(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 501 470 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
05.02.2025 Bulletin 2025/06

(21) Application number: **23934311.4**

(22) Date of filing: **20.09.2023**

(51) International Patent Classification (IPC):
B05D 1/30 *(2006.01)* ***B05C 13/00*** *(2006.01)*
B05D 1/04 *(2006.01)* ***B05D 3/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B05C 13/00; B05D 1/04; B05D 1/30; B05D 3/00; B05D 3/14; B05D 7/00; B05D 7/04

(86) International application number:
PCT/JP2023/034039

(87) International publication number:
WO 2024/236832 (21.11.2024 Gazette 2024/47)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **15.05.2023 JP 2023079864**

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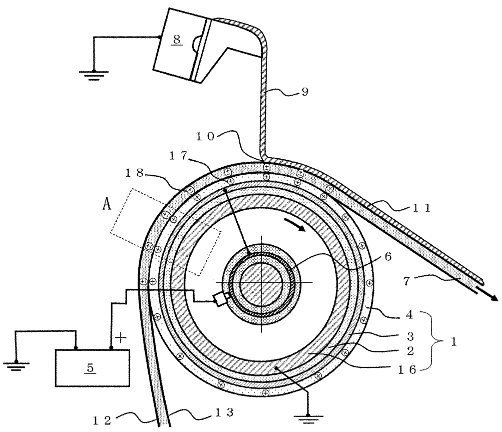
(54) **ELECTROSTATICALLY ASSISTED COATING METHOD USING BACKING ROLL HAVING INTERNAL ELECTRODE TO WHICH HIGH VOLTAGE CAN BE APPLIED**

(57) There is provided a coating method for a web having a wide width, and the coating method enables high-speed safe coating and is excellent in uniformity of the coating thickness. A method of coating a flexible plastic web with a coating liquid includes conveying the web to a backing roll for coating, causing the web to pass through a coating point while causing a second surface of the web to adhere to a part of a surface of the backing roll to which a DC voltage is applied and which is rotating by means of an electrostatic field of the backing roll; and attracting, at the coating point, the coating liquid by electrostatic force generated due to configuration of charges of the same polarity as that of the DC voltage applied and coating the first surface of the web with the coating liquid. The backing roll includes an outermost layer, an internal electrode layer, and an insulating layer in this order, the backing roll is configured to enable application of a predetermined voltage to the internal electrode layer, and the outermost layer is a ceramic material layer having a volume-specific resistance value of 10^7 Ωcm to 10^{13} Ωcm at a temperature of 25°C to 100°C.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to a method in which in a step of coating, by a curtain coating method, a bead coating method, or the like, a surface of a flexible belt-shaped support (hereinafter, referred to as web) continuously running while being supported by a backing roll, with one or a plurality of layers of a coating liquid containing a liquid composition, in particular, a water-soluble composition, electrostatic force is caused to act on a contact line portion (hereinafter, coating point) where the coating liquid comes into contact with the web, so that an air layer accompanying a front-side surface (coating surface) of the web is prevented from being taken in between the coating liquid and the web to promote the web to uniformly become wet with the coating liquid, to thereby increase uniformity of the coating thickness and the coating speed.

[0002] Further, the present invention relates to a method of causing a rear-side surface (backing roll-side surface) of the web to adhere to a surface of the backing roll to prevent an air layer accompanying the rear-side surface of the web and the surface of the roll from intruding between the web and the roll, thereby making it possible to raise the web speed limit until occurrence of a running trouble such as variation of web tension and speed, and swinging.

[0003] The present invention is applied to improvement of a coating method of a liquid composition, in particular, a water-soluble composition in manufacture of photographic film, photographic paper, magnetic recording tape, adhesive tape, pressuresensitive/heat-sensitive recording paper, coated paper, and the like.

Background Art

[0004] In curtain coating and bead coating, each of the front-side surface and the rear-side surface of a web moving at high speed is accompanied with an air layer.

