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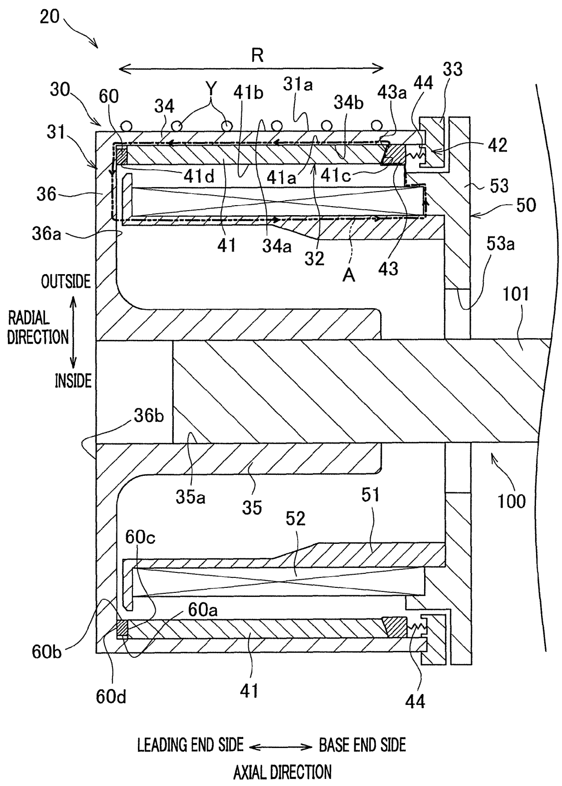
(54) INDUCTION HEATING ROLLER AND SPUN YARN DRAWING DEVICE

(57) An object of the present invention is to effectively reduce the temperature dispersion of a cylindrical portion of a roller main body in the axial direction of an induction heating roller.

An induction heating roller 20 includes a rotatable roller unit 30 and a coil 52. A roller unit 30 includes an outer cylindrical portion 34 (cylindrical portion) extending in an axial direction of the roller unit 30, a roller main body 31 in which the outer cylindrical portion 34 is induction-heated when a current flows in the coil 52, a heat equalizing member 32 which is able to transfer the heat generated in the outer cylindrical portion 34 in the axial direction and which more easily transfers the heat in the axial direction than the outer cylindrical portion 34 does, and a heat generating member 60 which is provided at an end portion of the outer cylindrical portion 34 in the axial direction and which is induction-heated when a current flows in the coil 52. The heat generating member 60 is made of a material which is lower in electric resistivity than a material forming the outer cylindrical portion 34 and a material forming the heat equalizing member 32. The heat generating member 60 is provided to be adjacent to at least one of the outer cylindrical portion 34 and the heat equalizing member 32.

FIG.2



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an induction heating roller and a spun yarn drawing device including one or more induction heating rollers.

[0002] Patent Literatures 1 and 2 (Japanese Laid-Open Patent Publication No. 2018-35488 and Japanese Laid-Open Patent Publication No. H10-31379) disclose an induction heating roller configured to heat heating targets (e.g., yarns or toner). The induction heating roller includes a coil and a roller (hereinafter, a roller unit) including an outer cylindrical portion (hereinafter, a cylindrical portion) configured to be induction-heated. When the flow of an alternating current in the coil results in the generation of magnetic flux, an eddy current is generated in a circumferential direction of the cylindrical portion of the roller unit by electromagnetic induction. As a result, heat is generated in the cylindrical portion by Joule heat. Such induction heating allows the heat targets in contact with the roller unit to be heated.

SUMMARY OF THE INVENTION

[0003] Generally, magnetic flux tends not to uniformly flow in an axial direction of a roller unit (hereinafter, this direction will be simply referred to as the axial direction) in an induction heating roller because of leakage of the magnetic flux. Therefore, heat in a cylindrical portion in the axial direction tends not to be uniform. To be more specific, because an amount of magnetic flux passing through an end portion in the axial direction of the cylindrical portion is smaller than an amount of magnetic flux passing through a central portion in the axial direction of the cylindrical portion, heat tends not to be generated in the end portion of the cylindrical portion in the axial direction. Generally, an end portion of the roller unit in the axial direction is larger than a central portion of the roller unit in the axial direction, in terms of the area exposed to the outside air. Therefore, the end portion of the cylindrical portion in the axial direction tends to be cooled by heat radiation. Because a temperature at the end portion of the cylindrical portion in the axial direction tends to be lower than a temperature at the central portion of the cylindrical portion in the axial direction because of the difficulty in heat generation and the easiness in heat radiation, a temperature of the cylindrical portion tends to be disadvantageously uneven in the axial direction.

[0004] In relation to this, an inner circumferential surface of a cylindrical portion is in contact with a heat equalizing unit (this unit is referred to as a heat equalizing member in Patent Literature 1) which is higher in heat conductivity than the cylindrical portion in the axial direction in an induction heating roller disclosed in Patent Literature 1. With this heat equalizing unit, the heat generated in the cylindrical portion is easily transmitted in the axial direction so as to reduce temperature dispersion of the cylindrical portion in the axial direction. However, the present inventors have found that there is still a room for improvement in this structure.

[0005] In an induction heating roller disclosed in Patent Literature 2, an end portion of an inner circumferential surface of a cylindrical portion (this portion is referred to as a fixing roller in Patent Literature 2) in the axial direction is in contact with a ring member which is lower in electric resistivity than the cylindrical portion. Magnetic flux passes through the ring member so that an eddy current is generated in the ring member. Therefore, an amount of heat increases in the vicinity of the end portion of the cylindrical portion in the axial direction. Because of this, the temperature dispersion of the cylindrical portion in the axial direction is suppressed. However, an unusual amount of heat may be generated in the ring member because the eddy current excessively flows in the ring member which is low in electric resistivity in this structure. As a result, the temperature distribution of the cylindrical portion may be deteriorated.

[0006] An object of the present invention is to effectively reduce the temperature dispersion of a cylindrical portion of a roller main body in the axial direction of an induction heating roller.

[Solution to Problem]

[0007] According to a first aspect of the invention, an induction heating roller includes a rotatable roller unit and a coil, the roller unit including: a roller main body which includes a cylindrical portion extending in an axial direction of the roller unit and in which the cylindrical portion is induction-heated when a current flows in the coil; a heat equalizing unit which is able to transfer heat generated in the cylindrical portion in the axial direction and which more easily transfers heat in the axial direction than the cylindrical portion does; and a heat generating unit which is provided at an end portion of the cylindrical portion in the axial direction and which is induction-heated when a current flows in the coil, the heat generating unit being made of a material which is lower in electric resistivity than a material forming the cylindrical portion and a material forming the heat equalizing unit, and being provided to be adjacent to at least one of the cylindrical portion and the heat equalizing unit.

[0008] In the present invention, the heat generating unit the electric resistivity of which is low is induction-heated so as to increase the amount of heat generated in the vicinity of the end portion of the cylindrical portion in the axial direction. This makes it to easy to increase the temperature in the vicinity of the end portion of the cylindrical portion in the axial direction.

[0009] In the present invention, the heat generating unit is provided to be adjacent to at least one of the cylindrical portion and the heat equalizing unit. Because of this, the heat generated in the heat generating unit is directly transmitted to the heat equalizing unit or is transmitted to the heat equalizing unit via the cylindrical portion. Therefore, the heat is substantially uniformly transmitted to the cylindrical portion of the roller main body in the axial direction by the heat equalizing unit. As a result, a significant increase of the temperature only at the end portion of the cylindrical portion in the axial direction is suppressed.

[0010] As such, it is possible to effectively reduce the temperature dispersion of the cylindrical portion of the roller main body in the axial direction of the induction heating roller.

[0011] According to a second aspect of the invention, the induction heating roller of the first aspect is arranged such that the heat generating unit includes a ring-shaped heat generating member which is provided to be independent from the roller main body and the heat equalizing unit and which is in contact with at least one of the cylindrical portion and the heat equalizing unit.

[0012] The heat generating unit made of a material which is lower in electric resistivity than the cylindrical portion may be integrally formed with the cylindrical portion or the heat equalizing unit by, e.g., pressure welding. However, this arrangement may increase the labor and cost for manufacturing the heat generating unit. In the present invention, the ring-shaped heat generating member which can be easily manufactured with low cost is provided to be independent from the cylindrical portion and the heat equalizing unit. It is therefore possible to save the labor and cost for manufacturing the heat generating unit as compared to cases where the heat generating unit is integrally formed with the cylindrical portion or heat equalizing unit.

[0013] According to a third aspect of the invention, the induction heating roller of the first or second aspect is arranged such that the heat equalizing unit includes a heat equalizing member which is provided to be independent from the roller main body, which is in contact with an inner circumferential surface of the cylindrical portion, and which is higher in heat conductivity than the outer cylindrical portion in the axial direction.

[0014] For example, a jacket chamber in which a heating medium allowing heat to move in the axial direction is enclosed may be provided as the heat equalizing unit in the roller unit. However, this arrangement may complexify the structure of the roller unit. In the present invention, the heat equalizing unit simply includes the heat equalizing member the heat conductivity of which is high. Therefore, the structure of the roller unit is simplified as compared to a structure in which, e.g., the jacket chamber is provided.

[0015] According to a fourth aspect of the invention, the induction heating roller of any one of the first to third aspects is arranged such that the heat equalizing unit is provided inside the cylindrical portion in a radial direction of the roller unit, and the heat generating unit and the heat equalizing unit are aligned in the axial direction.

[0016] When the heat equalizing unit is provided radially inside the cylindrical portion and, for example, the heat generating unit is provided radially inside the heat equalizing unit, the heat generating unit is far from the cylindrical portion in the radial direction. In this case, the amount of heat which is radiated without being transmitted to the cylindrical portion among the heat generated in the heat generating unit may be large, with the result that the heating efficiency of the cylindrical portion may be deteriorated. In the present invention, the heat generating unit is provided side by side with the heat equalizing unit in the axial direction. In other words, the heat generating unit is provided in the vicinity of the cylindrical portion in the radial direction. It is therefore possible to suppress the deterioration of the heating efficiency of the cylindrical portion.

[0017] According to a fifth aspect of the invention, the induction heating roller of any one of the first to fourth aspects is arranged such that the heat generating unit is provided to be adjacent to the heat equalizing unit.

[0018] In the present invention, the heat generated in the heat generating unit is directly transmittable to the heat equalizing unit. Therefore, the temperature of the cylindrical portion is effectively equalized in the axial direction by the heat equalizing unit.

[0019] According to a sixth aspect of the invention, the induction heating roller of the fifth aspect is arranged such that the heat generating unit is provided to be separated from the cylindrical portion.

[0020] In the present invention, the heat generated in the heat generating unit is not directly transmitted to the cylindrical portion but is indirectly transmitted to cylindrical portion via the heat equalizing unit. Therefore, the significant increase of the temperature only at the end portion of the cylindrical portion in the axial direction is further reliably suppressed as compared to cases where the heat generated in the heat generating unit is directly transmitted to the cylindrical portion.

[0021] According to a seventh aspect of the invention, the induction heating roller of any one of the first to fifth aspects is arranged such that the heat generating unit is provided to be adjacent to the cylindrical portion.

[0022] In the present invention, the heat generated in the heat generating unit is directly transmittable to the cylindrical portion. Because the cylindrical portion is effectively heated, this arrangement is effective in cases where the amount of heat generated in the heat generating unit is small.

