4, as shown in FIG. 5.
- [0080] In this state, the base 51 of the scraping lead-out unit 5 slides away from the substrate support unit 4 as shown in FIG. 6. Therefore, the CNT array 32 is scraped by the tooth row portion 55 at the tip of the comb-toothed member 53, thereby leading out the CNT web 33 from the CNT array 32 (a first lead-out process). At this time, the winding roller 62 of the winding lead-out unit 6 is retracted at the low position.
- [0081] Afterward, the winding roller 62 of the winding lead-out unit 6 moves upward, while its rotation being stopped, and the winding roller 62 comes from the lower side to abut against the CNT web 33 spread between the CNT substrate 3 and the comb-toothed

member 53. Afterward, the scraping arm 52 of the scraping lead-out unit 5 rotates to reach a position as drawn in chained lines in FIG. 6. Therefore, the CNT web 3 is cut in such a way as to be torn between the winding roller 62 and the comb-toothed member 53.

[0082] Incidentally, the CNT web is previously wound on at least a part of the outer circumferential surface of the winding roller 62. Therefore, due to an action of intermolecular force (adhesive force), the CNT web 33 can be easily stuck to an upper portion of the winding roller 62, thereby enabling transference of the CNT web 33 from the scraping lead-out unit 5 to the winding lead-out unit 6. The previous winding of the CNT web can be realized by leaving the CNT web wound in a preceding work.

[0083] Referring to FIG. 7, after the cutting of the CNT web 33 by rotating the scraping arm 52 is finished, the winding roller 62 starts rotating so as to pull and wind the CNT web 33 contacting the upper portion thereof in a substantially tangential direction from the CNT substrate 3. In some parts of the following description, the rotation of the winding roller 62 in this direction is referred to as forward rotation.

[0084] Referring to FIG. 8, the winding lead-out unit 6 slides the winding roller 62 slightly away from the substrate support unit 4 while keeping the winding roller 62 rotating.

[0085] Due to the forward rotation of the winding roller 62, the CNT web 33 is further led out from the CNT substrate 3 (a second lead-out process). As mentioned above, the CNT web 33 scraped by the scraping lead-out unit 5 initially includes many partial lacks in the web width direction. The CNT web 33 sometimes has the lacks in its width directional end portion, and sometimes in its width directional center portion. The total width of the CNT web 33 is sometimes less than a desired full width because of the lacks. However, as the CNT web 33 wound by the winding roller 62 is continuously led out from the CNT substrate 3, the CNTs adjoining one another in the web width direction are led out while being pulled by their intermolecular forces so that the partial lacks are gradually vanishing. Finally, the CNT web 33 becomes completely continuous from one end to the other end in the web width direction between the winding roller 62 and the CNT substrate 3.

[0086] In the present embodiment, at first, the CNT web 33 is led out by the comb-toothed member 53 of the scraping lead-out unit 5. However, afterward, the CNT web 33 is delivered to the winding roller 62 of the winding lead-out unit 6 and is led out by the winding roller 62. Therefore, due to the rotation of the winding roller 62, the CNT web 33 is stably led out to a great extent. As a result, the led-out CNT web 33 has a sufficient length to eliminate the partial lacks, thereby obtaining the lead-out end 35 having a high quality.

[0087] Further, in the present embodiment, at the outset, the CNT web 33 is led out by scraping the CNT array 32 by the comb-toothed member 53 including the tooth row

portion 55 having the small teeth 54 aligned at small intervals. Therefore, in the starting lead-out process, each of the partial lacks in the width direction of the CNT web 33 is made smaller, so that in the winding process with the winding roller 62, the lacks are eliminated quickly so as to reduce the led-out length of the CNT web 33.

[0088] The CNT substrate lead-out end preparation apparatus 2 of the present embodiment further includes an inspection unit 8 which scans the CNT web 33 in the web width direction so as to detect presence or absence of the CNT web 33 led out by the winding lead-out unit 6.

[0089] Referring to FIG. 8, the inspection unit 8 includes a detection sensor 81 and a reflecting plate 82. Incidentally, the detection sensor 81 and the reflection plate 82 are omitted in FIG. 3. The detection sensor 81 and the reflection plate 82 are movable appropriately so that when they are inactivated, they are retracted at an unillustrated retraction position, and when they are activated, they come to a position as shown in FIG. 8.

[0090] The detection sensor 81 includes a contactless optical sensor. The detection sensor 81 is disposed above a traveling route of the CNT web 33. The detection sensor 81 is supported via an appropriate sliding mechanism so as to be reciprocally movable in the web width direction. The detection sensor 81 irradiates light to the reflection plate 82, and detects light reflected by the reflection plate 82.

[0091] The reflection plate 82 includes a long and narrow white plate-shaped member extended in the web width direction. The reflection plate 82 is opposed to the detection sensor 81 with respect to the CNT web 33.

[0092] When the CNT web 33 exists between the detection sensor 81 and the reflection plate 82, the light is interrupted so that an intensity of light detected by the detection sensor 81 is reduced, thereby enabling detection of the existence of the CNT web 33.

[0093] The CNT substrate lead-out preparation apparatus 2 includes an unillustrated computer serving as a control unit. The computer controls various actuators for activating the scraping lead-out unit 5, the winding lead-out unit 6, the bunching unit 7, the inspection unit 8 and so on (including an actuator for reciprocally moving the detection sensor 81). The detection sensor 81 is electrically connected to the computer.

[0094] The computer commands the detection sensor 81 to reciprocally move in the web width direction in a predetermined stroke so as to continuously acquire detection results from the detection sensor 81, thereby acquiring distribution of existence and absence of the CNT web 33 in the web width direction. Until a predetermined standard (in the present embodiment, non-existence of the lack portion in a predetermined width range of the CNT web 33) is satisfied, the computer continuously gives commands to the winding roller 62 for winding the CNT web 33, and to the inspection unit 8 for inspection, thereby performing an inspection process.