[0005] Thicknesses of the accompanying air layers of the front-side surface and the rear-side surface are increased corresponding to the moving speed of the web. Therefore, when the speed reaches the limit speed, uniformity of the coating is lowered, or slip and swinging of the web occur. Thus, stable coating cannot be performed, and the coating speed cannot be increased to the limit speed or higher. To increase the speed while maintaining uniformity of the coating, a method of taking countermeasures against influence of the accompanying air layers on the front-side surface and the rear-side surface of the web at the same time is necessary.

[0006] On the front-side surface of the web, when the moving speed of the web is increased and the accompanying air layer is increased beyond a certain limit, the air layer intrudes under the coating liquid transferred to the web at the coating point, and the air layer cannot be extruded by the coating liquid. When the air layer intrudes under the coating layer, wet spread of the coating liquid on the front-side surface of the web is hindered, or the air layer is taken into the coating liquid to generate bubbles, which lowers uniformity of the coating layer. Therefore, the coating speed cannot be increased.

[0007] In the conventional curtain coating and bead coating, it is well known that, when assisting the coating point by a static electric field, it is possible to attract the coating liquid and to cause the coating liquid to adhere to the front surface of the web by electrostatic force with respect to ions and dipolar molecules in the coating liquid, thereby increasing the upper limit of the coating speed. As a method of assisting the coating point by the static electric field, 1) a method in which static charges are applied to the web from a corona discharge electrode disposed in a space, and then, the web is caused to pass through the coating point while the web is supported by a grounded coating backing roll, 2) a method in which a DC voltage is applied to a conductive coating backing roll (hereinafter, backing roll) insulated from the ground, and an electric field is formed between the surface of the web and the coating liquid at the coating point, and 3) a method in which these two methods are combined, are disclosed.

[0008] For example, Patent Literatures 1 to 4 each disclose the method 1) in which charges are applied to a dielectric web made of polyester or the like. When the web of a dielectric material in which bound polar charges are applied between a rear-side surface and a front-side surface opposing each other is conveyed to the coating point while being supported on the surface of the grounded conductive backing roll, the polar charges remaining on the front-side surface of the web attract the coating liquid to function so as to strongly eliminate the air layer under the coating liquid. As a result, the coating speed is increased. Patent Literatures 5 to 7 each disclose the method 2) in which a DC voltage is applied to a conductive backing roll insulated from the ground to charge the surface of the backing roll, the web is transferred to the coating point while being supported on the surface of the backing roll, an electric field is caused to act between the web and the coating liquid to cause the coating liquid to adhere to the web. Further, Patent Literature 7 discloses the method in which the methods 2) and 3) are combined.

[0009] An effect of applying the static charges to the web or an effect of assisting the surface of the conductive backing roll by static electricity indicates that a phenomenon in which the air layer accompanying the web is taken in between the front-side surface of the web and the coating liquid to hinder wet spread of the coating liquid is suppressed, and the limit speed at which transparency and thickness of the coating begin to become nonuniform is increased. In the conventional electrostatic-assisted coating 1) to 3), it is known that the accompanying air layer is more strongly eliminated as adhesion force of the coating liquid with respect to the front-side surface of the web is increased, and therefore, the coating speed is increased as the charge potential of the static electricity on the front-side surface of the web or the voltage on the surface of the backing roll is higher. In the electrostatic-assisted coating in which a voltage is applied to the conductive backing roll, however, it is known that, when the application voltage exceeds 1500 V, spark discharge from the backing roll to peripheral devices and a short-circuit current penetrating through the web easily occur. Further, even in the method in which the static charges are applied to the web, when the charge potential on the front-side surface of the web is increased, a short-circuit current penetrating through the web may occur between the coating liquid and the surface of the conductive backing roll at a pinhole or a portion with low insulation resistance in the web. Therefore, the surface potential of the web by the charges disclosed in Patent Literature 1 is 1200 V or less. In addition, for example, Patent Literature 4 discloses the electrostatic-assisted coating technique in which the surface potential of the web is set to be lower than 700 V to 800 V by simultaneously using a polarization effect of the coating liquid with a surfactant added therein, and Patent Literature 2 discloses the electrostatic-assisted coating technique in which the surface potential of the web is set to be lower than 700 V to 800 V by simultaneously using a method of charging the web by a conductive brush; however, the surface potential standardly recommended is as low as 400 V to 500 V. As described above, in the conventional electrostatic-assisted coating using the conductive backing roll, it is not possible to cause a sufficient potential to act on the coating point, and the effect of increasing the limit speed until occurrence of coating failure due to increase in accompanying air is insufficient.

