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(72) Inventors:
• **Kagata, Kakeru**
Kyoto-shi, Kyoto 612-8686 (JP)
• **Morinaga, Ryo**
Kyoto-shi, Kyoto 612-8686 (JP)
• **Hashimoto, Kinzo**
Kyoto-shi, Kyoto 612-8686 (JP)

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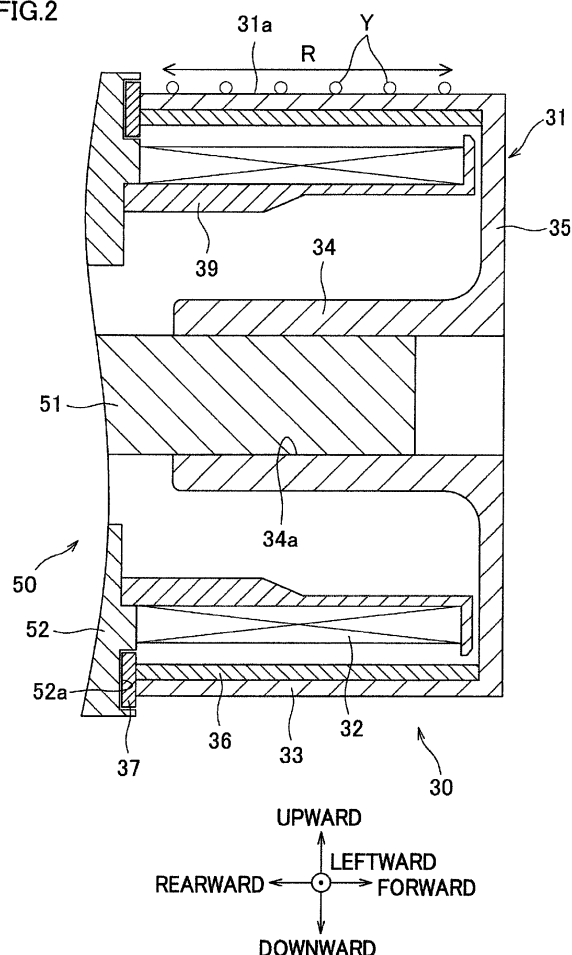
(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(71) Applicant: **TMT Machinery, Inc.**
Osaka-shi, Osaka 541-0041 (JP)

(54) **INDUCTION HEATING ROLLER**

(57) Both uniformization of temperature distribution on the roller surface in the axial direction and effective heating of the roller surface are achieved. In an induction heating roller 30 including: a coil 32; a roller main body 31 having an outer cylindrical part 33 which is cylindrical in shape and is provided on an outer side in a radiation direction of the coil 32; and a heat leveling member 36 provided on the outer side in the radial direction of the coil 32 and on an inner side in the radial direction of the outer cylindrical part 33 and being in contact with an inner circumferential surface of the outer cylindrical part 33, heat conductivity of the heat leveling member 36 is higher than heat conductivity of the outer cylindrical part 33 in an axial direction, and electric resistivity of the heat leveling member 36 is higher than electric resistivity of the outer cylindrical part 33 in a circumferential direction.

FIG.2



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an induction heating roller used for heating yarns.

[0002] An induction heating roller configured to heat a roller surface by induction heating using a coil has been known as described in Patent Literatures 1 and 2 (Japanese Unexamined Patent Publication No. 7-218130 and Japanese Patent No. 4903327), for example. The induction heating roller of Patent Literature 1 is arranged such that a thin film layer which is a magnetic body is formed on an inner circumferential surface of a roller main body which is a non-magnetic body and is a high thermal conductor. When power is supplied to the coil, the thin film layer on the inner side of the roller main body is heated by induction heating, with the result that the roller surface is heated due to the heat conduction from the thin film layer to the roller surface. In the induction heating roller of Patent Literature 2, a conductor is provided on an inner circumferential surface of a roller main body which is made of carbon steel. In the same manner as in the induction heating roller of Patent Literature 1, the conductor on the inner side of the roller main body is heated by induction heating, with the result that the roller surface is heated due to the heat conduction from the conductor to the roller surface.

SUMMARY OF THE INVENTION

[0003] As described above, in the induction heating rollers of Patent Literatures 1 and 2, the roller main body does not directly generate heat by induction heating but a member on the inner side of the roller main body generates heat. In other words, a part far from the roller surface (outer circumferential surface of the roller main body) which is the target of heating generates heat, and hence the roller surface is not efficiently heated.

[0004] In addition to the above, in the induction heating roller, heat generation by induction heating is not evenly done in the axial direction, and hence the temperatures of the roller surface are uneven in the axial direction. On this account, when the induction heating roller is used for heating yarns, the degree of heating of yarns may be different between parts of the roller surface in contact with the yarns, with the result that the quality of the yarns may be unstable. In this connection, in the induction heating roller of Patent Literature 2, a jacket chamber in which a gas-liquid two-phase heating medium is sealed is provided in the roller main body. As this jacket chamber functions as a heat pipe, the temperatures of the roller surface are uniformized to some degree in the axial direction. This arrangement in which the jacket chamber (heat pipe) is provided in the roller main body is disadvantageous in that, because the roller main body is thick and hence the heat capacity of the roller main body is large, a large amount of heat is required to heat the roller main body,

so that effective heating of the roller surface is difficult.

[0005] In consideration of the problem above, an object of an induction heating roller of the present invention is to achieve both uniformization of temperature distribution on a roller surface in an axial direction and effective heating of the roller surface.

[0006] According to the first aspect of the invention, an induction heating roller includes: a coil; a roller main body having an outer cylindrical part which is cylindrical in shape and is provided on an outer side in a radiation direction of the coil; and a heat leveling member provided on the outer side in the radial direction of the coil and on an inner side in the radial direction of the outer cylindrical part and being in contact with an inner circumferential surface of the outer cylindrical part, heat conductivity of the heat leveling member being higher than heat conductivity of the outer cylindrical part in an axial direction, and electric resistivity of the heat leveling member being higher than electric resistivity of the outer cylindrical part in a circumferential direction.