- [0095] If the result of inspection indicates that the standard is satisfied, the rotation of the winding roller 62 is stopped. Afterward, as illustrated in chained lines in FIG. 9, the winding lead-out unit 6 is slid further away from the substrate support unit 4 while the winding roller 62 is kept from rotating. Accordingly, the CNT web 33 is further led out from the CNT substrate 3.
- [0096] Afterward, the winding lead-out unit 6 slightly lowers the winding roller 62, and subsequently slides the winding roller 62 toward the substrate support unit 4. In this process, the winding roller 62 is kept being stopped so that the CNT web 33 is loosened between the winding roller 62 and the CNT substrate 3.
- [0097] Substantially in cooperation with this, referring to FIG. 10, the bunching unit 7 slides the air sucker 72 toward the substrate support unit 4. Then, the bunching unit 7 generates a sucking flow in the sucking hole 72a so as to suck the CNT web 33 between the winding roller 62 and the CNT substrate 3. The winding roller 62 reversely rotates at a high speed almost simultaneously to the sucking of the CNT web 33 by the air sucker 72. Therefore, the CNT web 33 is cut in such a way as to be torn between the air sucker 72 and the winding roller 62.
- [0098] The loose portion of the CNT web 33, including an end portion thereof created by the cutting, is sucked into the sucking hole 72a. The CNT web 33 sucked in the sucking hole 72a is bunched and agglomerated tightly in the width direction thereof so as to be formed into the thread-shaped CNT portion 34 (an integration process).
- [0099] Afterward, the bunching portion 7 stops the sucking flow and slides the air sucker 72 away from the substrate support unit 4 as shown in FIG. 11. Consequently, the thread-shaped CNT portion 34 is released from the sucking hole 72a so as to be exposed.
- [0100] In this way, due to the CNT substrate lead-out end preparation apparatus 2, the CNT web 33 having the predetermined width is led out from the CNT substrate 3 and is formed at an utmost end thereof with the thread-shaped CNT portion 34 accessible to be caught, thereby being prepared as the CNT substrate 3a having the lead-out end 35.
- [0101] As described above, the CNT substrate lead-out end preparation apparatus 2 comprises the substrate support unit 4, the scraping lead-out unit 5, the winding lead-out unit 6, and the bunching unit 7. The substrate support unit 4 is configured to support the CNT substrate 3 on CNTs are formed. The scraping lead-out unit 5 is configured to contact the CNTs formed on the CNT substrate 3 and to lead out the CNT web 33 from the CNT substrate 3. The winding lead-out unit 5 is configured to receive the CNT web 33 led out by the scraping lead-out unit 5 and to lead out the CNT web 33 from the CNT substrate 3. The bunching unit 7 is configured to agglomerate the CNT web 33 between the CNT substrate 3 and the winding lead-out unit 6 in the web width direction to bunch the CNT web.
- [0102] Therefore, the CNT web 33, while being transferred via the scraping lead-out unit 5

and the winding lead-out unit 6, is surely and efficiently led out from the CNT substrate 3 so as to be prepared to facilitate a subsequent process.

[0103] The CNT substrate lead-out end preparation apparatus 2 of the present embodiment comprises the inspection unit 8 configured to inspect the CNT web 33 led out by the winding lead-out unit 6 so as to decide whether or not a lack portion missing a CNT exists in the predetermined width range of the CNT web 33.

[0104] Therefore, the CNT web 33 is agglomerated and bunched by the bunching unit 7 after the CNT web 33 being led out is confirmed as having the predetermined width.

[0105] In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the winding lead-out unit 6 is configured to continuously lead out the CNT web 33 until the inspection unit 7 decides that the lack portion does not exist in the predetermined width range.

[0106] Therefore, even if the CNT web 33 led out at an early stage includes a lack portion missing a CNT, due to the continuous lead-out of the CNT web 33, the missed CNT is newly led out by its intermolecular force such as to eliminate the lack portion, thereby improving a yield rate of the inspection.

[0107] In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the scraping lead-out unit 5 includes the comb-toothed member 53 adapted to contact the CNTs.

[0108] Therefore, the comb-toothed member 53 facilitates catching of the CNTs which are formed on the CNT substrate 3 to be led out as the CNT web 33.

[0109] In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the comb-toothed member 53 is adapted to contact the CNTs formed on the CNT substrate 3.

[0110] Therefore, the CNTs can be easily caught to be led out.

[0111] In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the winding lead-out unit 6 includes the winding roller 62 for winding the CNT web 33.

[0112] Therefore, the winding of the CNT web 33 onto the winding roller 62 facilitates leading out of the CNT web 33 in a large length.

[0113] In the CNT substrate lead-out end preparation apparatus 2 of the present embodiment, the bunching unit 7 includes the air sucker 72 for sucking the CNT web 33.

[0114] Therefore, the sucking flow facilitates bunching of the CNT web 33 tightly in the width direction.

[0115] The foregoing description is a preferred embodiment of the present invention. For example, the above-mentioned configuration may be modified to the following alternative configurations.

[0116] Regarding to the inspection unit 8, the inspection of the partial lacks in the width

direction of the CNT web 33 may be omitted, so that the inspection unit 8 may only inspect whether or not the CNT web 33 acquires the predetermined width.

[0117] The inspection unit 8 may inspect not only the existence of the CNT web 33 but also unevenness of CNTs on the CNT web 33.

[0118] Regarding to the bunching unit 7, instead of the configuration to tightly bunch the CNT web 33 by using the air sucker 72 sucking the CNT web 33, for example, the CNT web 33 may be nipped and pushed at mutually opposite portions thereof in the web width direction so as to be agglomerated tightly in the width direction.

[0119] Instead of the comb-toothed member 53, a lead-out member formed linear continuously from one end to the other end in a width required to lead out the CNT web 33 (a spatula-shaped lead-out member) may be used. In this case, the lead-out member can be easily formed.