[0023] According to an eighth aspect of the invention, the induction heating roller of any one of the first to seventh aspects is arranged such that the roller main body further includes a circular plate portion which extends inward in the radial direction of the roller unit from an end of the cylindrical portion on one side in the axial direction, the heat equalizing unit includes the heat equalizing member which is provided to be independent from the roller main body, which is in contact with the inner circumferential surface of the cylindrical portion, and which is higher in heat conductivity than the cylindrical portion in the axial direction, the heat generating unit further includes a ring-shaped heat generating member which is provided to be independent from the roller main body and the heat equalizing member and which is provided to be adjacent to the heat equalizing member in the axial direction, and a press portion is provided on the other side in the axial direction of the heat equalizing member and the heat generating member to press the heat equalizing member and the heat generating member toward the one side in the axial direction.

[0024] In the present invention, when the roller main body, the heat equalizing member, and the heat generating member are provided to be independent from each other, both of the heat equalizing member and the heat generating member are pressed by one press portion toward the one side (the circular plate portion side) in the axial direction. Because of this, it is possible to fix the heat equalizing member and the heat generating member to the roller main body by holding them between the press portion and the circular plate portion in the axial direction. Therefore, the heat generating member is fixed to the roller main body with a simple structure as compared to cases where the heat generating member is provided at a different location from the heat equalizing member in the radial direction.

[0025] According to a ninth aspect of the invention, the induction heating roller of any one of the first to eighth aspects is arranged such that the roller main body is cantilevered, and the heat generating unit is provided at an end portion of the cylindrical portion on a leading end side in the axial direction.

[0026] A leading end surface of the roller main body in the axial direction is generally exposed to the outside air in the induction heating roller in which the roller main body is cantilevered. Because of this, the amount of heat radiated from the leading end portion of the roller main body in the axial direction is large, with the result that the temperature at the leading end portion of the cylindrical portion in the axial direction tends to be especially decreased. In this regard, because heat is generated in the vicinity of the leading end portion of the cylindrical portion in the axial direction by the heat generating unit in the present invention, the decrease of the temperature at the leading end portion of the cylindrical portion in the axial direction is effectively suppressed. It is therefore possible to effectively reduce the temperature dispersion of the cylindrical portion.

[0027] According to a tenth aspect of the invention, the induction heating roller of any one of the first to ninth aspects is arranged such that the heat generating unit is made of a non-magnetic material.

[0028] When the heat generating unit is made of a magnetic material such as carbon steel, magnetic flux may flow differently from a case where the heat generating unit is formed of a non-magnetic material. Therefore, for example, magnetic flux may not easily pass through the cylindrical portion because of the arrangement of the heat generating unit and the like, with the result that the generation of heat from the cylindrical portion may be obstructed. In the present invention, because the heat generating unit is made of a non-magnetic material, it is possible to avoid an unintended flow of magnetic flux.

[0029] According to an eleventh aspect of the invention, the induction heating roller of any one of the first to tenth aspects is arranged such that density of the heat generating unit is lower than at least density of the cylindrical portion.

[0030] In the present invention, it is possible to suppress the increase in the weight of the induction heating roller due to provision of the heat generating unit.

[0031] According to a twelfth aspects of the invention, the induction heating roller of any one of the first to eleventh aspects is arranged such that a material forming the heat equalizing unit is higher in heat conductivity than a material forming the cylindrical portion in the axial direction, and the material forming the heat equalizing unit is higher in electric resistivity than the material forming the cylindrical portion in a circumferential direction of the roller unit.

[0032] The temperature of the induction heating roller is mainly increased by Joule heat which is generated when an eddy current flows in the circumferential direction of the roller unit. If an eddy current tends to flow in the heat equalizing unit rather than in the cylindrical portion in the circumferential direction, the following problems may occur. Firstly, when heat is generated in the heat equalizing unit provided to be more or less far from the cylindrical portion which is the target to be heated, the heat may diffuse not only into the cylindrical portion but also into other members and/or space. This heat diffused in this way may not be transmitted to the cylindrical portion in a uniform manner. Secondly, because the heat equalizing unit is shorter than the cylindrical portion in the axial direction, the distribution of heat generated by the heat equalizing unit is uneven for the cylindrical portion in the axial direction. Because of these problems, the temperature dispersion of the cylindrical portion in the axial direction may be increased. In the present invention, it is possible to facilitate transfer of heat in the axial direction by the heat equalizing unit, and to suppress the flow of an eddy current in the heat equalizing unit in the circumferential direction so as to suppress an unnecessary heat generation by the heat equalizing unit. Because of this, it is possible to suppress the increase in the temperature dispersion of the cylindrical portion due to the generation of heat from the heat equalizing unit.

[0033] According to a thirteenth aspect of the invention, a spun yarn drawing apparatus including the induction heating roller of any one of the first to twelfth aspects is arranged such that yarns are wound onto the cylindrical portion as heating targets, so as to be aligned in the axial direction.

[0034] In the present invention, the yarns are wound onto the cylindrical portion in which the temperature dispersion is reduced in the axial direction. Therefore, dispersion of quality is reduced between the yarns heated by the induction heating roller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035]

FIG. 1 is a schematic diagram of a spun yarn take-up machine including induction heating rollers of an embodiment.

FIG. 2 is a cross section of one of the induction heating rollers.

FIG. 3 is a table of physical properties of a roller main body, a heat equalizing member, and a heat generating member.

FIG. 4 is a graph of temperature distributions on an outer circumferential surface in an axial direction.

FIGs. 5(a) and 5(b) are tables of physical properties of a roller main body, heat equalizing member, and heat generating member which are related to modifications.

Each of FIGs. 6(a) to 6(f) illustrates an arrangement of a heat generating member related to a modification.

FIG. 7 shows an induction heating roller related to a modification.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036] The following will describe an embodiment of the present invention. Hereinafter, an un-down direction on the sheet of FIG. 1 is referred to as an up-down direction (i.e., vertical direction in which the gravity acts). Furthermore, a left-right direction on the sheet of FIG. 1 is referred to as a left-right direction. Furthermore, a vertical direction to the sheet of FIG. 1 is referred to as a front-rear direction.

(Spun Yarn Take-Up Machine)

[0037] The following will describe the structure of a spun yarn take-up machine 1 including induction heating rollers 20 of the present embodiment, with reference to FIG. 1. FIG. 1 is a schematic front view of the spun yarn take-up machine 1. The spun yarn take-up machine 1 is configured so that yarns Y (heating targets of the present invention) spun out from a spinning apparatus 2 are drawn by a spun yarn drawing apparatus 3 and then are wound up by a yarn winding apparatus 4.

[0038] The spinning apparatus 2 is configured to produce the yarns Y by continuously spinning out molten polymer such as polyester. To the yarns Y spun out from the spinning apparatus 2, oil is applied at an oil guide 10. After that, the yarns Y are sent to the spun yarn drawing apparatus 3 via a guide roller 11.

[0039] The spun yarn drawing apparatus 3 is an apparatus for drawing the yarns Y. The spun yarn drawing apparatus 3 is provided below the spinning apparatus 2. The spun yarn drawing apparatus 3 includes godet rollers 21 to 25 housed in a thermal insulation box 12. Each of the godet rollers 21 to 25 is rotationally driven by a corresponding motor (unillustrated). Each of the godet rollers 21 to 25 is an induction heating roller 20 (described later) heated by induction heating with use of a coil. The yarns Y are wound onto an outer circumferential surface of each of the godet rollers 21 to 25. At a lower part of a right side portion of the thermal insulation box 12, an inlet 12a is formed to introduce the yarns Y into the thermal insulation box 12. At an upper part of the right side portion of the thermal insulation box 12, an outlet 12b is formed to take the yarns Y out from the thermal insulation box 12. The yarns Y are wound onto each of the godet rollers 21 to 25, in order from the lowermost godet roller 21, at a winding angle smaller than 360 degrees.

[0040] The lower three godet rollers 21 to 23 are preheating rollers configured to preliminarily heat the yarns Y before drawing them. The surface temperatures of the godet rollers 21 to 23 are arranged to be equal to or higher than the glass transition temperature of the yarns Y (e.g., on the order of 90 to 100 degrees centigrade). The upper two godet rollers 24 and 25 are conditioning rollers used for thermally setting the drawn yarns Y. The surface temperatures of the godet rollers 24 and 25 are arranged to be higher than the roller surface temperatures of the godet rollers 21 to 23 (e.g., on the order of 150 to 200 degrees centigrade). The yarn feeding speeds of the godet rollers 24 and 25 are arranged to be higher than the yarn feeding speeds of the godet rollers 21 to 23.

[0041] The yarns Y introduced into the thermal insulation box 12 through the inlet 12a are preliminarily heated to a drawable temperature while being transferred by the godet rollers 21 to 23. The preliminarily-heated yarns Y are drawn on account of a difference of the yarn feeding speed between the godet roller 23 and the godet roller 24. The yarns Y are further heated while being transferred by the godet rollers 24 and 25. As a result, the yarns Y are thermally set in the drawn state. The yarns Y having been drawn in this way go out from the thermal insulation box 12 through the outlet 12b.

[0042] The yarns Y drawn by the spun yarn drawing apparatus 3 are sent to the yarn winding apparatus 4 via the guide roller 13. The yarn winding apparatus 4 is an apparatus for winding the yarns Y. The yarn winding apparatus 4 is provided below the spun yarn drawing apparatus 3. The yarn winding apparatus 4 includes members such as a bobbin holder 14 and a contact roller 15. The bobbin holder 14 is cylindrical in shape and extends in the front-rear direction. The bobbin holder 14 is rotationally driven by an unillustrated motor. To the bobbin holder 14, bobbins B are attached to be lined up in the front-rear direction. The yarn winding apparatus 4 is configured to wind the yarns Y onto the bobbins B at the same time by rotating the bobbin holder 14, to produce packages P. The contact roller 15 is configured to come into contact with the surfaces of the packages P to adjust the shape of each package P by applying a predetermined contact pressure to each package P.

(Structure of Induction Heating Rollers)

[0043] The following will describe the structure of each of the induction heating rollers 20 which are used as the godet rollers 21 to 25, with reference to a cross section of FIG. 2 and a table of FIG. 3. FIG. 2 is a cross section of each induction heating roller 20, which is taken along an axial center of the induction heating roller 20. As shown in FIG. 2, a roller unit 30 (described later) of the induction heating roller 20 is cantilevered by a motor 100 which rotationally drives the roller unit 30. A direction in which the roller unit 30 extends (i.e., a left-right direction on the sheet of FIG. 2) is hereinafter referred to as an axial direction of the roller unit 30. Hereinafter, the axial direction of the roller unit 30 is simply referred to as the axial direction. A side closer to the motor 100 (i.e., a right side on the sheet of FIG. 2) in the axial direction is referred to as a base end side (the other side in the present invention). A side opposite to the motor 100 (i.e., a left side on the sheet of FIG. 2) in the axial direction is referred to as a leading end side (one side in the present invention). Hereinafter, a radial direction (i.e., an up-down direction on the sheet of FIG. 2) of the roller unit 30 is simply referred to as the radial direction. Hereinafter, a circumferential direction (i.e., a direction orthogonal to both the axial direction and the radial direction) of the roller unit 30 is simply referred to as the circumferential direction.

[0044] As shown in FIG. 2, the induction heating roller 20 includes the rotatable roller unit 30 and a fixed portion 50 which does not rotate. The induction heating roller 20 is configured to raise the temperature on an outer circumferential surface (outer circumferential surface 31a of a later-described roller main body 31) of the roller unit 30 by induction heating with use of a later-described coil 52 provided in the fixed portion 50. Because of this, the induction heating roller 20 heats the yarns Y wound onto the outer circumferential surface 31a. The roller unit 30 is rotationally driven by the motor 100. The fixed portion 50 is fixed to, e.g., an unillustrated supporting portion attached to the motor 100.