[0007] According to the first aspect of the invention, the heat leveling member is provided to be in contact with the inner circumferential surface of the outer cylindrical part of the roller main body, and the thermal conductivity of the heat leveling member in the axial direction is arranged to be higher than that of the outer cylindrical part. On this account, the temperature distribution of the heat leveling member in the axial direction tends to be even, and hence the temperature distribution in the axial direction is uniformized in the outer cylindrical part which is in contact with the heat leveling member. Furthermore, because the electric resistivity of the heat leveling member in the circumferential direction is arranged to be higher than that of the outer cylindrical part, an eddy current on account of the electromagnetic induction flows more in the outer cylindrical part than in the heat leveling member, with the result that the induction heating in the outer cylindrical part is facilitated. Therefore the part close to the roller surface (i.e., the outer circumferential surface of the outer cylindrical part) as compared to the heat leveling member is heated more, and hence the roller surface is efficiently heated. Furthermore, because no heat pipe is required thanks to the heat leveling member, the thickness of the outer cylindrical part of the roller main body is reduced. As a result, the heat capacity of the outer cylindrical part is reduced and temperature increase in the entirety of the outer cylindrical part is facilitated, and hence the roller surface which is the outer circumferential surface of the outer cylindrical part is efficiently heated. In this way, according to the first aspect of the invention, it is possible to achieve both uniformization of temperature distribution on the roller surface in the axial direction and effective heating of the roller surface.

[0008] According to the second aspect of the invention, an induction heating roller includes: a coil; a roller main body having an outer cylindrical part which is cylindrical in shape and is provided on an outer side in a radiation direction of the coil; a heat leveling member provided on

the outer side in the radial direction of the coil and on an inner side in the radial direction of the outer cylindrical part and being in contact with an inner circumferential surface of the outer cylindrical part, heat conductivity of the heat leveling member being higher than heat conductivity of the outer cylindrical part in an axial direction, and relative permeability of the heat leveling member being lower than relative permeability of the outer cylindrical part.

[0009] According to the second aspect of the invention, the heat leveling member is provided to be in contact with the inner circumferential surface of the outer cylindrical part of the roller main body, and the thermal conductivity of the heat leveling member in the axial direction is arranged to be higher than that of the outer cylindrical part. On this account, the temperature distribution of the heat leveling member in the axial direction tends to be even, and hence the temperature distribution in the axial direction is uniformized in the outer cylindrical part which is in contact with the heat leveling member. Furthermore, because the relative permeability of the heat leveling member is lower than that of the outer cylindrical part, a magnetic flux flows more in the outer cylindrical part than in the heat leveling member, with the result that the induction heating in the outer cylindrical part is facilitated. Therefore the part close to the roller surface (i.e., the outer circumferential surface of the outer cylindrical part) as compared to the heat leveling member is heated more, and hence the roller surface is efficiently heated. Furthermore, because no heat pipe is required thanks to the heat leveling member, the thickness of the outer cylindrical part of the roller main body is reduced. As a result, the heat capacity of the outer cylindrical part is reduced and temperature increase in the entirety of the outer cylindrical part is facilitated, and hence the roller surface which is the outer circumferential surface of the outer cylindrical part is efficiently heated. In this way, according to the second aspect of the invention, it is possible to achieve both uniformization of temperature distribution on the roller surface in the axial direction and effective heating of the roller surface.

[0010] In the present invention, preferably, the heat leveling member is a cylindrical member having an outer diameter which is identical with an inner diameter of the outer cylindrical part.

[0011] In this case, because the entire circumstance of the heat leveling member is in contact with the inner circumferential surface of the outer cylindrical part, the temperature distribution of the roller surface is effectively uniformized in the circumferential direction, too.

[0012] In the present invention, preferably, the cylindrical member is divided into a plurality of pieces in the circumferential direction.

[0013] With this, the heat levelling member is easily formed as compared to cases where the member is a single cylindrical member. Furthermore, the mounting can be easily done.

[0014] In the present invention, preferably, the heat

leveling member is made of a material including a fiber material.

[0015] When the heat leveling member is formed to include the fiber material, because the thermal conductivity is high in the direction in which the fibers are oriented, the thermal conductivity and the electric resistivity of the heat leveling member are adjustable with a high degree of freedom, by changing the length and orientation of the fibers.

[0016] In the present invention, preferably, the fiber material is carbon fibers.

[0017] The carbon fibers are light and have high thermal conductivity. On this account, because the heat leveling member is made of a material including carbon fibers, the temperature distribution of the roller surface is effectively uniformized and the weight of the entire induction heating roller is reduced.

[0018] In the present invention, preferably, the carbon fibers are oriented in the axial direction.

[0019] When the carbon fibers are oriented in the axial direction, the thermal conductivity of the heat leveling member is high in the axial direction, with the result that the temperature distribution of the heat leveling member tends to be further uniformized in the axial direction and the temperature distribution of the roller surface is further uniformized in the axial direction. Furthermore, when the carbon fibers are oriented in the axial direction, the electric resistance of the heat leveling member is high in the circumferential direction. As a result, an eddy current due to the electromagnetic induction flows more in the outer cylindrical part than in the heat leveling member. The induction heating in the outer cylindrical part is therefore further facilitated, and the roller surface is more efficiently heated.

[0020] In the present invention, preferably, the carbon fibers are randomly oriented.

[0021] When the carbon fibers are randomly oriented, cost reduction is achieved because short fibers which are cheaper than long fibers can be used.

[0022] In the present invention, preferably, the carbon fibers are pitch-based carbon fibers.

[0023] As the carbon fibers, pitch-based carbon fibers utilizing petroleum pitch and PAN-based carbon fibers utilizing acrylic fibers are known. The thermal conductivity of the pitch-based carbon fibers is higher than that of the PAN-based carbon fibers. On this account, the thermal conductivity of the heat leveling member is further increased when the pitch-based carbon fibers are employed, and hence the temperature distribution of the roller surface is further effectively uniformized.