[0120] In the CNT substrate lead-out end preparation apparatus 2, a direction of setting the CNT substrate 3 and a direction of leading out the CNT web 33 from the CNT substrate 3 can be changed appropriately to correspond to a layout of the apparatus. The same applies to the yarn spinning apparatus 1.

[0121] The CNT substrate 3a with the lead-out end 35 prepared by the CNT substrate lead-out end preparation apparatus 2 can be used for another purpose than spinning.

Notation of Reference Numerals

[0122] 2 A CNT substrate lead-out preparation apparatus (a carbon nanotube substrate lead-out end preparation apparatus)

3 A CNT substrate (a carbon nanotube substrate)

4 A substrate support unit

5 A scraping lead-out unit (a first lead-out unit)

6 A winding lead-out unit (a second lead-out unit)

7 A bunching unit (an integration unit)

33 A CNT web (a carbon nanotube web)

Claims

- [Claim 1] A carbon nanotube substrate lead-out end preparation apparatus comprising:
a substrate support unit configured to support a carbon nanotube substrate on which carbon nanotubes are formed;
a first lead-out unit configured to contact the carbon nanotubes formed on the carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate;
a second lead-out unit configured to receive the carbon nanotube web led out by the first lead-out unit and to lead out the carbon nanotube web from the carbon nanotube substrate; and
an integration unit configured to agglomerate the carbon nanotube web between the carbon nanotube substrate and the second lead-out unit in the web width direction to bunch the carbon nanotube web.
- [Claim 2] The carbon nanotube substrate lead-out end preparation apparatus according to claim 1, further comprising:
an inspection unit configured to inspect the carbon nanotube web led out by the second lead-out unit so as to decide whether or not a lack portion missing a carbon nanotube exists in a predetermined width range of the carbon nanotube web.
- [Claim 3] The carbon nanotube substrate lead-out end preparation apparatus according to claim 2, wherein the second lead-out unit is configured to continuously lead out the carbon nanotube web until the inspection unit decides that the lack portion does not exist in the predetermined width range.
- [Claim 4] The carbon nanotube substrate lead-out end preparation apparatus according to any one of claims 1 to 3, wherein the first lead-out unit includes a lead-out member adapted to contact the carbon nanotubes.
- [Claim 5] The carbon nanotube substrate lead-out end preparation apparatus according to claim 4, wherein the lead-out member is a comb-toothed member.
- [Claim 6] The carbon nanotube substrate lead-out end preparation apparatus according to claim 4, wherein the lead-out member includes a tip adapted to contact the carbon nanotubes, the tip being formed linear continuously from one end to another end in a width required to lead out the carbon nanotube web.
- [Claim 7] The carbon nanotube substrate lead-out end preparation apparatus

according to any one of claims 1 to 6, wherein the second lead-out unit includes a roller for winding the carbon nanotube web.

[Claim 8] The carbon nanotube substrate lead-out end preparation apparatus according to any one of claims 1 to 7, wherein the integration unit includes a sucking device for sucking the carbon nanotube web.

[Claim 9] A spinning system comprising:
the carbon nanotube substrate lead-out end preparation apparatus according to any one of claims 1 to 8; and
a yarn forming apparatus configured to agglomerate the carbon nanotube web so as to form a yarn.

[Claim 10] The spinning system according to claim 9, wherein the yarn forming apparatus is configured to form the yarn by twisting the carbon nanotube web.

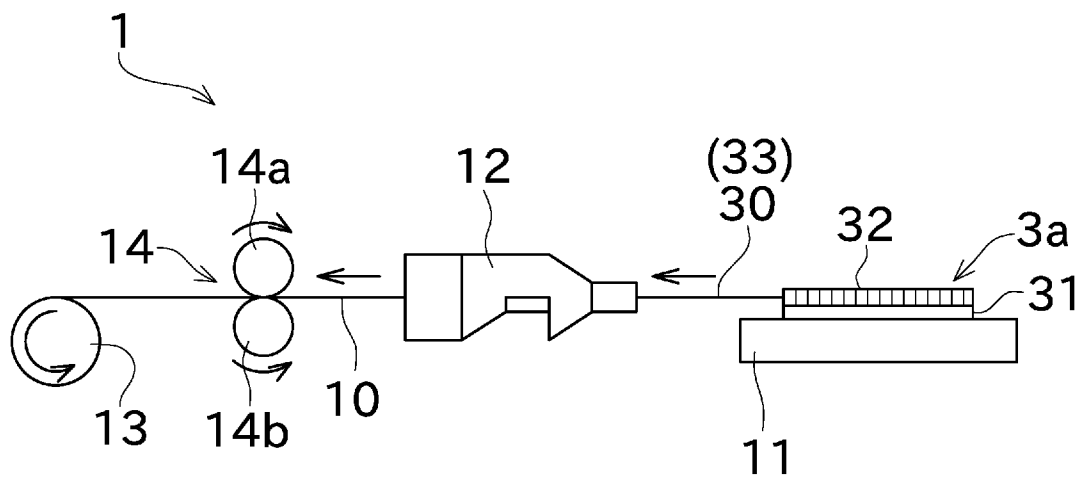
[Claim 11] The spinning system according to claim 10, wherein the twisting of the carbon nanotube web is false-twisting.

[Claim 12] A carbon nanotube substrate lead-out end preparation method comprising:
a first lead-out process of operating a first member to contact carbon nanotubes formed on a carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate;
a second lead-out process of operating a second member to receive the carbon nanotube web led out by the first process and to lead out the carbon nanotube web from the carbon nanotube substrate; and
an integration process of agglomerating the carbon nanotube web led out by the second lead-out process in a web width direction to bunch the carbon nanotube web.