[0045] The roller unit 30 includes a roller main body 31 and a heat equalizing member 32 (heat equalizing unit of the present invention). The roller main body 31 is a substantially cylindrical member. The roller main body 31 is rotationally driven by the motor 100. The heat equalizing member 32 is configured to equalize the temperature of the roller main body 31 in the axial direction. The roller main body 31 and the heat equalizing member 32 are fixed to each other via, e.g., a fixing ring 33 provided on a base end portion of the roller unit 30 in the axial direction.

[0046] The roller main body 31 is made of, e.g., carbon steel which is a magnetic body (ferromagnetic material) and a conductor. The relative permeability of carbon steel is 100 to 2000 (see FIG. 3). The roller main body 31 further includes an outer cylindrical portion 34 (cylindrical portion of the present invention), an a core portion 35, and a circular plate portion 36. The outer cylindrical portion 34 is a substantially cylindrical portion provided at the outermost part of the roller main body 31 in the radial direction. The outer cylindrical portion 34 is provided so as to extend along the axial direction. The axial direction, radial direction, and circumferential direction of the outer cylindrical portion 34 are substantially identical to the axial direction, radial direction, and circumferential direction of the roller unit 30, respectively. The core portion 35 is a substantially cylindrical portion provided radially inside the coil 52. The circular plate portion 36 is a substantially disc-shaped portion connecting a leading end portion of the outer cylindrical portion 34 and a leading end portion of the core portion 35. In other words, the circular plate portion 36 is a portion extending radially inward from the leading end portion of the outer cylindrical portion 34 in the axial direction. The roller main body 31 has an open end on the base end side in the axial direction.

[0047] In the present embodiment, the outer cylindrical portion 34, the core portion 35, and the circular plate portion 36 are unitarily formed as a single member. However, the disclosure is not limited to this. For example, the following configuration is possible: the outer cylindrical portion 34 is formed by one first component (not illustrated); and the core portion 35 and the circular plate portion 36 are formed by one second component (not illustrated). In this case, the first component and the second component are fixed to each other by, e.g., welding or are fixed to each other by a fixing member such as screws or the like.

[0048] For example, a coating layer (not illustrated) which is 0.05 mm in thickness is formed radially outside an outer circumferential surface 34a of the outer cylindrical portion 34. A surface of this coating layer is the outer circumferential surface 31a (roller surface) of the roller main body 31. Onto the outer circumferential surface 31a, the yarns Y are wound as heating targets so as to be aligned in the axial direction. (In other words, the yarns Y are wound around the outer cylindrical portion 34.) The coating layer is not necessarily provided. (In this case, the outer circumferential surface 34a of the outer cylindrical portion 34 is an outer circumferential surface of the roller main body 31.) The length of the outer circumferential surface 31a in the axial direction is, e.g., 150 mm. An inner circumferential surface 34b of the outer cylindrical portion 34 is in contact with the heat equalizing member 32. The core portion 35 has a shaft inserting hole 35a in which a drive shaft 101 of the motor 100 is inserted. The drive shaft 101 is fitted in the shaft inserting hole 35a. Because of this, the roller main body 31 is fixed to the drive shaft 101 and is integrally rotatable with the drive shaft 101. The roller main body 31 is cantilevered by the drive shaft 101. A heat generating member 60 (described later) is in contact with a surface (base end surface 36a) of the circular plate portion 36 on the base end side in the axial direction. In addition to that, a heat insulating material (not illustrated) which is substantially disc-shaped is attached to a surface (leading end surface 36b) of the circular plate portion 36 on the leading end side in the axial direction. The heat insulating material is exposed to the outside air (air in the thermal insulation box 12).

[0049] The heat equalizing member 32 is a member used to equalize, by transferring heat in the axial direction, the distribution of a surface temperature (i.e., temperature of the outer circumferential surface 31a) of the roller main body 31 in the axial direction. The axial direction, radial direction, and circumferential direction of the heat equalizing member 32 are substantially identical to the axial direction, radial direction, and circumferential direction of the roller unit 30, respectively. The heat equalizing member 32 is provided radially inside the outer cylindrical portion 34. The heat equalizing member 32 is provided radially outside the coil 52. The heat equalizing member 32 is pressed by the press portion 42 toward the leading end side in the axial direction (the details thereof will be described later). Because of this, the heat equalizing member 32 and the later-described heat generating member 60 are fixed to the roller main body 31.

[0050] The heat equalizing member 32 is a cylindrical member extending in the axial direction. The heat equalizing member 32 is made of, e.g., a C/C composite (carbon fiber reinforced-carbon matrix-composite) which is a composite material of carbon fibers and graphite. A C/C composite is a non-magnetic material. In the present embodiment, carbon fibers in a C/C composite are oriented in the axial direction. In other words, a material forming the heat equalizing member 32 is anisotropic in heat conductivity and in electric resistivity in the present embodiment, as described later. The heat conductivity of a C/C composite in the axial direction is higher than the heat conductivity of a material forming the roller main body 31 (i.e., higher than at least the heat conductivity of the inner circumferential surface 34b of the outer cylindrical portion 34). In other words, the heat equalizing member 32 transfers heat in the axial direction more easily than the outer cylindrical portion 34 does. For example, the heat conductivity of a carbon steel forming the roller main body 31 is 51.5 W/mk (see FIG. 3). Meanwhile, the heat conductivity in the axial direction of a C/C composite forming the heat equalizing member 32 is 404 W/mk (see FIG. 3). The heat conductivity in the axial direction of a material forming the heat equalizing member 32 is higher than the heat conductivity (15.2 W/mk; see FIG. 3) in the circumferential direction of the material forming the heat equalizing member 32. The heat equalizing member 32 is configured to equalize the temperature of the outer circumferential surface 31a of the roller main body 31 by transferring heat in the axial direction by means of heat conduction. In this regard, carbon fibers in a C/C composite are not necessarily oriented in the axial direction. Alternatively, the heat equalizing member 32 may be formed by a C/C composite in which carbon fibers are randomly oriented.

[0051] The heat equalizing member 32 is formed by a plurality of heat equalization pieces 41 in the circumferential direction. An outside surface (outer surface 41a) of each heat equalization piece 41 in the radial direction is in contact with the inner circumferential surface 34b of the outer cylindrical portion 34. Assume that an area extending in the axial direction, onto which the yarns Y are wound, of the outer circumferential surface 31a of the roller main body 31 is a wound region R. In this case, each heat equalization piece 41 is provided within a range which is roughly identical to the wound region R in the axial direction. An inside surface (inner surface 41b) of each heat equalization piece 41 in the radial direction opposes the coil 52 in the radial direction. A surface (base end surface 41c) of each heat equalization piece 41 on the base end side in the axial direction is tapered. To be more specific, the base end surface 41c is arranged so that its radially outer edge is on the base end side with respect to its radially inner edge, in the axial direction. In the axial direction, a gap is formed between a surface (leading end surface 41d) of each heat equalization piece 41 on the leading end side in the axial direction and the base end surface 36a of the circular plate portion 36. Within the gap, the later-described heat generating member 60 is provided.

[0052] Each heat equalization piece 41 is pressed by the press portion 42 toward the leading end side in the axial direction and radially outward. The press portion 42 includes a pressing member 43 and springs 44. For example, the pressing member 43 is a member which is substantially ring-shaped and which is made of carbon steel in the same manner as the roller main body 31. An outer circumferential surface of the pressing member 43 is provided at the substantially same position as, e.g., an outer surface 41a of each heat equalization piece 41 in the radial direction. An inner circumferential surface of the pressing member 43 is provided radially inside, e.g., an inner surface 41b of the heat equalization piece 41. A surface (leading end surface 43a) of the pressing member 43 on the leading end side in the axial direction is a tapered pressing surface. To be more specific, a leading end surface 43a is arranged so that its radially inner edge is on the leading end side with respect to its radially outer edge, in the axial direction. Because of this, the leading end surface 43a is in tight contact with the above-described base end surface 41c of the heat equalization piece 41.

[0053] Each of the springs 44 is provided between the pressing member 43 and the fixing ring 33 in the axial direction. A base end portion of the spring 44 is in contact with the fixing ring 33. A leading end portion of the spring 44 is in contact with the pressing member 43. The spring 44 is compressed by the fixing ring 33 and the pressing member 43 in the axial direction. Because of this, the spring 44 biases, with its elastic restoring force, the pressing member 43 toward the leading end side in the axial direction. The pressing member 43 is biased by the spring 44 so that the heat equalizing member 32 is pressed toward the leading end side in the axial direction. At this stage, each heat equalization piece 41 of the heat equalizing member 32 is pressed also radially outward by the tapered leading end surface 43a of the pressing member 43. Because of this, each heat equalization piece 41 is reliably brought into contact with the outer cylindrical portion 34. Therefore, when the amount of thermal expansion is different between the outer cylindrical portion 34 and the heat equalizing member 32, it is possible to prevent a gap from being formed between the outer cylindrical portion 34 and the heat equalizing member 32. It should be noted that the number of springs 44 is not particularly limited. Instead of the one or more springs 44, for example, a rubber elastic member may be used as a biasing member biasing the pressing member 43.

[0054] The fixing ring 33 is, e.g., a member which is substantially ring-shaped and which is made of carbon steel as same as the roller main body 31. The fixing ring 33 is fixed to a base end portion of the outer cylindrical portion 34 of the roller main body 31 in the axial direction by, e.g., unillustrated screws. The fixing ring 33 is provided so as to compress each spring 44 provided between the fixing ring 33 and the pressing member 43 in the axial direction. Because of this, the roller main body 31 and the heat equalizing member 32 are fixed to each other via the fixing ring 33, etc., as described above.

[0055] The following describes the fixed portion 50. As shown in FIG. 2, the fixed portion 50 includes a bobbin member 51, the coil 52, and a flange 53. Around the bobbin member 51 extending in the axial direction, the coil 52 is wound along the axial direction of the fixed portion 50. A base end portion of the bobbin member 51 in the axial direction is attached to the flange 53.

[0056] The bobbin member 51 is, e.g., a substantially cylindrical member made of carbon steel in the same manner as the roller main body 31. The bobbin member 51 extends along the axial direction of the roller unit 30. The circumferential direction of the bobbin member 51 is substantially identical to the circumferential direction of the roller unit 30. The bobbin member 51 is provided radially inside the outer cylindrical portion 34 of the roller main body 31. The bobbin member 51 is provided radially outside the core portion 35 of the roller main body 31. The coil 52 is wound around an outer circumference of the bobbin member 51 along the axial direction.

[0057] The coil 52 is provided for heating at least both of the outer cylindrical portion 34 and the later-described heat generating member 60 (heat generating unit of the present invention), by means of induction heating. The coil 52 is wound around the outer circumference of the bobbin member 51. The coil 52 wound around the outer circumference of the bobbin member 51 extends (see FIG. 2) along the extending direction of the bobbin member 51. In other words, the longitudinal direction in which the coil 52 extends is substantially identical to the axial direction of the roller unit 30. The coil 52 is provided radially inside the outer cylindrical portion 34 of the roller main body 31. The coil 52 is provided radially outside the core portion 35 of the roller main body 31. As an alternating voltage is applied to the coil 52 by, e.g., an unillustrated AC power source, an alternating current flows through the coil 52 so as to generate an alternating magnetic field. In this regard, the AC power source is, for example, a typical commercial power source (with a commercial power source of 50 or 60 Hz). However, the disclosure is not limited to this.