[0024] In the present invention, preferably, the heat leveling member is made of a carbon-fiber reinforced carbon composite material which is a composite material of carbon fibers and graphite.

[0025] The carbon-fiber reinforced carbon composite material has high thermal conductivity among composite materials including carbon fibers, and has high heat resistance. On this account, when the heat leveling mem-

ber is made of the carbon-fiber reinforced carbon composite material, the temperature distribution of the roller surface is further effectively uniformized and heat resistance is imparted to the induction heating roller.

[0026] In the present invention, preferably, the heat leveling member is made of carbon-fiber reinforced plastic which is a composite material of carbon fibers and resin.

[0027] The carbon-fiber reinforced plastic is lower in heat resistance than the carbon-fiber reinforced carbon composite material but is cheaper. On this account, when the induction heating roller is not required to have high heat resistance, cost reduction is achieved when the heat leveling member is made of the carbon-fiber reinforced plastic.

[0028] In the present invention, preferably, heat capacity of the heat leveling member is smaller than heat capacity of the outer cylindrical part.

[0029] With this arrangement, the temperature distribution of the outer cylindrical part is further rapidly uniformized, and hence the temperature distribution of the roller surface is further rapidly uniformized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

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

FIG. 2 is a cross section of the induction heating roller of the embodiment.

FIG. 3 is a table showing physical properties of a roller main body and a heat leveling member of the embodiment.

FIG. 4 is a graph showing the temperature transition of a roller surface.

FIG. 5 is a table showing physical properties of a roller main body and a heat leveling member of another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Spun Yarn Take-Up Machine)

[0031] The following will describe an embodiment of the present invention. FIG. 1 is a schematic diagram of a spun yarn take-up machine including an induction heating roller of the present embodiment. As shown in FIG. 1, a spun yarn take-up machine 1 is configured to draw plural (6 in this case) yarns spun out from a spinning apparatus 2 by a spun yarn drawing apparatus 3 and wind the yarns by a yarn winding apparatus 4. It is noted that the descriptions below rely on the directions indicated in the figures.

[0032] The spinning apparatus 2 is configured to generate the yarns Y by continuously spinning out a molten fibrous material such as polyester. To the yarns Y spun

out from the spinning apparatus 2, oil is applied at an oil guide 10, and the yarns Y are then sent to the spun yarn drawing apparatus 3 via a guide roller 11.

[0033] The spun yarn drawing apparatus 3 is an apparatus for drawing the yarns Y and is provided below the spinning apparatus 2. The spun yarn drawing apparatus 3 includes plural (five in this case) godet rollers 21 to 25 housed inside a thermal insulation box 12. Each of the godet rollers 21 to 25 is an induction heating roller which is rotationally driven by a motor and is induction-heated by a coil. On each roller, plural yarns Y are wound. At a lower part of a right side wall 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 wall of the thermal insulation box 12, an outlet 12b is formed to allow the yarns Y to go out from the thermal insulation box 12. The yarns Y are wound onto the lower godet roller 21 first and then on the remaining rollers 22 to 25 in order, each at a winding angle of less than 360 degrees.

[0034] The lower three godet rollers 21 to 23 are pre-heating rollers for preliminarily heating the yarns Y before drawing them. The roller surface temperature of each of these rollers is arranged to be equal to or higher than the glass transition temperature of the yarns Y (e.g., set at about 90 to 100 degrees centigrade). Meanwhile, the upper two godet rollers 24 and 25 are conditioning rollers for thermally setting the drawn yarns Y. The roller surface temperature of each of these rollers is arranged to be higher than the roller surface temperatures of the lower three godet rollers 21 to 23 (e.g., set at about 150 to 200 degrees centigrade). The yarn feeding speeds of the upper two godet rollers 24 and 25 are higher than the yarn feeding speeds of the lower three godet rollers 21 to 23.

[0035] The yarns Y introduced into the thermal insulation box 12 through the inlet 12a are, to begin with, 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 in yarn feeding speed between the godet roller 23 and the godet roller 24. The yarns Y are then further heated while being transferred by the godet rollers 24 and 25, with the result that the drawn state is thermally set. The yarns Y having been drawn in this way go out from the thermal insulation box 12 through the outlet 12b.

[0036] The yarns Y drawn by the spun yarn drawing apparatus 3 are sent to the yarn winding apparatus 4 via a guide roller 13. The yarn winding apparatus 4 is an apparatus for winding the yarns Y and 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 is long in the front-back direction. The bobbin holder 14 is rotationally driven by an unillustrated motor. To the bobbin holder 14, bobbins B are attached along the axial direction to be side by side. By rotating the bobbin holder 14, the yarn winding apparatus 4 simultaneously winds the yarns Y onto the bobbins B, so

as to produce packages P. The contact roller 15 makes 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.

(Induction Heating Roller)

[0037] FIG. 2 is a cross section of the induction heating roller of the present embodiment. In regard to a motor 50 to which the induction heating roller 30 is connected, FIG. 2 shows only parts of an output shaft 51 and a housing 52. The induction heating roller 30 shown in FIG. 2 is employed in all of the godet rollers 21 to 25 shown in FIG. 1.

[0038] The induction heating roller 30 includes a cylindrical roller main body 31 which extends along the axial direction (front-back direction) and a coil 32 provided inside the roller main body 31. The induction heating roller 30 heats the outer circumferential surface 31a (hereinafter, roller surface 31a) of the roller main body 31 by using induction heating by the coil 32, so as to heat the yarns Y wound on the roller surface 31a.

[0039] The roller main body 31 includes a cylindrical outer cylindrical part 33 provided on the outer side in the radial direction of the coil 32, a cylindrical shaft center part 34 provided on the inner side in the radial direction of the coil 32, and a disc-shaped end face part 35 which connects a front end portion of the outer cylindrical part 33 with a front end portion of the shaft center part 34. The roller main body 31 is open on the rear end side. The outer cylindrical part 33, the shaft center part 34, and the end face part 35 are integrally formed.