[0010] Further, the rear-side surface of the web and the surface of the backing roll are each accompanied by the air layer. Therefore, the web floats by the combined accompanying air, and the floating amount is increased as the web speed is increased. When the web floating amount exceeds a certain limit, conveyance of the web becomes unstable, and increase in the accompanying air layer on the rear-side surface of the web hinders increasing the coating speed.

[0011] Floating amount h (μm) of a web at an air temperature of 25°C is given by the following expression (1) using backing roll radius R (m), roller speed U_R (m/s), web speed U_W (m/s), and web tension T (N/m).

[Expression 1]

$$h = 1.347 \times 10^{-3} R \left(\frac{U_R + U_W}{T}\right)^{\frac{2}{3}} \quad \cdots\cdots \quad (1)$$

(Hiromu Hashimoto, "Basic Theory and Application of Web Handling", Converting Technical Institute, p. 73)

[0012] The expression (1) shows that the thicknesses of the accompanying air layers drawn into the rear-side surface of the web and the surface of the roll are reduced as the web tension T is increased, and are increased as the roll radius R, the web speed U_W, or the backing roll speed U_R is increased (normally $U_W \approx U_R$).

[0013] In the electrostatic-assisted coating in which a voltage is applied to a conductive backing roll, when the conveyance speed of the web is increased and the web floats by the accompanying air layer between the web and the backing roll, the distance from the surface of the backing roll to the front-side surface of the web is increased, and the electrostatic capacitance is lowered by the air layer between the conductive backing roll and the rear-side surface of the web. Therefore, the amount of polar charges deposited in the web is reduced, and electrostatic force between the web and the coating liquid is lowered.

[0014] When the thickness of the accompanying air layer on the rear-side surface of the web exceeds the sum of the surface roughness of the roll and a surface roughness of the rear-side surface of the web, contact between the web and the surface of the backing roll is reduced, and traction force for the web is reduced. When the traction force for the web is reduced, the tension and the speed of the web are varied, the web meanders, and an issue such as scratch occurs on the rear-side surface of the web. Therefore, to increase the coating speed, countermeasures against floating of the web caused by the accompanying air layer sandwiched between the rear-side surface of the web and the backing roll are surely necessary.

[0015] Figure 7 and Figure 8 each illustrate relationship between the web conveyance speed and the floating amount calculated from the expression (1). As illustrated in Figure 7, when the web tension T is increased, floating of the web can be suppressed. However, when the web tension is increased, the load on a web conveyance system is increased, and the deflection amount of the backing roll and the deflection amount of a guide roll in a conveyance path of the web are increased. In addition, in a case where the web is thin, wrinkle easily occurs. Therefore, there is a limit in the method in which the tension of the web is increased.