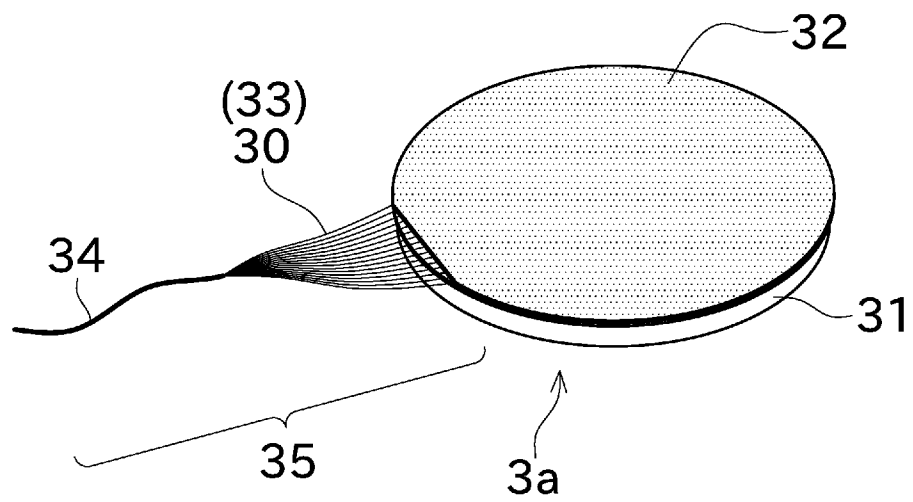
[Claim 13] A spinning method comprising:
a first lead-out process of operating a first member to contact carbon nanotubes formed on a carbon nanotube substrate and to lead out a carbon nanotube web from the carbon nanotube substrate;
a second lead-out process of operating a second member to receive the carbon nanotube web led out by the first process and to lead out the carbon nanotube web from the carbon nanotube substrate;
an integration process of agglomerating the carbon nanotube web led out by the second lead-out process in a web width direction to bunch the carbon nanotube web; and
a yarn forming process of using the lead-out end bunched by the integration process to lead out the carbon nanotube web from the carbon

nanotube substrate and to form a yarn by twisting the carbon nanotube web.

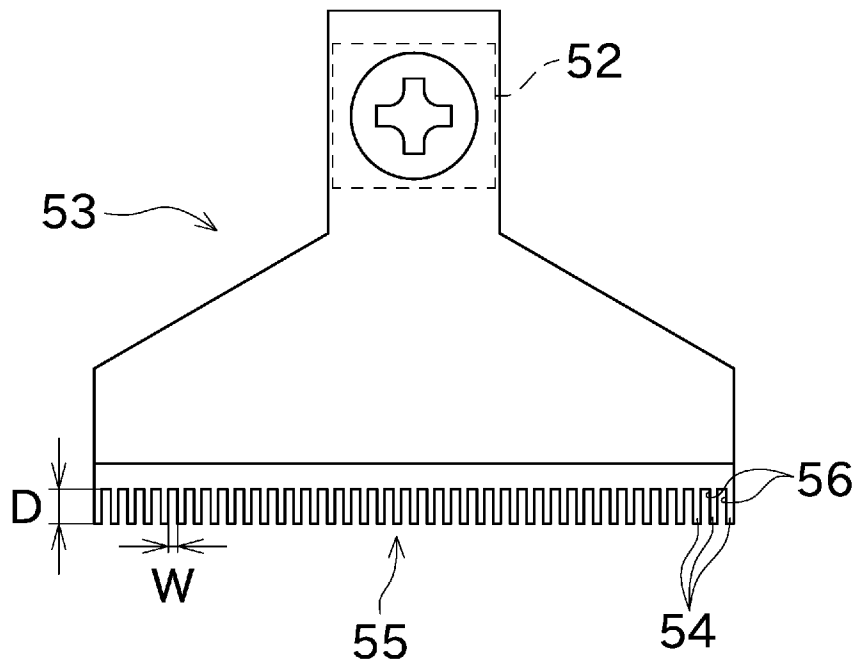
[Fig. 1]



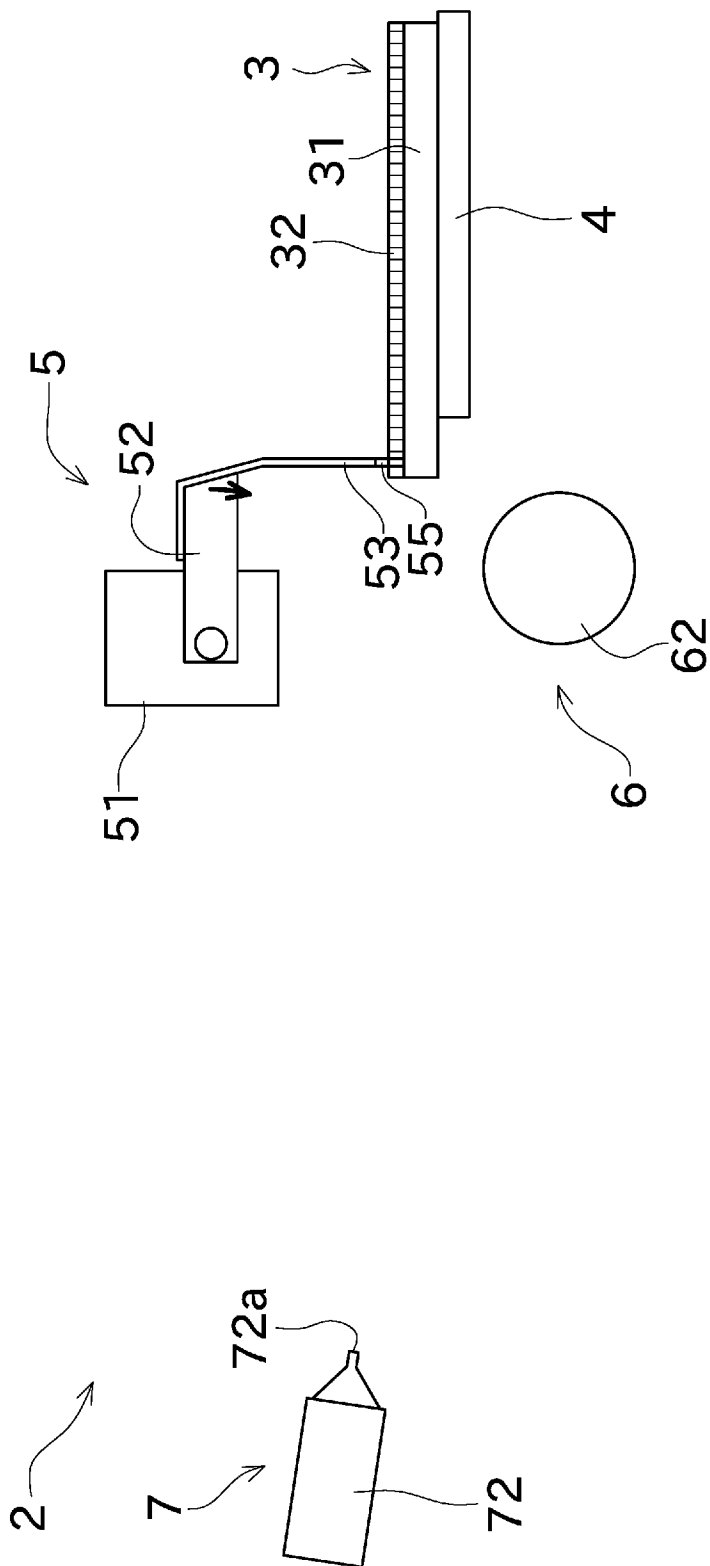
[Fig. 2]