[0040] On the inner side in the radial direction of the outer cylindrical part 33 of the roller main body 31 and on the outer side in the radial direction of the coil 32, a cylindrical heat leveling member 36 is provided. The outer diameter of the heat leveling member 36 is arranged to be identical with the inner diameter of the outer cylindrical part 33. (In a strict sense, the outer diameter of the heat leveling member 36 is slightly shorter than the inner diameter of the outer cylindrical part 33 in order to allow the heat leveling member 36 to be inserted into the outer cylindrical part 33.) With this arrangement, when the heat leveling member 36 is housed in the roller main body 31, the outer circumferential surface of the heat leveling member 36 is substantially entirely in contact with the inner circumferential surface of the outer cylindrical part 33. As shown in FIG. 2, provided that a region on the roller surface 31a, where the yarns Y are lined up in the axial direction, is a wound region R, the heat leveling member 36 is provided to correspond to a range in the axial direction, which includes the wound region R.

[0041] The heat leveling member 36 can be inserted into the outer cylindrical part 33 through the opening on the rear end side of the roller main body 31. The length in the axial direction of the heat leveling member 36 is substantially identical with the length of the outer cylindrical part 33, and the front end portion of the heat leveling

member 36 is in contact with the end face part 35 of the roller main body 31. Rear end portions of the outer cylindrical part 33 and the heat leveling member 36 are both fixed to an annular fixed component 37. The heat leveling member 36 is fixed to the roller main body 31 in this way.

[0042] In the shaft center part 34 of the roller main body 31, a shaft inserting hole 34a is formed to extend along the axial direction. To the shaft inserting hole 34a, an output shaft 51 of the motor 50 is fixed by unillustrated fixing means, so that the induction heating roller 30 and the output shaft 51 are rotatable together.

[0043] The coil 32 is arranged so that a wire is wound onto the outer circumferential surface of a cylindrical bobbin member 39. Although not illustrated, the bobbin member 39 is not completely cylindrical. The bobbin member 39 is C-shaped in cross section and is discontinued at a part in the circumferential direction. On this account, an eddy current is unlikely to flow along the circumferential direction in the bobbin member 39, and this restrains heat generation from the bobbin member 39. The bobbin member 39 is attached to a housing 52 of the motor 50. An annular recess 52a is formed in the housing 52. The above-mentioned fixed component 37 is provided inside the recess 52a so as not to be in contact with the bottom and side surfaces of the recess 52a. The output shaft 51 of the motor 50 is rotatably supported by the housing 52 via an unillustrated bearing. As the motor 50 is driven, the induction heating roller 30 rotates together with the output shaft 51.

[0044] In regard to the above, the roller main body 31 of the present embodiment is a magnetic body and is made of carbon steel which is conductor. The heat leveling member 36 is made of C/C composite (carbon-fiber reinforced carbon composite material) which is a composite material of carbon fibers and graphite. As the carbon fibers, pitch-based carbon fibers with high thermal conductivity are used. This C/C composite is arranged such that long carbon fibers are oriented in the axial direction so that the carbon fibers are continuous in the axial direction. To put it differently, in the C/C composite, the carbon fibers may not be continuous in the circumferential direction and in the thickness direction. FIG. 3 shows physical properties of the roller main body 31 and the heat leveling member 36 of the present embodiment. The physical properties shown in FIG. 3 are properties at room temperatures. (The same applies to FIG. 5.)

[0045] Because the C/C composite constituting the heat leveling member 36 is arranged such that the carbon fibers are oriented in the axial direction as described above, transmission of heat and electricity is facilitated in the axial direction (i.e., the thermal conductivity is high and the electric resistivity is low). In the meanwhile, heat and electricity are not easily transmitted in the circumferential direction because the fibers may not be continuous in that direction (i.e., the thermal conductivity is low and the electric resistivity is high). As the carbon fibers are oriented in a predetermined direction, the heat leveling

member 36 functions as an anisotropic material, and the physical properties in different directions are adjustable with a high degree of freedom.

[0046] As a high-frequency current is supplied to the coil 32, a variable magnetic field is generated around the coil 32. Induction heating utilizes Joule heat generated by an eddy current which flows in the circumferential direction due to the electromagnetic induction effect. In the present embodiment, the electric resistivity of the heat leveling member 36 in the circumferential direction is higher than that of the roller main body 31 (outer cylindrical part 33) (see FIG. 3). On this account, the eddy current runs more in the outer cylindrical part 33 than in the heat leveling member 36, and hence Joule heat is generated more in the outer cylindrical part 33 than in the heat leveling member 36. Because of the skin effect, the eddy current is mainly generated at or around the inner circumferential surface of the outer cylindrical part 33.

[0047] In the present embodiment, the thermal conductivity of the heat leveling member 36 in the axial direction is higher than that of the roller main body 31 (outer cylindrical part 33) (see FIG. 3). On this account, the temperature distribution of the heat leveling member 36 in the axial direction tends to be even, and hence the temperature distribution in the axial direction is uniformized in the outer cylindrical part 33 which is in contact with the heat leveling member 36. A specific value of the thermal conductivity of the heat leveling member 36 in the axial direction is, for example, preferably equal to or higher than $200\text{W}/(\text{m}\cdot\text{K})$. Furthermore, in the present embodiment, the heat capacity of the heat leveling member 36 is arranged to be smaller than the heat capacity of the outer cylindrical part 33 in order to rapidly uniformize the temperature distribution of the heat leveling member 36.

[0048] In consideration of efficient increase in the temperature of the roller surface 31a, it is preferable to increase the amount of heat generated at the outer cylindrical part 33 which is close to the roller surface 31a as much as possible, as compared to the heat leveling member 36 which is far from the roller surface 31a. The heat leveling member 36, however, may generate a small amount of heat. When the heat leveling member 36 generates heat, the amount of the heat is preferably smaller than the amount of heat generated by the outer cylindrical part 33.