[0016] As illustrated in Figure 8, when the diameter of the backing roll is reduced, the web floating amount is reduced. However, when the diameter of the backing roll is reduced, rigidity of the roll is reduced, and the deflection amount is increased. Further, when the diameter of the roll is reduced, the rotation number of the roll is increased based on the rate of reduction of the diameter. Therefore, the roll vibrates and a vibration pattern is generated in a coated film as the speed of the web is increased and the web is widened. In the roller curtain coating and the bead coating for the wide web having a width of 1500 mm or more, the diameter of the backing roll is preferably 100 mm or more in consideration of securement of deflection strength of the roll and an area necessary for installing a coating head (applicator). Although depending on the strength and the thickness of the web, the web tension is normally about 75 N/m to about 300 N/m in consideration of stretch and deformation of the web. As illustrated in Figure 7, in a case of using the backing roll having a diameter of 100 mm, even when the web tension is set to 150 N/m, the web floating amount is 6 μm at the moving speed of 100 m/minute. In a roll having a smooth surface, the traction force is lowered, and the tension and the speed are varied. Based on determination from the web floating amount illustrated in Figures 7 and 8, to increase the web conveyance speed to 100 m/minute or more in a case where the diameter of the backing roll is set to 100 mm or more, it is necessary to prevent the web from floating by the accompanying air layer on the rear-side surface of the web.

[0017] Patent Literature 7 discloses countermeasures against floating of the web by the accompanying air layer on the rear-surface side of the web in the electrostatic-assisted curtain coating in which the DC voltage is applied to the conductive backing roll having the diameter of 100 mm or more. In Patent Literature 7, in Examples, circumferential grooves (groove depth of 0.15 mm, width of 0.43 mm, and pitch of 1 mm) are formed on the surface of the backing roll having a diameter of 200 mm at a rate of 10% to 30% of the surface area of the roll, the accompanying air layer is discharged to the microgrooves to suppress floating of the web, thereby making it possible to increase the conveyance speed. However, the application voltage to the conductive backing roll is 800 V or less, and the electrostatic assistance action is lowered in the grooves. Thus, coating unevenness easily occurs. Therefore, in the case of using the microgrooves and the electrostatic assistance together, the increasing amount of the coating speed is up to 144 m/minute that is not so large.

Citation List

Patent Literature

[0018]

Patent Literature 1: Japanese Patent No. 2835659
Patent Literature 2: Japanese Patent Publication No. H01-035702
Patent Literature 3: Japanese Patent Laid-Open No. H08-252517
Patent Literature 4: Japanese Patent No. 2509316
Patent Literature 5: Japanese Patent Publication No. H06-009671
Patent Literature 6: Japanese Patent Publication No. S46-027423
Patent Literature 7: U.S. Patent No. 6177141

Non Patent Literature

[0019] Non Patent Literature 1: Hiromu Hashimoto, "Basic Theory and Application of Web Handling", Converting Technical Institute, p. 73

Summary of Invention

Technical Problem

[0020] In the curtain coating and the bead coating, the front-side surface (coating surface) and the rear-side surface (backing roll side) of a web moving at high speed are both accompanied with air layers, and thicknesses of the air layers on both surfaces are increased with increase in moving speed of the web. However, issues caused by the accompanying air layers are different between the front-side surface and the rear-side surface. On the front-side surface, a phenomenon in which the web goes not become wet with the coating liquid occurs, whereas on the rear-side surface, a phenomenon in which the web floats due to the accompanying air layer intruding between the rear-side surface of the web and the backing roll to unstabilize running of the web occurs. It is desirable to provide a high-speed coating technique that can simultaneously cope with the different issues caused by the accompanying air flows on the front-side surface and the rear-side surface of the web.

[0021] When a backing roll that enables increase in voltage applied to the surface of the roll to 1.5 kV or more, preferably up to about 3.5 kV is used, the dielectric web is more strongly polarized, and the electric field between the surface of the web and the coating liquid at the contact line portion (coating point) of the coating liquid and the web can be made much stronger than the electric field by the conventional method. Therefore, the coating speed can be increased as necessary only by adjustment of the application voltage.

[0022] At the same time, the rear-side surface of the web strongly polarized by the high voltage of the backing roll is strongly attracted to the backing roll by the electric field by positive charges on the surface of the backing roll, extrudes the accompanying air layer, and adheres to the surface of the backing roll. Thus, it is possible to increase the limit speed until occurrence of a running trouble of the web.

Solution to Problem

[0023] To achieve the above-described objects, the present invention adopts the following method.