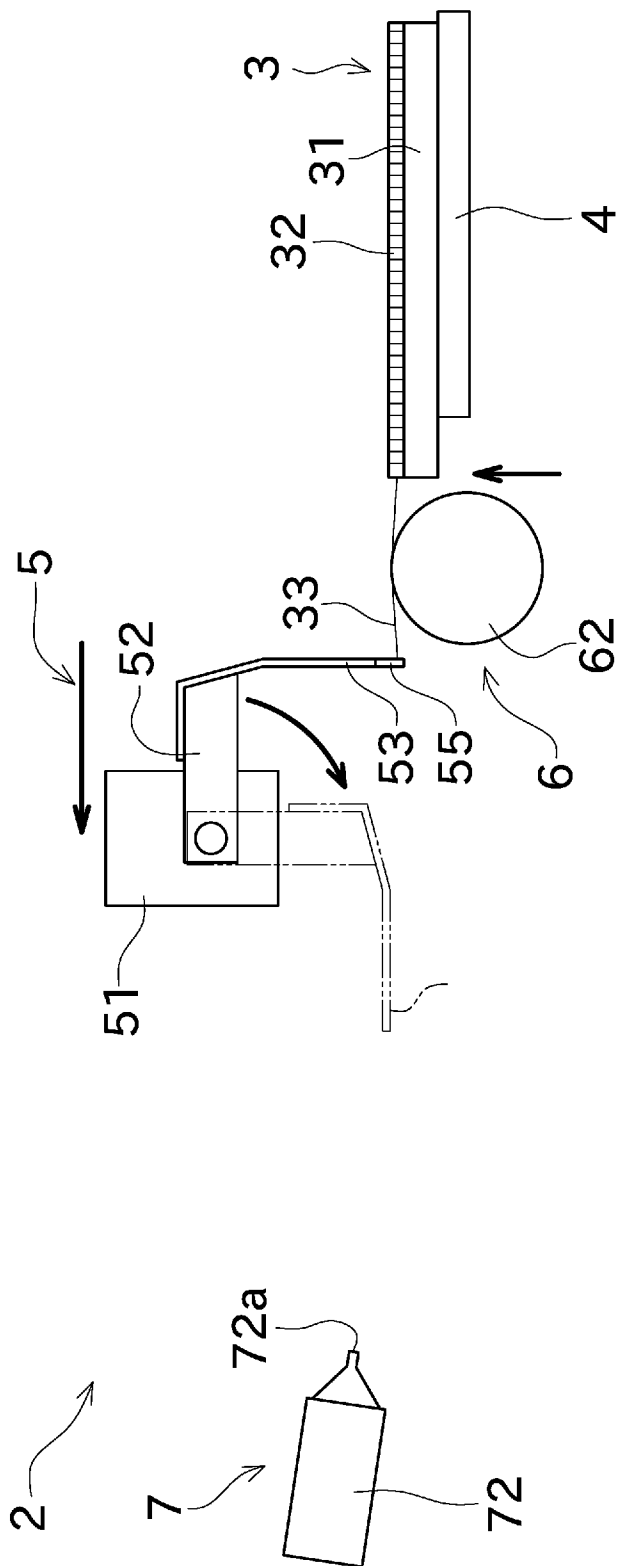
[Fig. 4]