(Effects)

[0049] As described above, in the induction heating roller 30 of the present embodiment, the heat leveling member 36 is provided to be in contact with the inner circumferential surface of the outer cylindrical part 33 of the roller main body 31, and the thermal conductivity of the heat leveling member 36 in the axial direction is arranged to be higher than that of the outer cylindrical part 33. On this account, the temperature distribution of the heat leveling member 36 in the axial direction tends to

be even, and hence the temperature distribution in the axial direction is uniformized in the outer cylindrical part 33 which is in contact with the heat leveling member 36. Furthermore, because the electric resistivity of the heat leveling member 36 in the circumferential direction is arranged to be higher than that of the outer cylindrical part 33, an eddy current on account of the electromagnetic induction flows more in the outer cylindrical part 33 than in the heat leveling member 36, with the result that the induction heating in the outer cylindrical part 33 is facilitated. Therefore the part close to the roller surface 31a as compared to the heat leveling member 36 is heated more, and hence the roller surface 31a is efficiently heated. Furthermore, because no heat pipe is required thanks to the heat leveling member 36, the thickness of the outer cylindrical part 33 of the roller main body 31 is reduced. As a result, the heat capacity of the outer cylindrical part 33 is reduced and temperature increase in the entirety of the outer cylindrical part 33 is facilitated, and hence the roller surface 31a which is the outer circumferential surface of the outer cylindrical part 33 is efficiently heated. In this way, the induction heating roller 30 of the present embodiment makes it possible to achieve both uniformization of temperature distribution on the roller surface 31a in the axial direction and effective heating of the roller surface 31a.

[0050] FIG. 4 is a graph showing the temperature transition of a roller surface, in which the induction heating roller 30 of the present embodiment is compared with a known induction heating roller utilizing a heat pipe, as disclosed in Patent Literature 2. The heater output is identical between these cases, and the temperature transition until the temperature becomes substantially constant is shown. As clearly shown in FIG. 4, the speed of temperature increase is higher in the induction heating roller 30 of the present embodiment than in the known induction heating roller, and the time until the temperature becomes constant is shorter in the induction heating roller 30 than in the known induction heating roller. In short, the induction heating roller 30 of the present embodiment makes it possible to efficiently heat the roller surface 31a.

[0051] In the present embodiment, the heat leveling member 36 is a cylindrical member having the outer diameter which is identical with the inner diameter of the outer cylindrical part 33. On this account, the entire circumference of the heat leveling member 36 is in contact with the inner circumferential surface of the outer cylindrical part 33, and hence the temperature distribution of the roller surface 31a is effectively uniformized in the circumferential direction, too.

[0052] In the present embodiment, the heat leveling member 36 is made of a material including fibers. Because the thermal conductivity is high in the direction in which the fibers are oriented, the thermal conductivity and the electric resistivity of the heat leveling member 36 are adjustable with a high degree of freedom, by changing the length and orientation of the fibers.

[0053] In the present embodiment, the fibers are car-

bon fibers. The carbon fibers are light and have high thermal conductivity. On this account, because the heat leveling member 36 is made of a material including carbon fibers, the temperature distribution of the roller surface 31a is effectively uniformized and the weight of the entire induction heating roller 30 is reduced.

[0054] In the present embodiment, the carbon fibers are oriented in the axial direction. When the carbon fibers are oriented in the axial direction, the thermal conductivity of the heat leveling member 36 is high in the axial direction, with the result that the temperature distribution of the heat leveling member 36 tends to be further uniformized in the axial direction and the temperature distribution of the roller surface 31a is further uniformized in the axial direction. Furthermore, when the carbon fibers are oriented in the axial direction, the electric resistance of the heat leveling member 36 is high in the circumferential direction. As a result, an eddy current due to the electromagnetic induction flows more in the outer cylindrical part 33 than in the heat leveling member 36. The induction heating in the outer cylindrical part 33 is therefore further facilitated, and the roller surface 31a is more efficiently heated.

[0055] In the present embodiment, the carbon fibers are pitch-based carbon fibers. As the carbon fibers, pitch-based carbon fibers utilizing petroleum pitch and PAN-based carbon fibers utilizing acrylic fibers are known. The thermal conductivity of the pitch-based carbon fibers is higher than that of the PAN-based carbon fibers. On this account, the thermal conductivity of the heat leveling member 36 is further increased when the pitch-based carbon fibers are employed, and hence the temperature distribution of the roller surface 31a is further effectively uniformized.

[0056] In the present embodiment, the heat leveling member 36 is made of C/C composite (carbon-fiber reinforced carbon composite material) which is a composite material of carbon fibers and graphite. The C/C composite has high thermal conductivity among composite materials including carbon fibers, and has high heat resistance. On this account, when the heat leveling member 36 is made of the C/C composite, the temperature distribution of the roller surface 31a is further effectively uniformized and heat resistance is imparted to the induction heating roller 30.

[0057] In the present embodiment, the heat capacity of the heat leveling member 36 is smaller than the heat capacity of the outer cylindrical part 33. On this account, the temperature distribution of the outer cylindrical part 33 is further rapidly uniformized, and hence the temperature distribution of the roller surface 31a is further rapidly uniformized.

(Other embodiments)

[0058] The present invention is not limited to the embodiment above. Various modifications and variations are possible within the scope of the spirit of the invention,

as described below.

[0059] While in the embodiment above the heat leveling member 36 is made of the C/C composite, it may be made of, instead of the C/C composite, CFRP (carbon-fiber reinforced plastic) which is a composite material of carbon fibers and resin (e.g., epoxy resin). The CFRP is lower in heat resistance than the C/C composite but is cheaper. On this account, cost reduction is achieved by, for example, employing the C/C composite as the heat leveling member 36 only in the godet rollers 24 and 25 which are conditioning rollers set at relatively high temperatures, and employing the CFRP as the heat leveling member 36 in the godet rollers 21 to 23 which are pre-heating rollers set at relatively low temperatures.