[0058] The flange 53 is, e.g., a member which is substantially disc-shaped and which is made of carbon steel as same as the roller main body 31. The flange 53 is provided at a base end portion of the fixed portion 50 in the axial direction. The flange 53 has, at its radially central portion, a through hole 53a so that the flange 53 and the drive shaft 101 of the motor 100 do not interfere with each other. A base end portion of the bobbin member 51 in the axial direction is attached to the flange 53. The flange 53 is fixed to an unillustrated supporting portion provided at the motor 100. The flange 53 is, for example, provided side by side with the fixing ring 33 in the axial direction. The flange 53 and the fixing ring 33 are provided to be separated from each other.

[0059] As an alternating voltage is applied to the coil 52 in each induction heating roller 20 structured as described above, an alternating current flows through the coil 52 so as to generate an alternating magnetic field. Because of this, magnetic flux passes (see a two-dot chain line arrow A in FIG. 2) the outer cylindrical portion 34 of the roller main body 31 in the axial direction. At this stage, an eddy current flows in the roller main body 31 in the circumferential direction, and heat is generated in the outer cylindrical portion 34 by Joule heating.

[0060] Generally, magnetic flux tends not to uniformly flow in the induction heating roller 20 in the axial direction because of leakage of magnetic flux. Therefore, heat in the outer cylindrical portion 34 tends not to be uniform in the axial direction. To be more specific, because an amount of magnetic flux passing through end portions in the axial direction of the outer cylindrical portion 34 is smaller than an amount of magnetic flux passing through a central portion in the axial direction of the outer cylindrical portion 34, heat tends not to be generated in the end portions (i.e., both end portions) in the axial direction of the outer cylindrical portion 34. In addition to that, heat tends to be radiated through the circular plate portion 36 at a leading end portion of the roller unit 30 in the axial direction. (It is difficult to completely eliminate heat radiation even though heat radiation is suppressed by the above-described heat insulating material.) Therefore, the leading end portion of the outer cylindrical portion 34 in the axial direction tends to be cooled by heat radiation. Because a temperature at a leading end portion of the outer circumferential surface 31a in the axial direction tends to be lower than a temperature at a central portion of the outer circumferential surface 31a in the axial direction because of the difficulty in heat generation and the easiness in heat radiation, a temperature of the outer circumferential surface 31a tends to be disadvantageously uneven in the axial direction.

[0061] In the present embodiment, because the heat generated in the outer cylindrical portion 34 is easily transmitted (transferred) by the heat equalizing member 32 in the axial direction, the temperature dispersion of the outer circumferential surface 31a is reduced in the axial direction as compared to cases where the heat equalizing member 32 is not provided. However, the present inventors have found that there is still a room for improvement in this structure. The roller unit 30 of the present embodiment is structured as follows in order to effectively reduce the temperature dispersion of the outer circumferential surface 31a (roller surface) in the axial direction.

(Roller Unit)

[0062] The roller unit 30 will be detailed with reference to FIG. 2 and FIG. 3. As shown in FIG. 2, the roller unit 30 further includes the heat generating member 60 provided on the leading end side of the heat equalizing member 32 in the axial direction. The heat generating member 60 is configured to heat, by being induction-heated, the leading end portion of the outer cylindrical portion 34 and its surroundings. In the present embodiment, the heat generating member 60 is independent from the roller main body 31 and the heat equalizing member 32.

[0063] The heat generating member 60 is a ring-shaped member which is electrically conductive. The word "ring-shaped" means that the member is formed across the entire heat generating member 60 in the circumferential direction. For example, the heat generating member 60 may be annular or rectangular in shape. Alternatively, the heat generating member 60 may be formed by a plurality of ring pieces (not illustrated), which are electrically conductive, in the circumferential direction and may be arranged so that each two adjacent ring pieces are in contact with each other in the circumferential direction. The circumferential direction of the heat generating member 60 is substantially identical to the circumferential direction of the outer cylindrical portion 34. The cross section (see FIG. 2) of the heat generating member 60 is, e.g., substantially rectangular in shape. In other words, the heat generating member 60 includes members such as an outer circumferential surface 60a provided on the outer side in the radial direction, an inner circumferential surface 60b provided on the inner side in the radial direction, a base end surface 60c provided on the base end side in the axial direction, and a leading end surface 60d provided on the leading end side in the axial direction.

[0064] A preferred material forming the heat generating member 60 is aluminum. In other words, at least in the circumferential direction, the electric resistivity of a material forming the heat generating member 60 is lower than the electric resistivity of a material forming the roller main body 31 and the electric resistivity of a material forming the heat equalizing member 32. To be more specific, the electric resistivity of aluminum which is a material forming the heat generating member 60 is 3.0 $\mu\Omega$ cm (see FIG. 3). The electric resistivity of carbon steel forming the roller main body 31 is 11.8 $\mu\Omega$ cm (see FIG. 3). The electric resistivity in the circumferential direction of a C/C composite forming the heat equalizing member 32 is higher than the electric resistivity of a material forming the roller main body 31 (i.e., outer cylindrical portion 34), and is 1.3×10^6 $\mu\Omega$ cm (see FIG. 3). The electric resistivity in the circumferential direction of a material forming the heat equalizing member 32 is higher than the electric resistivity (3.9×10^4 $\mu\Omega$ cm; see FIG. 3) in the axial direction of the material forming the heat equalizing member 32. The heat generating member 60 is preferably made of a non-magnetic material (i.e., a material which is not ferromagnetic) in order not to prevent magnetic flux from passing through the roller main body 31. Aluminum is a non-magnetic material (i.e., the relative permeability of aluminum is 1.0). This meets the above condition. The density of a material forming the heat generating member 60 is preferably low in order to avoid the increase in weight of the roller unit 30 as much as possible. In relation to this, the density of aluminum is 2.7 g/cm^3 (see FIG. 3). The density of carbon steel is 7.8 g/cm^3 (see FIG. 3). The density of a C/C composite is 1.7 g/cm^3 (see FIG. 3). In the present embodiment, the density of the heat generating member 60 (i.e., the density of a material forming the heat generating member 60) is therefore lower than at least the density of the roller main body 31 (i.e., the density of a material forming the roller main body 31).

[0065] When the heat generating member 60 is made of aluminum as in the present embodiment, the preferred thickness of the heat generating member 60 is, e.g., 2 mm in the axial direction. However, the thickness of the heat generating member 60 is not limited to this.

[0066] The following describes the arrangement of the heat generating member 60. The heat generating member 60 is provided at a position provided at an end portion of the outer cylindrical portion 34 on the leading end side in the axial direction. In the present embodiment, "a position provided at an end portion of the outer cylindrical portion 34 on the leading end side" indicates a position between the base end surface 36a of the circular plate portion 36 and the leading end (i.e., leading end surface 41d of each heat equalization piece 41) of the heat equalizing member 32 in the axial direction. The heat generating member 60 is provided on the inner side in the radial direction of the outer cylindrical portion 34 and on the base end side of the circular plate portion 36 in the axial direction. The heat generating member 60 is provided on the leading end side of the heat equalizing member 32 in the axial direction. The heat generating member 60 is provided to be adjacent to the heat equalizing member 32 in the axial direction. The base end surface 60c of the heat generating member 60 is in contact with a leading end surface 41d of the heat equalizing member 32. Because of this, heat is transmittable between the heat generating member 60 and the heat equalizing member 32 without requiring other members such as the roller main body 31. In other words, heat is directly transmittable between the heat generating member 60 and the heat equalizing member 32.

[0067] The leading end surface 60d of the heat generating member 60 is in contact with the base end surface 36a of the circular plate portion 36. Meanwhile, the heat generating member 60 is provided to be separated from the outer cylindrical portion 34 in the radial direction. In other words, the outer circumferential surface 60a of the heat generating member 60 is far from the inner circumferential surface 34b of the outer cylindrical portion 34. The inner circumferential surface 60b of the heat generating member 60 is provided to be substantially flush with the inner surface 41b of each heat equalization piece 41. However, the disclosure is not limited to this. In the present embodiment, the heat generating member 60 is provided at a position overlapping the wound region R at least in part in the axial direction. However, the disclosure is not limited to this.

[0068] The heat generating member 60 is pressed together with the heat equalizing member 32 by the above-described pressing member 43 and each spring 44, toward the leading end side in the axial direction. Because of this, the heat generating member 60 is fixed by being held between heat equalizing member 32 and the circular plate portion 36 of the roller main body 31 in the axial direction.

(Mechanism of Reducing Temperature Dispersion)

[0069] The temperature of the outer circumferential surface 31a is equalized as follows in each induction heating roller 20 structured as described above. Among magnetic flux which is generated due to a current flowing in the coil 52, most of magnetic flux passes through the roller main body 31 (see the arrow A in FIG. 2). Meanwhile, some of magnetic flux leaks from the roller main body 31 and passes through the heat generating member 60. Among the some of magnetic flux, a component passing through the heat generating member 60 in the axial direction generates induced electromotive force in the heat generating member 60 in the circumferential direction of the heat generating member 60. The induced electromotive force allows an eddy current to flow along the circumferential direction of the heat generating member 60, and heat is generated in the heat generating member 60 by Joule heating. As described above, the electric resistivity of a material forming the heat generating member 60 is lower than the electric resistivity of a material forming the roller main body 31. Therefore, because a large eddy current is likely to flow inside the heat generating member 60, a large amount of heat is generated from the heat generating member 60. As such, the heat generating member 60 is induction-heated so as to increase the amount of heat generated in the vicinity of the end portion of the outer cylindrical portion 34 in the axial direction. Because of this, the temperature in the vicinity of the end portion of the outer cylindrical portion 34 in the axial direction is likely to be increased.

[0070] In the present embodiment, the heat generated in the heat generating member 60 is directly transmitted to the heat equalizing member 32 in contact with the heat generating member 60. Because of this, the heat generated in the heat generating member 60 can be substantially uniformly transmitted to the outer cylindrical portion 34 in the axial direction by the heat equalizing member 32, and thus the heat can be substantially uniformly transmitted to the outer circumferential surface 31a of the roller main body 31. Therefore, a significant increase of the temperature only at the end portion of the outer circumferential surface 31a in the axial direction is suppressed. The heat generated in heat generating member 60 is not directly transmitted to the outer cylindrical portion 34, but indirectly transmitted to the outer cylindrical portion 34 via the heat equalizing member 32. Therefore, the significant increase of the temperature only at the end portion of the outer circumferential surface 31a in the axial direction is further effectively suppressed as compared to cases where the heat generated in the heat generating member 60 is directly transmitted to the outer cylindrical portion 34. The mechanism described above reduces the temperature dispersion of the outer circumferential surface 31a in the axial direction.

(Results of Testing Effect of Reducing Temperature Dispersion)

[0071] The following will specifically describe test results regarding the effect of reducing the temperature dispersion by the heat generating member 60, with reference to a graph of FIG. 4. The present inventors measured the temperature distribution on the outer circumferential surface 31a of the roller main body 31 in the axial direction in a case (Example) where the heat generating member 60 was provided in the roller unit 30 and in a case (Comparative Example) where the heat generating member 60 was not provided in the roller unit 30, and compared these two cases in terms of the temperature distribution. In both cases, the temperature of the outer circumferential surface 31a was set to 200 degrees centigrade.