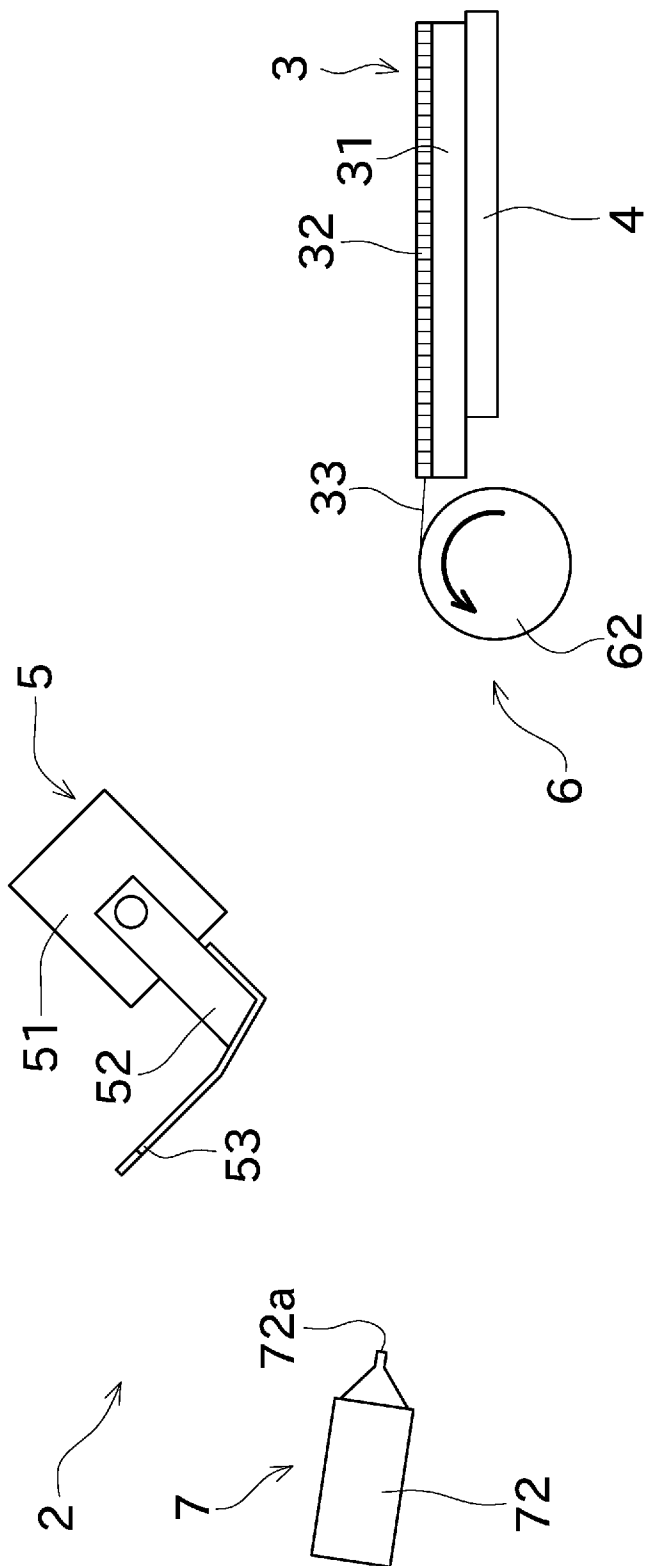
[Fig. 5]



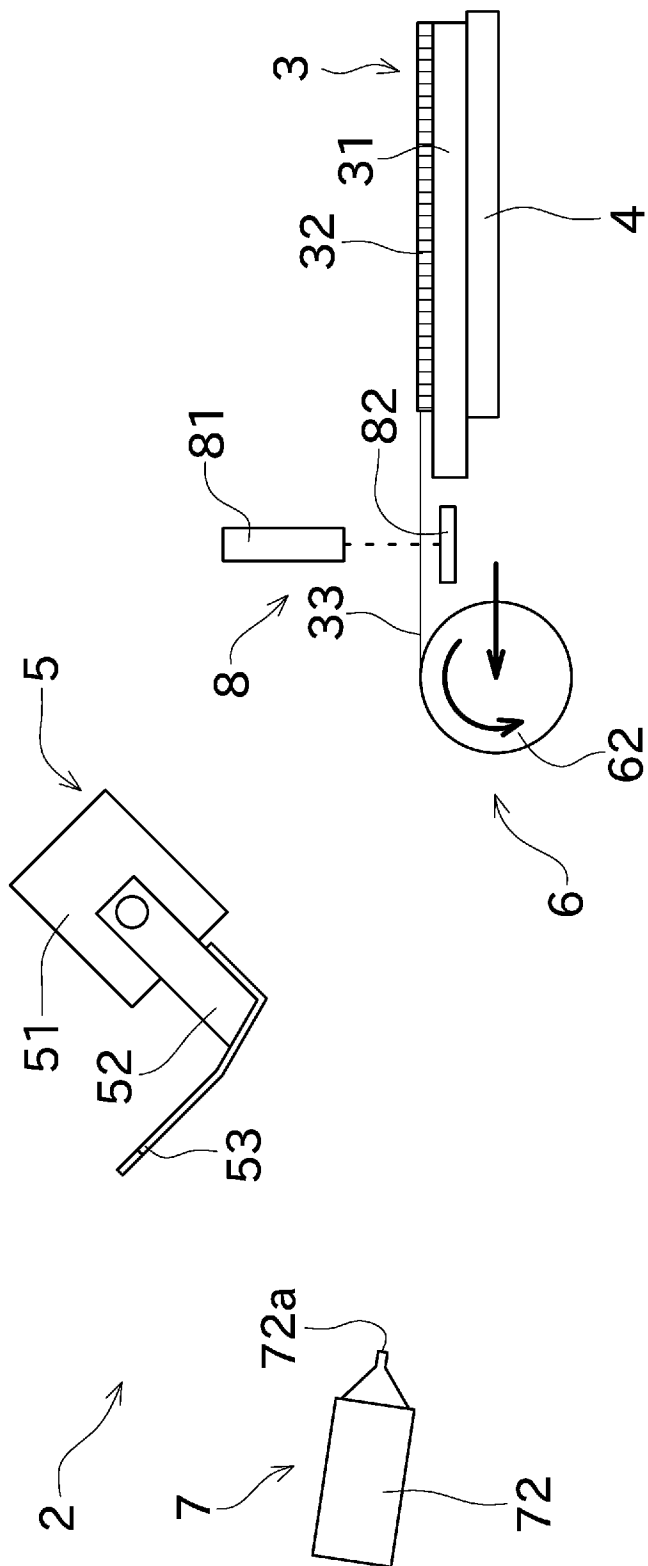
[Fig. 6]