[0060] The carbon fibers forming the heat leveling member 36 may be PAN-based carbon fibers utilizing acrylic fibers, instead of the pitch-based carbon fibers. Furthermore, as long as the physical properties are sufficient, the carbon fibers may not be oriented in the axial direction but be oriented in the circumferential direction or in a helix direction. Furthermore, short carbon fibers may be randomly oriented. Even when the random orientation is employed, as shown in FIG. 3, the thermal conductivity of the heat leveling member 36 is higher than that of the outer cylindrical part 33, and the electric resistivity of the heat leveling member 36 is higher than that of the outer cylindrical part 33. It is therefore possible to achieve both uniformization of temperature distribution on the roller surface 31a in the axial direction and effective heating of the roller surface 31a. In addition to the above, short carbon fibers are advantageous over long carbon fibers in costs. Furthermore, on condition that the form of the carbon fibers is suitably maintained as, for example, they are stored in a casing, carbon fibers may be used alone, instead of a composite material such as C/C composite and CFRP. Furthermore, the fibers may be different from the carbon fibers.

[0061] The heat leveling member 36 may be formed of a metal material such as aluminum and copper, for example. In this case, because the thermal conductivity of the heat leveling member 36 in the axial direction is higher than that of the outer cylindrical part 33 (see FIG. 5), the temperature distribution of the heat leveling member 36 in the axial direction tends to be uniform, and hence the temperature distribution in the axial direction is uniformized in the outer cylindrical part 33 which is in contact with the heat leveling member 36. Furthermore, because the relative permeability of the heat leveling member 36 is lower than that of the outer cylindrical part 33, a magnetic flux flows more in the outer cylindrical part 33 than in the heat leveling member 36, with the result that the induction heating in the outer cylindrical part 33 is facilitated. On this account, in the same manner as in the embodiment above, it is possible to achieve both uniformization of temperature distribution on the roller surface 31a in the axial direction and effective heating of the roller surface 31a. The metal materials above, however, are higher in density than the C/C composite. For

this reason, the C/C composite is optimum as the material of the heat leveling member 36, when weight reduction of the induction heating roller 30 is taken into consideration.

[0062] In cases of randomly-oriented carbon fibers and isotropic materials such as metal materials including carbon steel, aluminum, and copper, the physical properties such as thermal conductivity, electric resistivity, and relative permeability are unique values irrespective of the direction. For this reason, in case of isotropic materials, the limitations such as "in the axial direction" and the "circumferential direction" to the physical properties are meaningless, and the physical properties are unique values even if they are restricted as above.

[0063] While in the embodiment above the roller main body 31 (outer cylindrical part 33) is made of carbon steel, the roller main body 31 may not be made of carbon steel. The material may be aluminum or copper, for example.

[0064] While in the embodiment above the heat leveling member 36 is a cylindrical member, it may not be formed to be cylindrical. For example, the heat leveling member 36 may be formed by providing, in the circumferential direction, narrow pieces which are formed by dividing a cylindrical member in the circumferential direction. With this, the heat levelling member is easily formed as compared to cases where the member is a single cylindrical member. Furthermore, the heat levelling member is easily mounted.

[0065] In the embodiment above, a plurality of yarns Y are wound onto a single induction heating roller 30. Because the temperature distribution of the roller surface 31a is uniformized in the axial direction, the unevenness of quality of the yarns Y is advantageously restrained. However, as a matter of course, the present invention can be applied to an induction heating roller on which a single yarn is wound.

Claims

1. An induction heating roller comprising:

a coil;
a roller main body having an outer cylindrical part which is cylindrical in shape and is provided on an outer side in a radiation direction of the coil; and
a heat leveling member provided on the outer side in the radial direction of the coil and on an inner side in the radial direction of the outer cylindrical part and being in contact with an inner circumferential surface of the outer cylindrical part,
heat conductivity of the heat leveling member being higher than heat conductivity of the outer cylindrical part in an axial direction, and electric resistivity of the heat leveling member being higher than electric resistivity of the outer cylindrical part in a circumferential direction.

drical part in a circumferential direction.

2. An induction heating roller comprising:

a coil;
a roller main body having an outer cylindrical part which is cylindrical in shape and is provided on an outer side in a radiation direction of the coil;
a heat leveling member provided on the outer side in the radial direction of the coil and on an inner side in the radial direction of the outer cylindrical part and being in contact with an inner circumferential surface of the outer cylindrical part,
heat conductivity of the heat leveling member being higher than heat conductivity of the outer cylindrical part in an axial direction, and relative permeability of the heat leveling member being lower than relative permeability of the outer cylindrical part.

3. The induction heating roller according to claim 1 or 2, wherein, the heat leveling member is a cylindrical member having an outer diameter which is identical with an inner diameter of the outer cylindrical part.

4. The induction heating roller according to claim 3, wherein, the cylindrical member is divided into a plurality of pieces in the circumferential direction.

5. The induction heating roller according to any one of claims 1 to 4, wherein, the heat leveling member is made of a material including a fiber material.

6. The induction heating roller according to claim 5, wherein, the fiber material is carbon fibers.

7. The induction heating roller according to claim 6, wherein, the carbon fibers are oriented in the axial direction.

8. The induction heating roller according to claim 6, wherein, the carbon fibers are randomly oriented.

9. The induction heating roller according to any one of claims 6 to 8, wherein, the carbon fibers are pitch-based carbon fibers.

10. The induction heating roller according to any one of claims 6 to 9, wherein, the heat leveling member is made of a carbon-fiber reinforced carbon composite material which is a composite material of carbon fibers and graphite.

11. The induction heating roller according to any one of claims 6 to 9, wherein, the heat leveling member is made of carbon-fiber reinforced plastic which is a

composite material of carbon fibers and resin.