[0072] The result of the comparison is shown in FIG. 4. The horizontal axis in the graph represents the distance of a point on the outer circumferential surface 31a from a leading end of the roller main body 31. That is, the smaller the distance is, the closer the point is to the leading end of the roller main body 31 in the axial direction. The larger the distance is, the closer the point is to a base end of the roller main body 31 in the axial direction. As described above, the length of the outer circumferential surface 31a in the axial direction is 150 mm. The wound region R onto which the yarns Y are wound is, e.g., an area within a range of 16 to 140 mm from the leading end of the roller main body 31 in the axial direction toward the base end of the roller main body 31 in the axial direction. The vertical axis in the graph represents the difference between the temperature of the outer circumferential surface 31a and the set temperature (200 degrees centigrade). In Comparative Example (see blank circles in FIG. 4), the temperature at a part far from the central portion of the outer circumferential surface 31a in the axial direction is significantly lowered. Especially, the temperature of the outer circumferential surface 31a was lower than the set temperature by about 5 degrees centigrade at the leading end (i.e., position which was on the base end side in the axial direction and which was away from the leading end of the roller main body 31 by 16 mm) of the wound region R in the axial direction. Meanwhile, in Example (see solid circles in FIG. 4), the difference between the temperature at the leading end portion of the wound region R in the axial direction and the set temperature was decreased to about 1.5 degrees centigrade. Therefore, it was verified that the heat equalizing member 32 and the heat generating member 60 reduced the temperature dispersion of the outer circumferential surface 31a in the axial direction in the induction heating roller 20.

[0073] As described above, the heat generating member 60 in which the electric resistivity is low is induction-heated so as to increase the amount of heat generated in the vicinity of the end portion of the outer cylindrical portion 34 in the axial direction. This makes it easy to increase the temperature in the vicinity of the end portion of the outer cylindrical portion 34 in the axial direction. Furthermore, the heat generated in the heat generating member 60 is directly transmitted to the heat equalizing member 32. Because of this, this heat can be substantially uniformly transmitted to the outer cylindrical portion 34 in the axial direction by the heat equalizing member 32, with the result that the heat can be substantially uniformly transmitted to the outer circumferential surface 31a of the roller main body 31. Therefore, it is possible to suppress the significant increase of the temperature only at the end portion of the outer circumferential surface 31a of the roller main body 31 in the axial direction. As such, it is possible to effectively suppress the temperature dispersion of the outer cylindrical portion 34 in the axial direction and the temperature dispersion of the outer circumferential surface 31a in the induction heating roller 20.

[0074] The ring-shaped heat generating member 60 can be easily manufactured with low cost, and is independent from the roller main body 31 and the heat equalizing member 32. It is therefore possible to save the labor and cost for manufacturing the heat generating member 60 as compared to cases where the heat generating member 60 is integrally formed with the roller main body 31 or heat equalizing member 32.

[0075] The heat equalizing member 32 in which the heat conductivity is high is simply provided as a heat equalizing unit configured to transfer heat in the axial direction. Therefore, the structure of the roller unit 30 is simplified as compared to a structure in which, e.g., a jacket chamber (described later) is provided as the heat equalizing unit.

[0076] In the present embodiment, the heat equalizing member 32 is provided radially inside the outer cylindrical portion 34, and the heat generating member 60 is adjacent to the heat equalizing member 32 in the axial direction. The heat generating member 60 is therefore provided in the vicinity of the outer cylindrical portion 34 in the radial direction as compared to cases where, for example, the heat generating member 60 is provided radially inside the heat equalizing member 32. It is therefore possible to suppress the deterioration of the heating efficiency of the outer cylindrical portion 34.

[0077] In the present embodiment, the heat generated in the heat generating member 60 is directly transmittable to the heat equalizing member 32. Because of this, it is possible to suppress the significant increase of the temperature only at the end portion of the outer circumferential surface 31a in the axial direction. Therefore, the temperature of the outer cylindrical portion 34 is effectively equalized in the axial direction, with the result that the temperature dispersion of the outer circumferential surface 31a of the roller main body 31 is reduced.

[0078] In the present embodiment, the heat generated in the heat generating member 60 is not directly transmitted to the outer cylindrical portion 34 but is indirectly transmitted to the outer cylindrical portion 34 via the heat equalizing member 32. Therefore, the significant increase of the temperature only at the end portion of the outer cylindrical portion 34 in the axial direction is further reliably suppressed as compared to cases where the heat generated in the heat generating member 60 is directly transmitted to the outer cylindrical portion 34.

[0079] In the present embodiment, when the roller main body 31, the heat equalizing member 32, and the heat generating member 60 are provided to be independent from each other, both of the heat equalizing member 32 and the heat generating member 60 are pressed by one press portion 42 toward the leading end side (the circular plate portion 36 side) in the axial direction. Because of this, it is possible to fix the heat equalizing member 32 and the heat generating member 60 to the roller main body 31 by holding them between the press portion 42 and the circular plate portion 36 in the axial direction. Therefore, the heat generating member 60 is fixed to the roller main body 31 with a simple structure as compared to cases where the heat generating member 60 is provided at a different location from the heat equalizing member 32 in the radial direction.

[0080] In the present embodiment, the end surface (leading end surface 36b) of the roller main body 31 in the axial direction is exposed to the outside air in the induction heating roller 20 in which the roller main body 31 is cantilevered. Because of this, the amount of heat radiated from the leading end portion of the roller main body 31 in the axial direction is large, with the result that the temperature at the leading end portion of the outer cylindrical portion 34 in the axial direction tends to be especially decreased. In this regard, because heat is generated in the vicinity of the leading end portion of the outer cylindrical portion 34 in the axial direction by the heat generating member 60 in the present embodiment, the decrease of the temperature at the leading end portion of the outer cylindrical portion 34 in the axial direction is effectively suppressed. Therefore, the temperature dispersion of the outer cylindrical portion 34 is effectively reduced, with the result that the temperature dispersion of the outer circumferential surface 31a of the roller main body 31 is reduced.

[0081] The heat generating member 60 is made of a non-magnetic material. It is therefore possible to avoid an unintended flow of magnetic flux.

[0082] The density of the heat generating member 60 (i.e., the density of aluminum which is a material forming the heat generating member 60) is lower than at least the density of the outer cylindrical portion 34 (i.e., the density of carbon steel which is a material forming the outer cylindrical portion 34). It is therefore possible to suppress the increase in the weight of the induction heating roller 20 due to provision of the heat generating member 60.

[0083] When an eddy current tends to flow in the heat equalizing member 32 rather than in the outer cylindrical portion 34 in the circumferential direction, the following problems may occur. Firstly, when heat is generated in the heat equalizing member 32 provided to be more or less far from the outer cylindrical portion 34 which is the target to be heated, the heat may diffuse not only into the outer cylindrical portion 34 but also into other members and/or space. The heat diffused in this way may not be transmitted to the outer cylindrical portion 34 in a uniform manner. Secondly, because the heat equalizing member 32 is shorter than the outer cylindrical portion 34 in the axial direction, the distribution of heat generated by the heat equalizing member 32 is uneven for the outer cylindrical portion 34 in the axial direction. Because of these problems, the temperature dispersion of the outer cylindrical portion 34 in the axial direction may be increased. In the present embodiment, in the axial direction, the heat conductivity of a material forming the heat equalizing member 32 is higher than the heat conductivity of a material forming the outer cylindrical portion 34. In addition to that, in the circumferential direction, the electric resistivity of a material forming the heat equalizing member 32 is higher than the electric resistivity of a material forming the outer cylindrical portion 34. It is therefore possible to facilitate transfer of heat in the axial direction by the heat equalizing member 32, and to suppress the flow of an eddy current in the heat equalizing member 32 in the circumferential direction so as to suppress an unnecessary heat generation by the heat equalizing member 32. Because of this, it is possible to suppress the increase in the temperature dispersion of the outer cylindrical portion 34 due to the generation of heat from the heat equalizing member 32.

[0084] In the spun yarn drawing apparatus 3 of the present embodiment, the yarns Y are wound onto the outer cylindrical portion 34 in which the temperature dispersion is reduced in the axial direction. Therefore, dispersion of quality is reduced between the yarns Y heated by each induction heating roller 20.

[0085] The following will describe modifications of the above-described embodiment. The members identical with those in the embodiment above will be denoted by the same reference numerals and the explanations thereof are not repeated.

(1) In the embodiment above, the heat equalizing member 32 is made of a C/C composite in which carbon fibers are oriented in the axial direction, and the heat generating member 60 is made of aluminum. However, the disclosure is not limited to this. In addition to that, a material forming the heat equalizing member 32 is anisotropic in heat conductivity (i.e., heat conductivity in the axial direction is different from heat conductivity in circumferential direction) and in electric resistivity (i.e., electric resistivity in axial direction is different from electric resistivity in the circumferential direction). However, the disclosure is not limited to this. For example, as shown in FIG. 5(a), the heat equalizing member 32 may be made of a C/C composite in which carbon fibers are randomly oriented. The heat generating member 60 may be made of zinc. To be more specific, the electric resistivity of a C/C composite in which carbon fibers are randomly oriented is 1.3×10^3 $\mu\Omega$ cm. The electric resistivity of zinc is 6.0 $\mu\Omega$ cm. In this modification, the density of zinc forming the heat generating member 60 is 7.1 g/cm^3 and is lower than the density (7.8 g/cm^3) of carbon steel forming the roller main body 31.

(2) While in the embodiment above the density of a material forming the heat generating member 60 is lower than the density of a material forming the roller main body 31, the disclosure is not limited to this. For example, as shown in FIG. 5(b), the heat equalizing member 32 may be formed of aluminum (a metal material) and the heat generating member 60 may be formed of copper the electric resistivity (1.9 $\mu\Omega$ cm) of which is lower than the electric resistivity (3.0 $\mu\Omega$ cm) of aluminum. In this case, the density of copper forming the heat generating member 60 is 8.9 g/cm^3 and is higher than the density (7.8 g/cm^3) of carbon steel forming the roller main body 31. As described above, the heat equalizing member 32 may not be necessarily made of a C/C composite. The heat conductivity in the axial direction of a material forming the heat equalizing member 32 may be higher than at least the heat conductivity in the axial direction of a material forming the roller main body 31. To be more specific, the heat conductivity of aluminum is 222 W/mk and is higher than the heat conductivity (51.5 W/mk) of carbon steel. When the heat equalizing member 32 is made of a metal material, the heat equalizing member 32 may not be necessarily formed by a plurality of the heat equalization pieces 41 (i.e., may be constituted by, e.g., one mem-

ber which is substantially cylindrical).

The combination of materials which respectively form the roller main body 31, the heat equalizing member 32, and the heat generating member 60 is not limited to the combination described above. The heat generating member 60 may be made of a material which is lower in electric resistivity than at least both of a material forming the roller main body 31 and a material forming the heat equalizing member 32. For example, the heat generating member 60 may be made of brass, gold, or silver. When the heat generating member 60 is formed by a plurality of ring pieces, a plurality of the ring pieces may not be made of the same material in type. In other words, a plurality of the ring pieces may be made of different materials. In the circumferential direction, the electric resistivity of a material forming the heat equalizing member 32 may not be necessarily higher than the electric resistivity of a material forming the roller main body 31 (outer cylindrical portion 34).

(3) While in the embodiment above the heat generating member 60 is made of a non-magnetic material, the disclosure is not limited to this. When the heat generating member 60 is made of a ferromagnetic material, the leading end portion of the outer cylindrical portion 34 in the axial direction may be heated by the heat generating member 60 without obstructing the passing of magnetic flux through the leading end portion of the outer cylindrical portion 34 in the axial direction as much as possible in such a way that the size and arrangement of the heat generating member 60 are suitably changed.