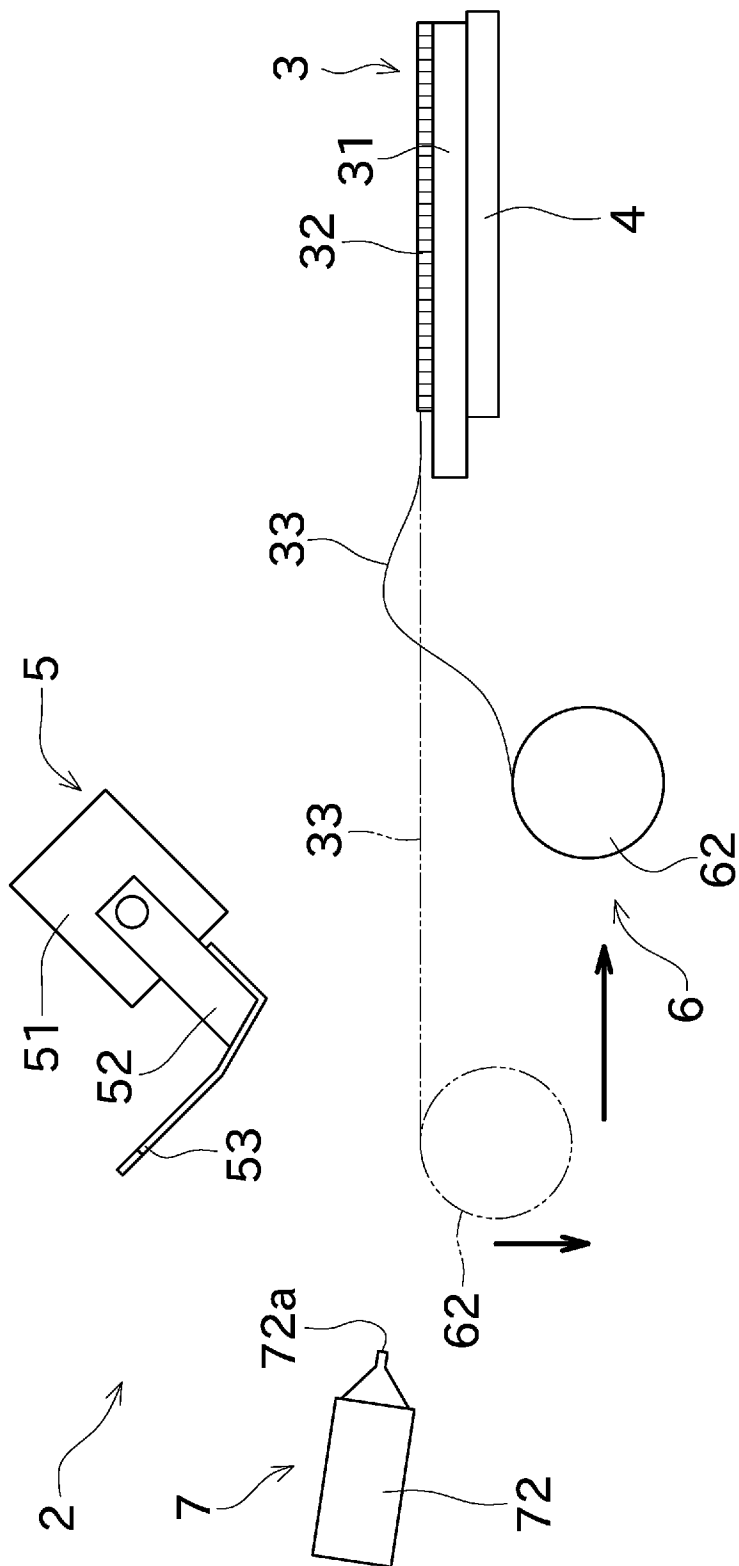
[Fig. 7]



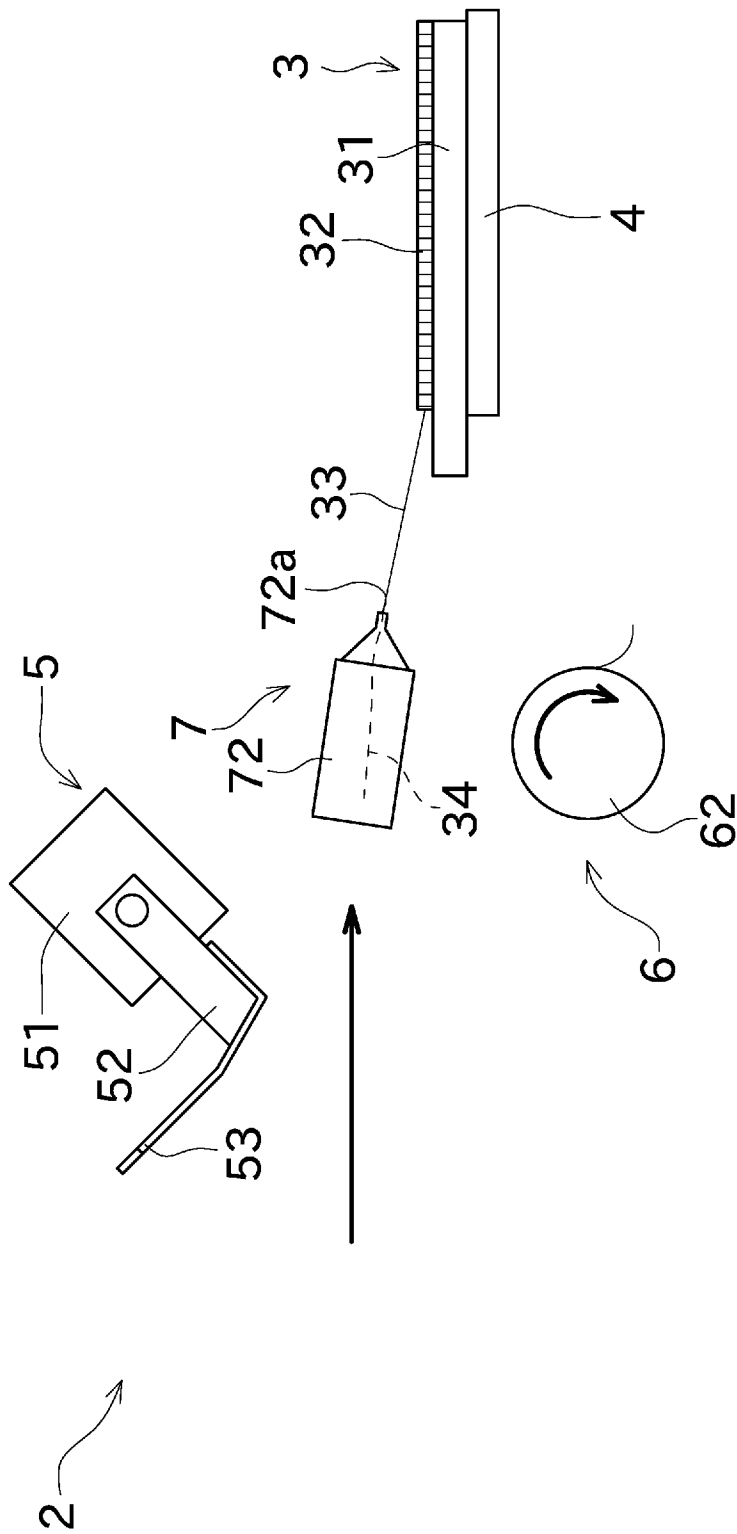
[Fig. 8]