12. The induction heating roller according to any one of claims 1 to 11, wherein, heat capacity of the heat leveling member is smaller than heat capacity of the outer cylindrical part. 5

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FIG.1

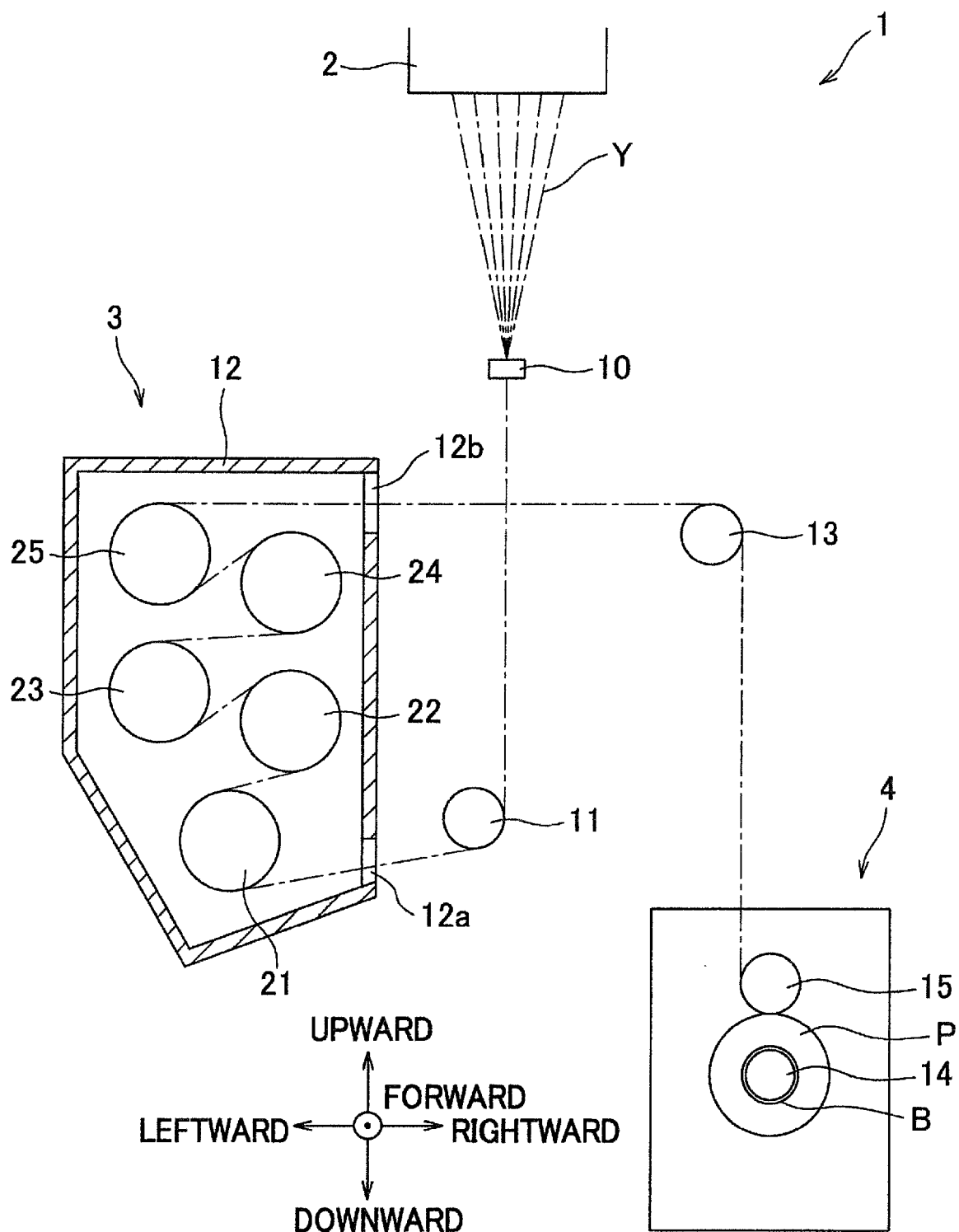


FIG.2

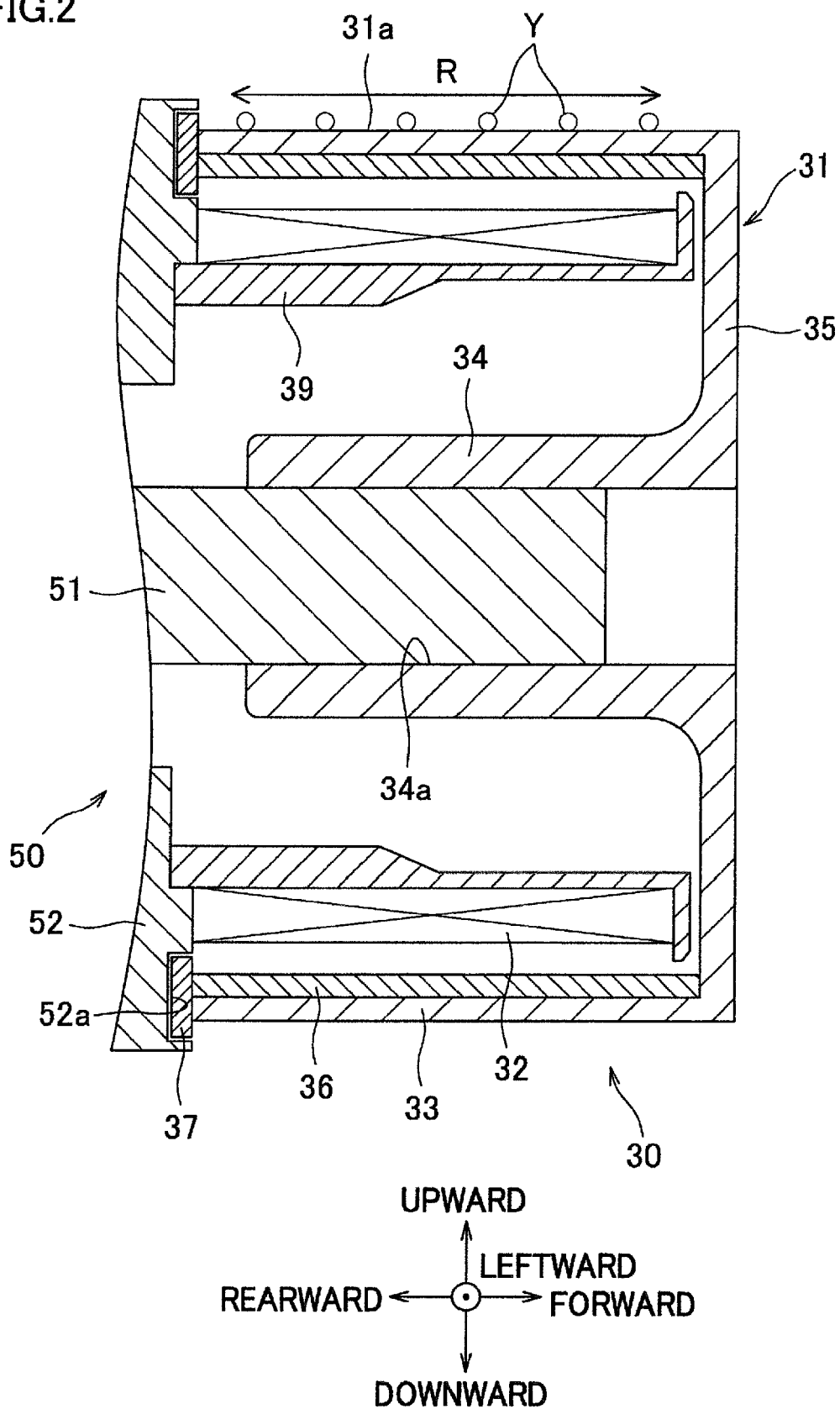


FIG.3

	MATERIAL		HEAT CONDUCTIVITY [W/(m·K)]	ELECTRIC RESISTIVITY [$\mu\Omega\cdot\text{cm}$]	RELATIVE PERMEABILITY [-]	DENSITY [g/cm ³]
ROLLER MAIN BODY (OUTER CYLINDRICAL PART)	CARBON STEEL		51.5	11.8	100~2000	7.8