(4) The roller main body 31 may be made of a ferromagnetic material (e.g., cobalt or nickel) other than carbon steel. Alternatively, the roller main body 31 may not be necessarily made of a ferromagnetic material.

(5) While in the embodiment above the heat generating member 60, etc., is in contact with the base end surface 36a of the circular plate portion 36, the disclosure is not limited to this. In the axial direction, for example, an unillustrated spacer may be provided between the heat generating member 60 and the circular plate portion 36.

(6) While in the embodiment above the heat generating member 60 is provided to be separated from the outer cylindrical portion 34 in the radial direction, the disclosure is not limited to this. For example, as shown in FIG. 6(a), an outer circumferential surface 61a of a heat generating member 61 may be in contact with the inner circumferential surface 34b of the outer cylindrical portion 34. Because of this, heat may be directly transmittable between the heat generating member 61 and the outer cylindrical portion 34. This structure is achieved by preheating and expanding the roller main body 31 in advance when the heat generating member 61 is fitted to the roller main body 31 in manufacturing (i.e., by shrink-fitting). In this structure, the outer cylindrical portion 34 is effectively heated by the heat generated in the heat generating member 61. Therefore, this structure is effective in cases where the amount of heat generated in the heat generating member 61 is small. Furthermore, in this structure, the heat generating member 61 may not be necessarily in contact with the heat equalizing member 32. In other words, heat may not be necessarily directly transmittable between the heat generating member 61 and the heat equalizing member 32. For a specific example, as shown in FIG. 6(b), a ring member 62 may be provided between the heat generating member 61 and the heat equalizing member 32 in the axial direction. The heat conductivity of a material forming the ring member 62 may be lower than, e.g., the heat conductivity of a material forming the roller main body 31. In this case, the heat generated in the heat generating member 61 is transmitted to the outer cylindrical portion 34 at first, and then is transmitted to the heat equalizing member 32 via the outer cylindrical portion 34.

(7) While in the embodiment above the inner circumferential surface 60b of the heat generating member 60 is provided to be substantially flush with the inner surface 41a of each heat equalization piece 41, the disclosure is not limited to this. For example, as shown in FIG. 6(c), an inner surface 63b of a heat generating member 63 may be provided radially outside the inner surface 41b of each heat equalization piece 41. Alternatively, as shown in FIG. 6(d), an inner surface 64b of a heat generating member 64 may be provided radially inside the inner surface 41b.

Alternatively, as shown in FIG. 6(e), a heat generating member 65 which is L-shaped in cross section may be provided to be in contact with both of the leading end surface 41d and inner surface 41b of the heat equalization piece 41. In this case, "a position provided at an end portion of the outer cylindrical portion 34 on the leading end side" indicates, e.g., a position in an area within a range of up to 15 mm from the leading end surface 36b of the circular plate portion 36 toward the base end side in the axial direction. In other words, the heat generating member 65 is provided to be in an area within a range of up to 15 mm from the leading end surface 36b to the base end side in the axial direction. In this regard, it is further preferable that this area does not overlap the wound region R (see FIG. 2) in the axial direction. In this case, the structure of a part forming the wound region R in the roller unit 30 is substantially uniform in the axial direction.

(8) While in the embodiment above the heat generating member 60, etc., and the heat equalizing member 32 are aligned in the axial direction, the disclosure is not limited to this. For example, as shown in FIG. 6(f), a heat generating member 66 may be pro-

vided radially inside the heat equalization piece 41 and may be in contact with the inner surface 41b. In this case, the heat generating member 66 may be fixed to the circular plate portion 36 of the roller main body 31 by, e.g., an unillustrated screw. In this case, "a position provided at an end portion of the outer cylindrical portion 34 on the leading end side" indicates the same position as the above-described modification in (7).

(9) While in the embodiment above the coil 52 is provided radially inside the outer cylindrical portion 34, the disclosure is not limited to this. Instead of the coil 52, an unillustrated coil may be provided radially outside the outer cylindrical portion 34. In this case, the heat generating member 60 may be provided radially outside the outer cylindrical portion 34 so as to be adjacent to the outer cylindrical portion 34. In addition to that, at least a part of the heat generating member 60 in the axial direction may be provided on the leading end side in the axial direction as compared to the base end surface 36a of the circular plate portion 36.

(10) While in the embodiment above the heat generating member 60, etc., is provided at the end portion of the outer cylindrical portion 34 on the leading end side in the axial direction, the disclosure is not limited to this. The heat generating member 60, etc., may be provided at a position provided at the end portion of the outer cylindrical portion 34 on the base end side in the axial direction (e.g., the heat generating member 60, etc. may be provided in an area within a range of up to 10 mm from the base end side of the outer cylindrical portion 34 toward the leading end side of the outer cylindrical portion 34 in the axial direction) . In this regard, it is further preferable that this area does not overlap the wound region R (see FIG. 2) in the axial direction.

(11) While in the embodiment above the roller main body 31 is supported in a cantilever manner, the disclosure is not limited to this. That is, the induction heating roller 20 may include a roller main body (not illustrated) supported at its both ends. In addition to that, circular plate portions (not illustrated) each of which is identical to the above-described circular plate portion 36 may be provided at both end portions of this roller main body in the axial direction.

(12) While in the embodiment above the heat equalizing member 32 (heat equalizing unit) is provided to be independent from the roller main body 31 (i.e., to be detachable from each other), the disclosure is not limited to this. The following explanation is given with reference to FIG. 7. As shown in FIG. 7, a roller main body 71 of a roller unit 70 includes an outer cylindrical portion 74 instead of the above-described outer cylindrical portion 34 in an induction heating roller 20A. The roller unit 70 includes a heat equalizing unit 72 provided in the roller main body 71. The heat equalizing unit 72 is provided between an outer circumferential surface 74a of the outer cylindrical portion 74 and an inner circumferential surface 74b of the outer cylindrical portion 74 in the radial direction. To be more specific, the heat equalizing unit 72 includes a jacket chamber 75 formed inside the outer cylindrical portion 74. The jacket chamber 75 extends in the axial direction. In the jacket chamber 75, a gas-liquid two-phase heating medium (not illustrated) is enclosed. The heating unit 72 functions as a so-called heat pipe. To be more specific, the gas in the jacket chamber 75 moves at high-speed in the axial direction so that heat moves at high-speed in the axial direction. By the heat equalizing unit 72, heat may be transferred in the axial direction so as to equalize the temperature on an outer circumferential surface 71a of the roller main body 71. In this case, a heat generating member 67 may be in contact with the inner circumferential surface 74b of the outer cylindrical portion 74. In the present modification, a fixing ring 73 is provided instead of the fixing ring 33. However, the fixing ring 73 may not be necessarily provided to be independent from the roller main body 71. The fixing ring 73 may be integrally formed with the roller main body 71.

(13) While in the embodiment above, for example, the heat generating member 60 is provided to be independent from the roller main body 31 and the heat equalizing member 32, the disclosure is not limited to this. For example, a ring portion (not illustrated) which is lower in electric resistivity than the outer cylindrical portion 34 and which functions as a heat generating unit configured to be induction-heated may be pressure-welded (welded) to the leading end portion of the outer cylindrical portion 34 in the axial direction. The ring portion may be integrally formed with the outer cylindrical portion 34 in this way. In this structure, the ring portion pressure-welded to the outer cylindrical portion 34 is provided to be adjacent to the outer cylindrical portion 34. Because of this, heat may be transmittable between the ring portion and the outer cylindrical portion 34 directly (i.e., without requiring other members). The ring portion pressure-welded to the outer cylindrical portion 34 may be in contact with the heat equalizing member 32, or may be separated from the heat equalizing member 32. Alternatively, this ring portion may be pressure-welded to the heat equalizing member 32. The ring portion pressure-welded to the heat equalizing member 32 is provided to be adjacent to the heat equalizing member 32. Because of this, heat is directly transmittable between the ring portion and the heat equalizing member 32. The ring portion pressure-welded to the heat equalizing member 32 may be in contact with the outer cylindrical portion 34, or may be separated from the outer cylindrical portion 34.

(14) A heat generating unit such as the heat generating member 60 may be provided in an induction

heating roller (not illustrated) used for heating the heating targets (e.g., toner for a printer) other than the yarns Y.

Claims

1. An induction heating roller (20) comprising a rotatable roller unit (30) and a coil (52), the roller unit (30) including:

   a roller main body (31) which includes a cylindrical portion (34) extending in an axial direction of the roller unit (30) and in which the cylindrical portion (34) is induction-heated when a current flows in the coil (52);
   a heat equalizing unit (32) which is able to transfer heat generated in the cylindrical portion (34) in the axial direction and which more easily transfers heat in the axial direction than the cylindrical portion (34) does; and
   a heat generating unit (60) which is provided at an end portion of the cylindrical portion (34) in the axial direction and which is induction-heated when a current flows in the coil (52),
   the heat generating unit (60) being made of a material which is lower in electric resistivity than a material forming the cylindrical portion (34) and a material forming the heat equalizing unit (32), and being provided to be adjacent to at least one of the cylindrical portion (34) and the heat equalizing unit (32).

2. The induction heating roller (20) according to claim 1, wherein, the heat generating unit (60) includes a ring-shaped heat generating member (60) which is provided to be independent from the roller main body (31) and the heat equalizing unit (32) and which is in contact with at least one of the cylindrical portion (34) and the heat equalizing unit (32).

3. The induction heating roller (20) according to claim 1 or 2, wherein, the heat equalizing unit (32) includes a heat equalizing member (32) which is provided to be independent from the roller main body (31), which is in contact with an inner circumferential surface (34a) of the cylindrical portion (34), and which is higher in heat conductivity than the outer cylindrical portion (34) in the axial direction.

4. The induction heating roller (20) according to any one of claims 1 to 3, wherein, the heat equalizing unit (32) is provided inside the cylindrical portion (34) in a radial direction of the roller unit (30), and
   the heat generating unit (60) and the heat equalizing unit (32) are aligned in the axial direction.

5. The induction heating roller (20) according to any one of claims 1 to 4, wherein, the heat generating unit (60) is provided to be adjacent to the heat equalizing unit (32).

6. The induction heating roller (20) according to claim 5, wherein, the heat generating unit (60) is provided to be separated from the cylindrical portion (34).

7. The induction heating roller (20) according to any one of claims 1 to 5, wherein, the heat generating unit (60) is provided to be adjacent to the cylindrical portion (34).

8. The induction heating roller (20) according to any one of claims 1 to 7, wherein, the roller main body (31) further includes a circular plate portion (36) which extends inward in the radial direction of the roller unit (30) from an end of the cylindrical portion (34) on one side in the axial direction,
   the heat equalizing unit (32) includes the heat equalizing member (32) which is provided to be independent from the roller main body (31), which is in contact with the inner circumferential surface (34a) of the cylindrical portion (34), and which is higher in heat conductivity than the cylindrical portion (34) in the axial direction,
   the heat generating unit (60) further includes a ring-shaped heat generating member (60) which is provided to be independent from the roller main body (31) and the heat equalizing member (32) and which is provided to be adjacent to the heat equalizing member (32) in the axial direction, and
   a press portion (42) is provided on the other side in the axial direction of the heat equalizing member (32) and the heat generating member (60) to press the heat equalizing member (32) and the heat generating member (60) toward the one side in the axial direction.

9. The induction heating roller (20) according to any one of claims 1 to 8, wherein, the roller main body (31) is cantilevered, and
   the heat generating unit (60) is provided at an end portion of the cylindrical portion (34) on a leading end side in the axial direction.