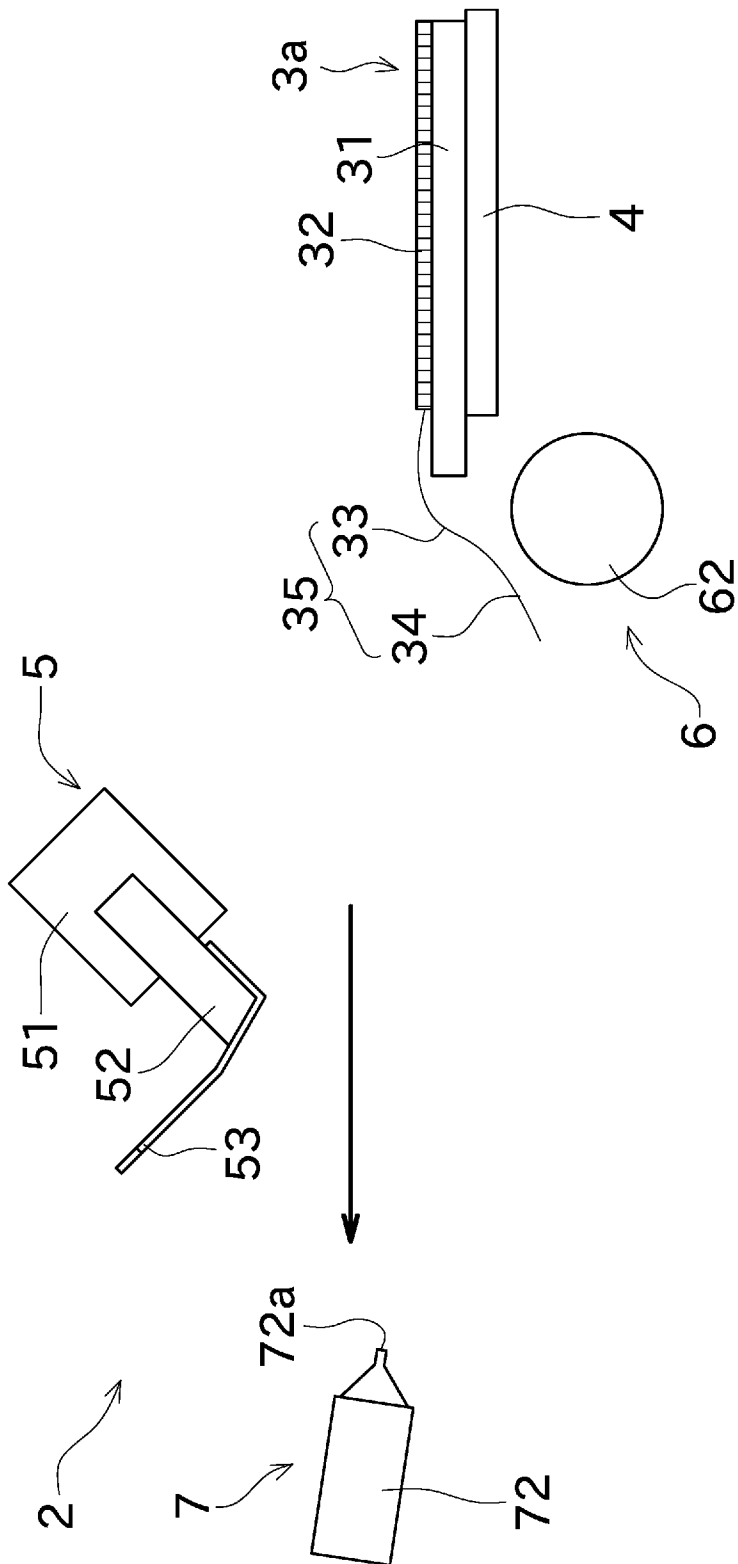
[Fig. 9]



[Fig. 10]



[Fig. 11]



INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2019/014910

A. CLASSIFICATION OF SUBJECT MATTER
 INV. C01B32/168 D02G3/02
 ADD.

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)

C01B D02G D01F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 3 279 375 A1 (HITACHI SHIPBUILDING ENG CO [JP]) 7 February 2018 (2018-02-07) abstract figure 2 paragraphs [0193], [0194], [0195], [0116], [0123], [0124], [0196] - [0198] -----	1-13
X	WO 2017/010180 A1 (HITACHI SHIPBUILDING ENG CO [JP]; YAMAHA CORP [JP]) 19 January 2017 (2017-01-19) abstract claims 1-11 figure 1 ----- -/--	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

9 July 2019

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 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Mertins, Frédéric

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2019/014910

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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