HEAT LEVELING MEMBER	C/C COMPOSITE (ORIENTED IN AXIAL DIRECTION)	AXIAL DIRECTION	404	3.9×10^4	—	1.7
		CIRCUMFERENTIAL DIRECTION	15.2	1.3×10^6	—	
	C/C COMPOSITE (RANDOMLY ORIENTED)		120	1.3×10^3	—	1.6

FIG.4

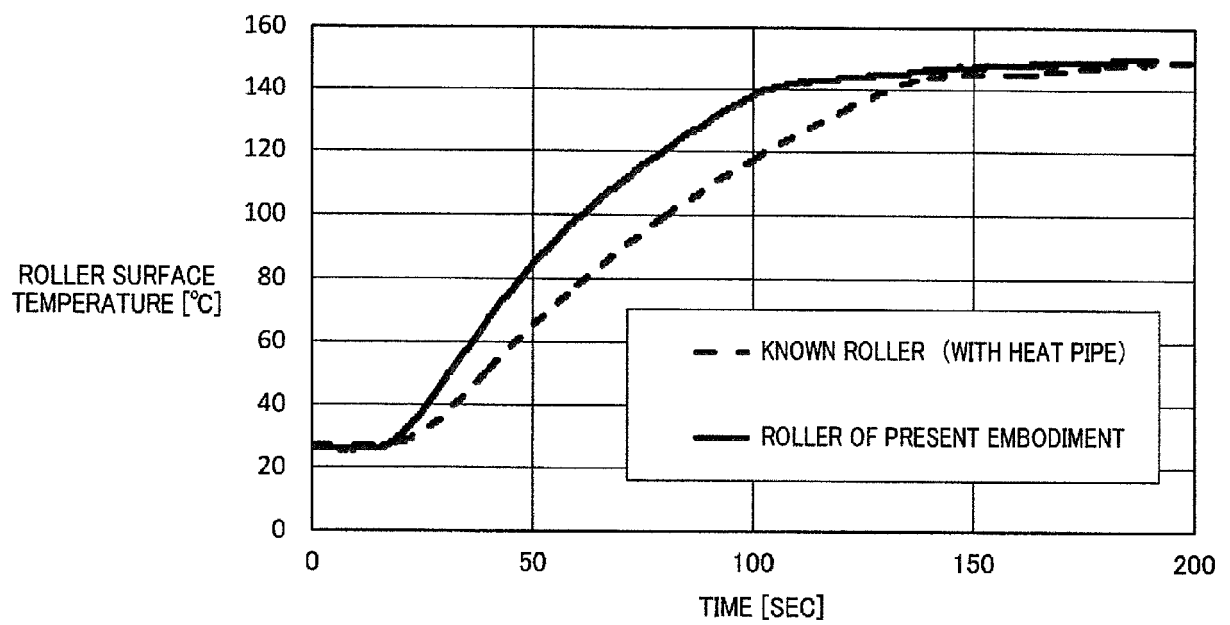


FIG.5

	MATERIAL	HEAT CONDUCTIVITY [W/(m·K)]	ELECTRIC RESISTIVITY [$\mu\Omega\cdot\text{cm}$]	RELATIVE PERMEABILITY [-]	DENSITY [g/cm ³]
ROLLER MAIN BODY (OUTER CYLINDRICAL PART)	CARBON STEEL	51.5	11.8	100~2000	7.8
HEAT LEVELING MEMBER	ALUMINUM	222	3.0	1.0	2.7
	COPPER	355	1.86	1.0	8.9



EUROPEAN SEARCH REPORT

 Application Number
 EP 17 18 5897

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