10. The induction heating roller (20) according to any one of claims 1 to 9, wherein, the heat generating unit (60) is made of a non-magnetic material.

11. The induction heating roller (20) according to any one of claims 1 to 10, wherein, density of the heat generating unit (60) is lower than at least density of the cylindrical portion (34).

12. The induction heating roller (20) according to any one of claims 1 to 11, wherein, a material forming the heat equalizing unit (32) is higher in heat con-

ductivity than a material forming the cylindrical portion (34) in the axial direction, and
the material forming the heat equalizing unit (32) is higher in electric resistivity than the material forming the cylindrical portion (34) in a circumferential direction of the roller unit (30).

13. A spun yarn drawing apparatus (3) comprising the induction heating roller (20) according to any one of claims 1 to 12, wherein,
yarns (Y) are wound onto the cylindrical portion (34) as heating targets, so as to be aligned in the axial direction.

FIG.1

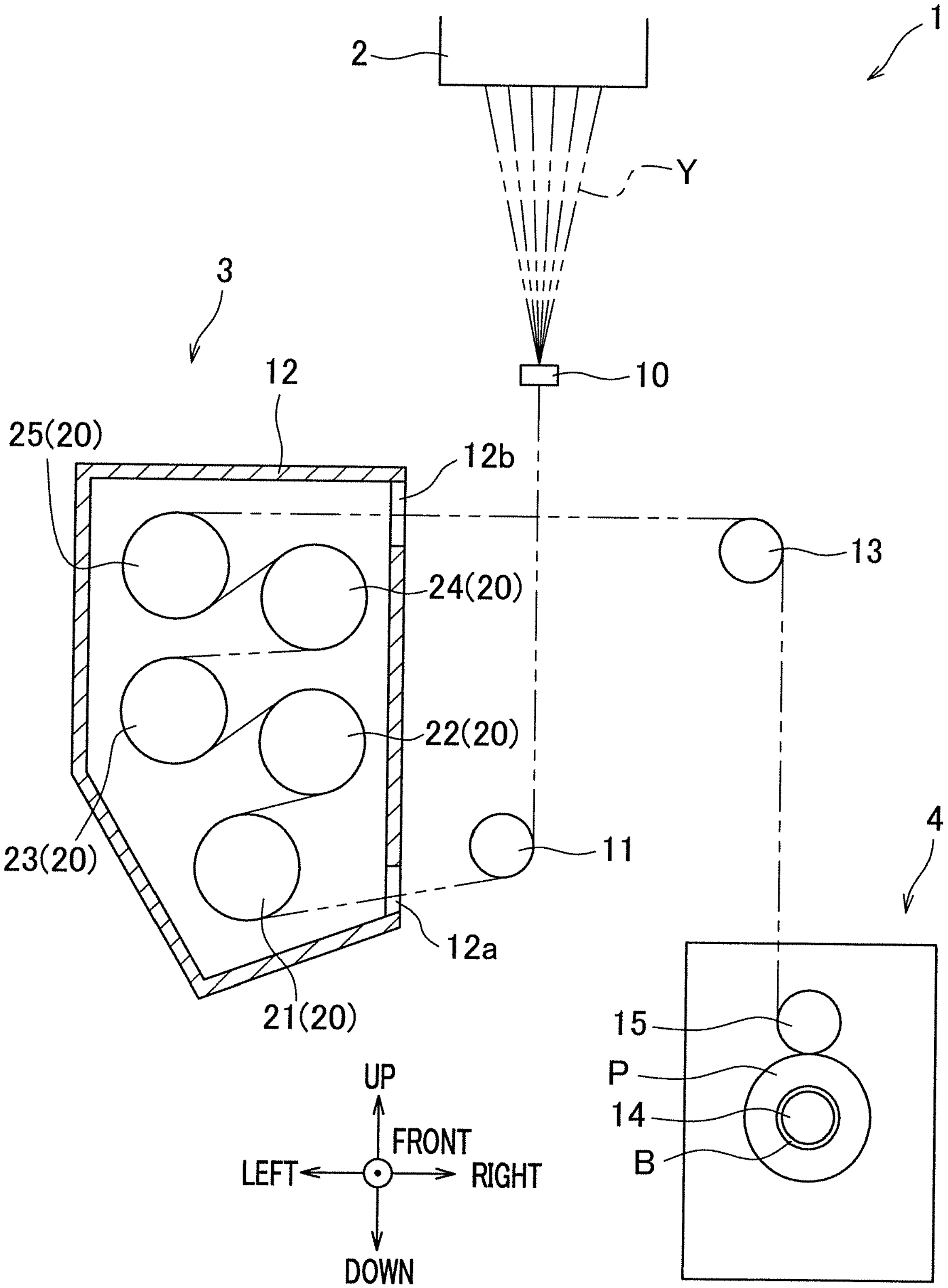

1
2
Y
3
12
10
25(20)
12b
13
24(20)
22(20)
23(20)
11
4
12a
21(20)
15
P
14
B
UP
FRONT
LEFT
RIGHT
DOWN

FIG.2

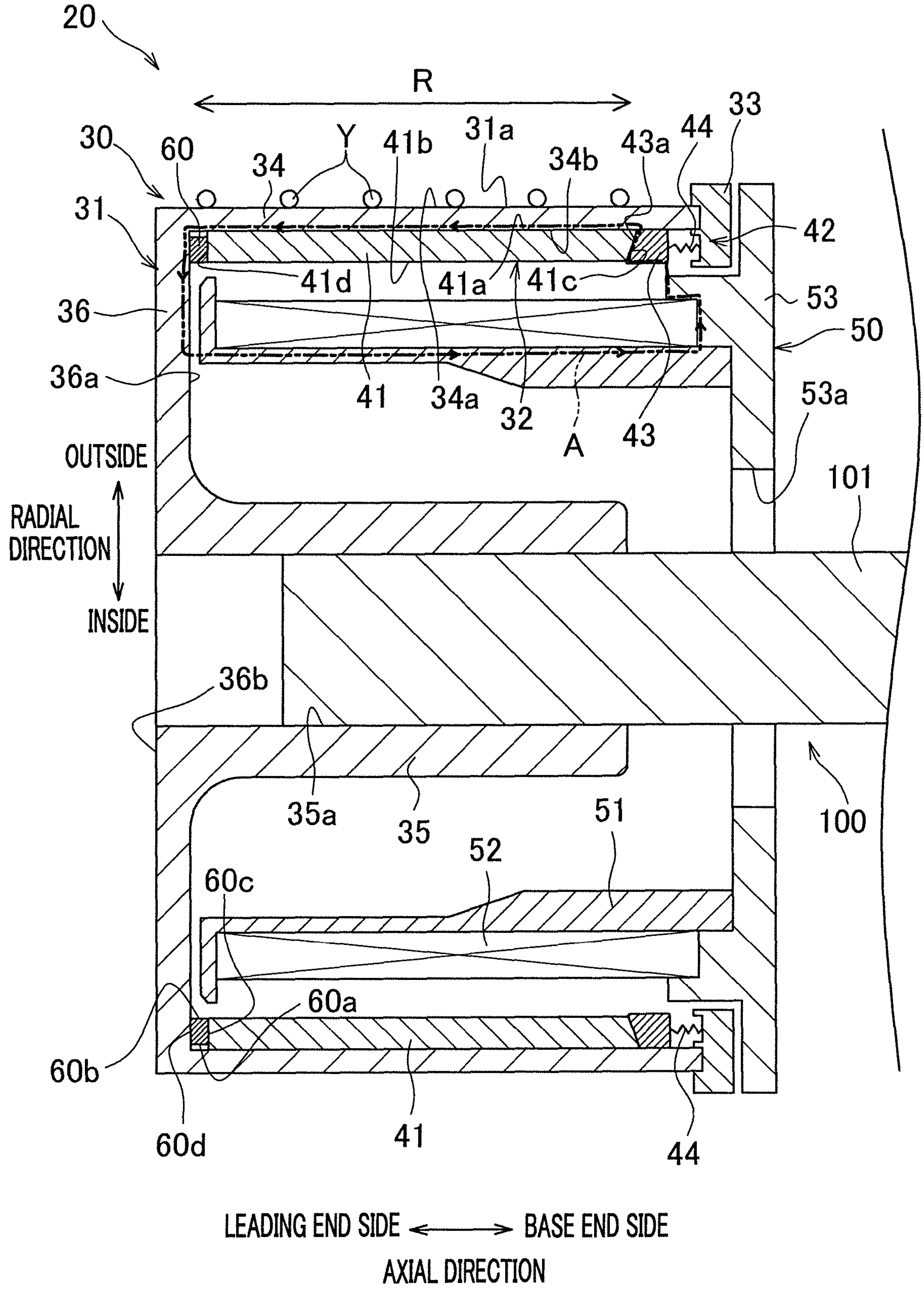

20
R
30
60
34
Y
41b
31a
34b
43a
44
33
31
42
41d
41a
41c
36
53
50
36a
41
34a
32
43
53a
A
OUTSIDE
RADIAL DIRECTION
INSIDE
101
36b
35a
35
51
100
52
60c
60a
60b
60d
41
44
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION

FIG.3

	MATERIAL		HEAT CONDUCTIVITY [W/(m·k)]	ELECTRIC RESISTIVITY [$\mu\Omega\cdot$cm]	RELATIVE PERMEABILITY [-]	DENSITY [g/cm^3]
ROLLER MAIN BODY (OUTER CYLINDRICAL PORTION)	CARBON STEEL		51.5	11.8	100～2000	7.8
HEAT EQUALIZING MEMBER	C/C COMPOSITE (ORIENTATION IN AXIAL DIRECTION)	AXIAL DIRECTION	404	3.9×10^4	1.0	1.7
		CIRCUMFERENTIAL DIRECTION	15.2	1.3×10^6	1.0	
HEAT GENERATING MEMBER	ALUMINUM		222	3.0	1.0	2.7