[0024] The present invention provides an electrostatic-assisted coating method using a backing roll with high safety that does not cause spark discharge to peripheral devices even when a DC high voltage up to 6 kV is applied, does not cause a short-circuit current on a web that continuously runs while being supported by the roll, and does not cause electric shock even if a human body touches a surface of the roll, in a step of coating the web with a liquid composition (in particular, water-soluble composition). In the backing roll, a three-layer structure including an outermost layer, an internal electrode layer, and a lowermost layer without any gap is formed on the surface of the roll by using a high-insulating ceramic material for the lowermost layer, a conductive metal for the internal electrode layer, and a high-resistance ceramic material layer for the outermost layer. The internal electrode layer is completely electrically shielded from a core metal of the backing roll and the peripheral devices by the outermost layer and the lowermost layer. The insulation withstand voltage of each of the outermost layer and the lowermost layer is 6 kV or more. Therefore, even when the DC high voltage up to 6 kV is applied to the internal electrode layer, occurrence of spark discharge to the peripheral devices and a short-circuit current in the web are completely prevented.

[0025] More specifically, a method according to the present invention is

(1) a coating method of coating a first surface of a continuously moving flexible plastic web including the first surface and a second surface opposing to each other with a coating liquid composed of a liquid composition by causing the coating liquid to flow out from a grounded applicator, the method comprising:

conveying the web to a backing roll for coating along a path and causing the web to pass through a coating point while causing the second surface of the web to adhere to a part of a surface of the backing roll to which a DC voltage is applied and which is rotating by means of an electrostatic field of the backing roll to support the web; and attracting, at the coating point, the coating liquid by electrostatic force generated due to configuration of charges of the same polarity as that of the DC voltage applied to the baking roll on the first surface of the web to coati the first surface of the web with the coating liquid,

wherein the backing roll includes an outermost layer to which the web adheres, a conductive monopolar internal electrode layer adjacent to an inside of the outermost layer, and an insulating layer adjacent to an inside of the internal electrode layer, wherein the backing roll is configured to enable application of a predetermined voltage to the internal electrode layer, wherein the outermost layer is a ceramic material layer having a volume-specific resistance value of 10^7 Ωcm to 10^{13} Ωcm at a temperature of 25°C to 100°C, wherein in a state where the predetermined voltage is applied to the internal electrode layer, the surface of the backing roll charges the outermost layer with charges of the same sign as that of the voltage applied to the internal electrode layer, the second surface of the web coming into contact with the outermost layer by electrostatic force of the charges is caused to adhere to the outermost layer and is rotationally transferred, and the coating liquid is attracted to and brought into contact with the first surface of the web under rotational transfer to be deposited on the first surface of the web.

[0026] In the above-described coating method,

(2) before the coating liquid comes into contact with the web under rotational transfer, charges of a polarity opposite to that of the DC voltage applied to the internal electrode layer are applied to the first surface on a side opposite to the second surface of the web,
(3) the DC voltage applied to the internal electrode layer is 0.3 KV to 6.0 KV,
(4) the backing roll has a diameter of 100 mm or more,
(5) at least one of the insulating layer, the internal electrode layer, and the outermost layer is a layer member formed by a thermal spraying method or a layer member using either one of an inorganic binder or an organic binder, and at least one of the insulating layer, the internal electrode layer, and the outermost layer of the backing roll is subjected to sealing treatment,
(6) the outermost layer is made of a ceramic material, and the ceramic material is an alumina ceramic, a zirconium oxide ceramic or a magnesium oxide ceramic containing a compound selected from titanium oxide, chromium oxide, silicon oxide, manganese oxide, nickel oxide, and iron oxide or is an aluminum oxide ceramic containing 5 wt% to 17 wt% of titanium oxide,
(7) the ceramic material contains at least one selected from an aluminum nitride material, a silicon carbide material, and a silicon nitride material and contains an organic or inorganic binder,