FIG.4

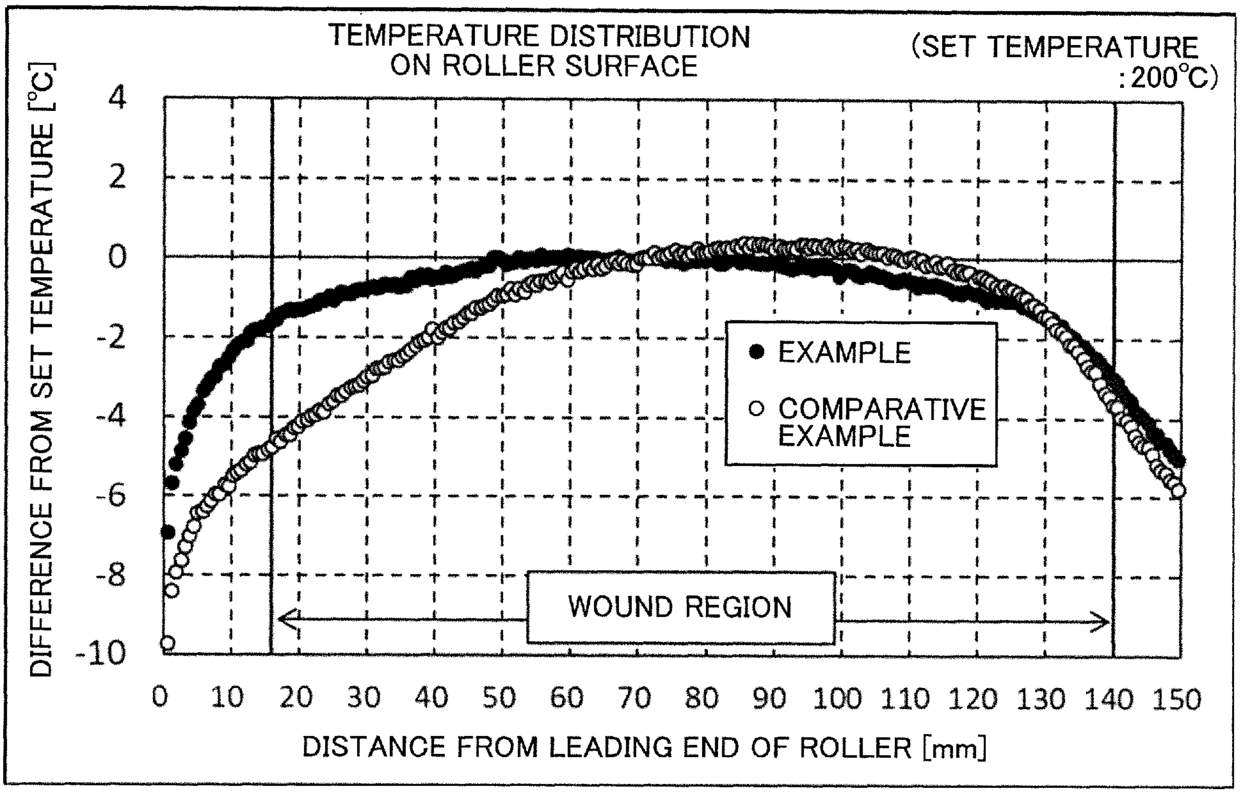

TEMPERATURE DISTRIBUTION
ON ROLLER SURFACE
(SET TEMPERATURE
: 200°C)
DIFFERENCE FROM SET TEMPERATURE [°C]
4
2
0
-2
-4
-6
-8
-10
● EXAMPLE
○ COMPARATIVE
EXAMPLE
WOUND REGION
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
DISTANCE FROM LEADING END OF ROLLER [mm]

FIG.5

(a)

	MATERIAL(EXAMPLE)	HEAT CONDUCTIVITY [W/(m·k)]	ELECTRIC RESISTIVITY [$\mu\Omega\cdot$cm]	RELATIVE PERMEABILITY [-]	DENSITY [g/cm^3]
ROLLER MAIN BODY (OUTER CYLINDRICAL PORTION)	CARBON STEEL	51.5	11.8	100～2000	7.8
HEAT EQUALIZING MEMBER	C/C COMPOSITE (RANDOM ORIENTATION)	120	1.3×10^3	1.0	1.6
HEAT GENERATING MEMBER	ZINC	113	6.0	1.0	7.1

(b)

	MATERIAL(EXAMPLE)	HEAT CONDUCTIVITY [W/(m·k)]	ELECTRIC RESISTIVITY [$\mu\Omega\cdot$cm]	RELATIVE PERMEABILITY [-]	DENSITY [g/cm^3]
ROLLER MAIN BODY (OUTER CYLINDRICAL PORTION)	CARBON STEEL	51.5	11.8	100～2000	7.8
HEAT EQUALIZING MEMBER	ALUMINUM	222	3.0	1.0	2.7
HEAT GENERATING MEMBER	COPPER	355	1.9	1.0	8.9

FIG.6

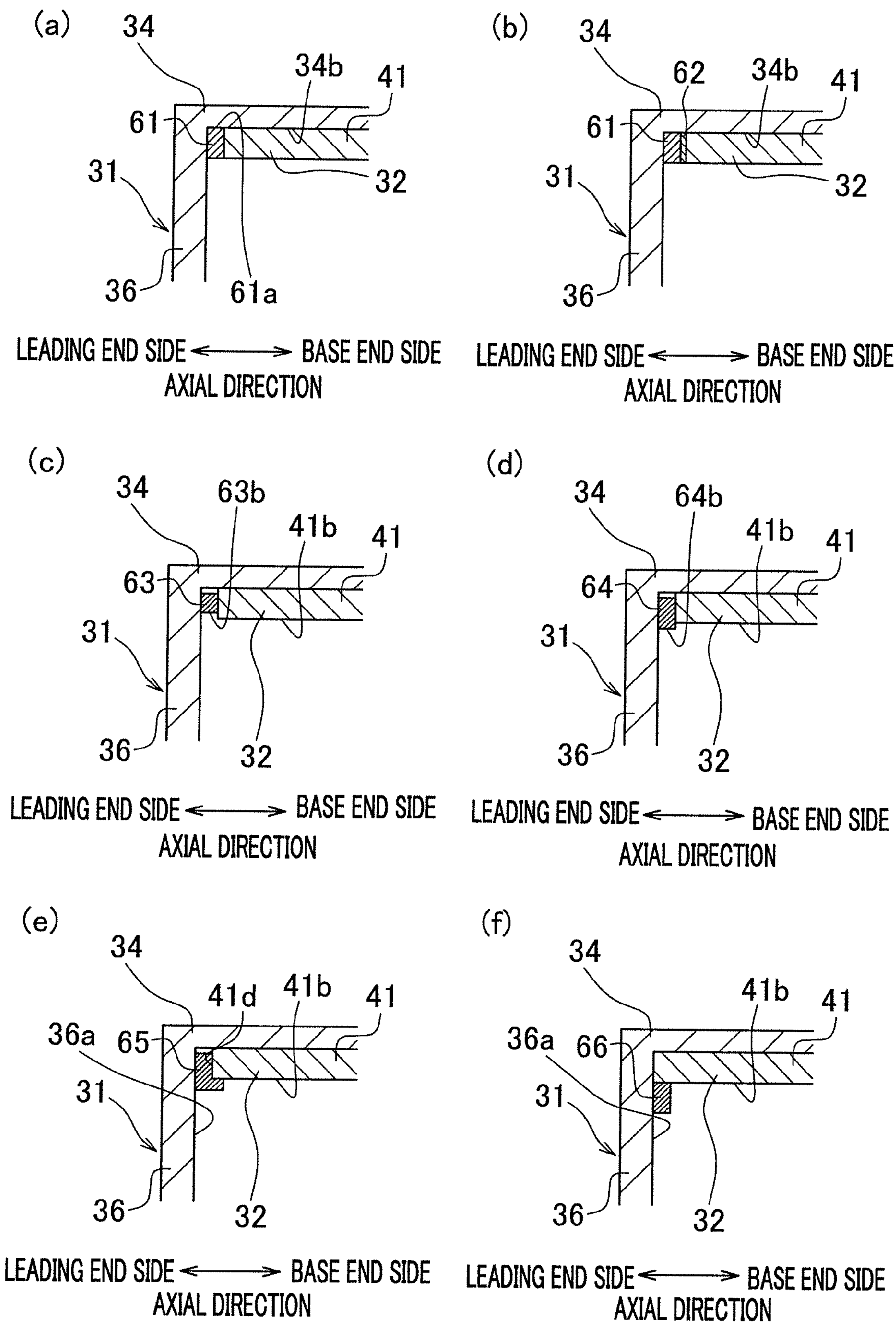
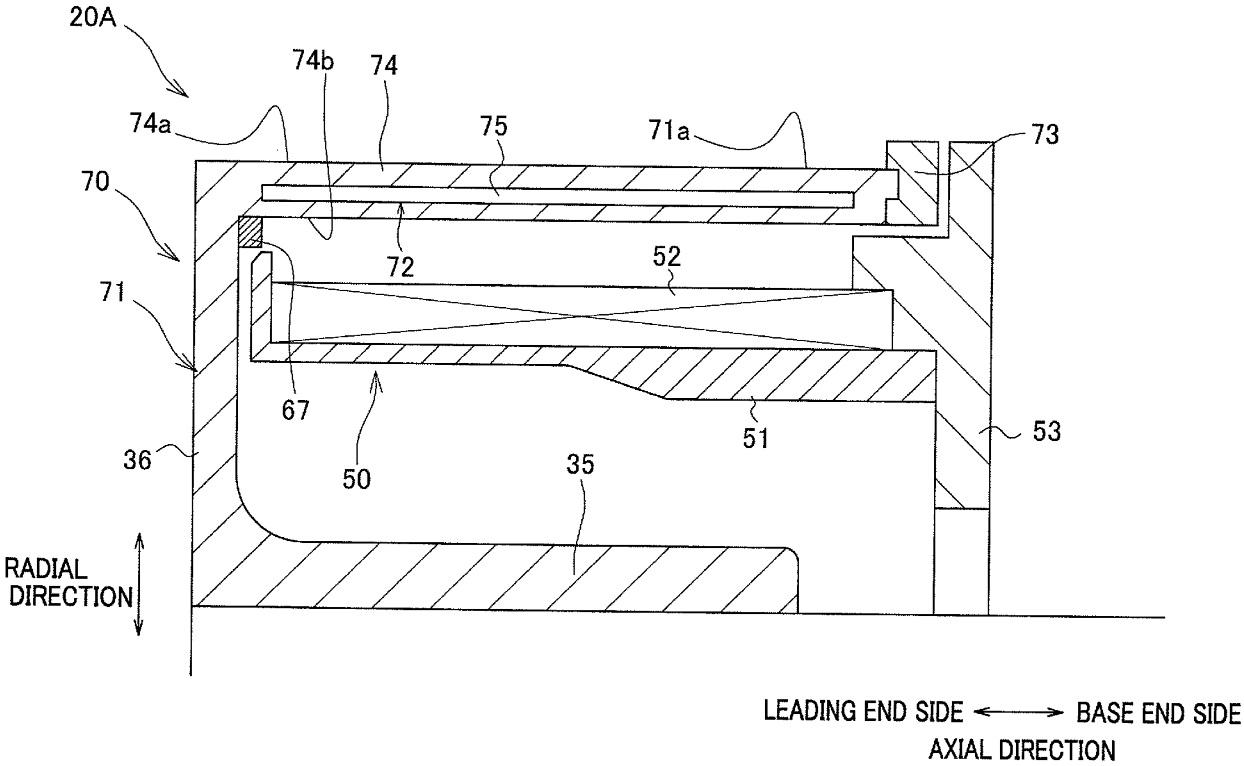

(a)
34
34b
41
61
31
32
36
61a
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION
(b)
34
62
34b
41
61
31
32
36
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION
(c)
34
63b
41b
41
63
31
36
32
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION
(d)
34
64b
41b
41
64
31
36
32
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION
(e)
34
41d
41b
41
36a
65
31
36
32
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION
(f)
34
41b
41
36a
66
31
36
32
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION

FIG.7


20A
74b
74
74a
75
71a
73
70
72
52
71
67
51
53
36
50
35
RADIAL DIRECTION
LEADING END SIDE
BASE END SIDE
AXIAL DIRECTION

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EUROPEAN SEARCH REPORT

Application Number
EP 21 17 2242

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A	* figure 2 *	2-12	
X	WO 2019/163314 A1 (TMT MACHINERY INC [JP]) 29 August 2019 (2019-08-29)	1,13	
A	* figure 2 *	2-12	
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A	* figure 2 *	2-12	

TECHNICAL FIELDS SEARCHED (IPC)

H05B
D02J
F16C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 October 2021	Pierron, Christophe

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

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11-10-2021

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		EP 3758445 A1	30-12-2020
		JP WO2019163311 A1	07-01-2021
		TW 201937986 A	16-09-2019
		WO 2019163311 A1	29-08-2019
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		EP 3700302 A1	26-08-2020
		JP 6857744 B2	14-04-2021
		JP WO2019077914 A1	05-11-2020
		TW 201918116 A	01-05-2019
		WO 2019077914 A1	25-04-2019

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