(8) the outermost layer has a thickness of 50 μm to 500 μm,
(9) the outermost layer has a centerline average surface roughness Ra of 0.01 μm to 5 μm,
(10) the internal electrode layer is made of a conductive material containing tungsten or molybdenum,
(11) the internal electrode layer has a thickness of 5 μm to 50 μm,
(12) the insulating layer comprises at least one high-insulating material selected from aluminum oxide, an aluminum oxide ceramic material containing 2 wt% to 4 wt% of titanium oxide, a magnesium oxide ceramic material, a beryllium oxide ceramic material, an aluminum nitride ceramic material, a ceramic material containing silicon nitride, porcelain, and enamel,
(13) the insulating layer has a volume-specific resistance value of 10^{13} Ωcm or more, and
(14) the insulating layer has a thickness of 50 μm to 500 μm.

Advantageous Effects of Invention

[0027] The present invention is the electrostatic-assisted coating method using the backing roll with high safety that does not cause spark discharge to the peripheral devices even when the DC high voltage up to 6 kV is applied, does not cause a short-circuit current on the web that continuously runs while being supported by the roll, and does not cause electric shock even if a human body touches the surface of the roll, in the step of coating the web with the liquid composition (in particular, water-soluble composition). In the backing roll, the three-layer structure including the outermost layer, the internal electrode layer, and the insulating layer without any gap is formed on the surface of the roll by using a high-insulating ceramic material for the lowermost layer, a conductive metal for the internal electrode layer, and a high-resistance ceramic material layer for the outermost layer. The internal electrode layer is completely electrically shielded from the core metal of the backing roll and the peripheral devices by the outermost layer and the lowermost layer. The insulation withstand voltage of each of the outermost layer and the lowermost layer is 6 kV or more. Therefore, even when the DC high voltage up to 6 kV is applied to the internal electrode layer, occurrence of spark discharge to the peripheral devices is completely prevented.
[0028] The volume-specific resistance value of the high-resistance semiconductor ceramic as the outermost layer is 10^7 Ωcm to 10^{13} Ωcm. Therefore, when the DC voltage is applied to the internal electrode, the charges move from the internal electrode to the outermost surface, and the surface of the outermost layer is charged with the same polarity as that of the internal electrode. At the same time, the web coming into contact with the outermost surface of the backing roll is dielectrically polarized by the electric field of the internal electrode, the electric dipoles inside the web are coordinated so as to become charges of a polarity opposite to the polarity of the potential of the internal electrode toward a rear-side surface and to become the charges of the same polarity as that of the potential of the internal electrode toward a front-side surface. By the static charges of the same polarity as that of the internal electrode, coordinated on the surface side of the web, the coating liquid is attracted to the surface of the web and adheres to the web, eliminates the air layer accompanying the front-side surface of the web, and the coating liquid is promoted to wet the web. At the same time, the charges of a polarity opposite to that of the internal electrode, coordinated on the rear side of the web are attracted to free charges of the same polarity as that of the internal electrode, charged on the surface of the high-resistance semiconductor ceramic that is the outermost layer of the backing roll. Therefore, the web adheres to the surface of the backing roll. As described above, in the present invention, influence of the accompanying air layers on both the front-side surface and the rear-side surface of the web is eliminated, which makes it possible to largely increase the coating speed with respect to the web.
[0029] The present invention can achieve the following effects.

1. It is possible to perform coating of a liquid composition (in particular, water-soluble composition) by electrostatic assistance by applying a DC high voltage up to 6 kV to the internal electrode installed on the outer surface of the backing roll without generating spark discharge to the peripheral devices and without damaging the web by the short-circuit current.
2. It is possible to perform the electrostatic-assisted coating in which, in the state where the DC high voltage is applied to the internal electrode of the backing roll, an external assistance electrode is at the same time installed in an upper space of the front-side surface of the web, a DC voltage of 1.5 kV to 6 kV of a polarity opposite to that of the internal electrode is applied to apply charges of a polarity opposite to that of the internal electrode to the front-side surface of the web.
3. Even when the diameter of the backing roll is 100 mm or more, the web can be caused to completely adhere to the backing roll by electrostatic force by the static charges charged on the front surface of the high-resistance semiconductor ceramic present on the outermost surface, the electrostatic-assisted coating of the surface of the web can be effectively performed, swing and slip caused by floating of the web can be prevented, and the web conveyance speed can be increased to 400 m/minute or more.
4. Since the diameter of the backing roll can be increased based on the length of the roll, rigidity of the roll can be enhanced, and the web can be easily widened.

Brief Description of Drawings

[0030]

[Figure 1] Figure 1 is a cross-sectional view illustrating an example of a method according to the present invention for performing electrostatic-assisted coating using only a backing role in which a high voltage is applied to an internal electrode.
[Figure 2] Figure 2 is a diagram schematically illustrating a charge distribution state in a portion A illustrated in Figure 1.
[Figure 3] Figure 3 is an appearance diagram of the method according to the present invention as viewed from an oblique direction.
[Figure 4] Figure 4 is a cross-sectional view of a method according to a modification of the present invention for performing electrostatic-assisted coating by simultaneously using a backing roll in which a high voltage is applied to an internal electrode and a method in which static charges are applied to a web.
[Figure 5] Figure 5 is a diagram schematically illustrating a charge distribution state in a portion B illustrated in Figure 4.
[Figure 6] Figure 6 is an appearance diagram of the method according to the modification of the present invention as viewed from an oblique direction.
[Figure 7] Figure 7 is a graph illustrating change in web floating amount relative to tension and web speed in a backing roll having a diameter of 200 mm.
[Figure 8] Figure 8 is a graph illustrating change in web floating amount relative to diameter of a backing roll and web speed at a web tension of 150 N/m.

Description of Embodiment

[0031] Figure 1 to Figure 3 illustrate a method according to the present invention. Figure 2 schematically illustrates a charge distribution state in a portion A illustrated in Figure 1.

(1) To improve coating performance, it is important to lengthen a backing roll and to widen a web, in addition to increase in conveyance speed of the web. In a case where web tension is constant, however, the deflection amount of the roll is rapidly increased when the backing roll is lengthened. Therefore, to prevent deflection of the backing roll, it is necessary to enhance rigidity of the backing roll by increasing the diameter of the backing roll at the same time (deflection amount of roll is proportional to the third power of the roll length and is inversely proportional to the fourth power of the cross-sectional secondary moment (substantially proportional to roll diameter)). However, as described in the above-described expression (1), when the roll diameter is increased, an accompanying air layer on a rear-side surface of the web is proportionally increased. When the accompanying air layer is increased, the diameter of the backing roll cannot be increased and the roll cannot be lengthened in order to lower the upper limit of the web conveyance speed. In contrast, in the present invention, influence of the accompanying air layer on the rear side of the web can be eliminated. Thus, the diameter and the length of the backing roll can be increased as necessary, and the web can be widened. Based on recognition from Figure 8, influence of the accompanying air layer becomes remarkable when the diameter of a web conveyance roll is 100 mm or more. Therefore, the present invention is more effective when applied to a backing roll having a diameter of 100 mm or more.

[0032] An internal electrode layer 3 of a backing roll 1 according to the present invention is a conductor layer that is adjacent to the inside of an outermost layer 4 with no gap and is in contact with the outermost layer 4. The internal electrode layer 3 is of a monopolar type, and is connected to a DC high-voltage power supply 5 for application of a DC voltage, but is completely insulated from the ground and a core metal 16 of the backing roll 1 by an insulating layer 2 adjacent to the inside thereof.

[0033] As for the internal electrode layer 3, there are two types of a monopolar type and a bipolar type depending on a voltage application method. The monopolar type includes only a positive (+) or negative (-) single internal electrode, and a voltage is applied only to the single electrode relative to the ground. The bipolar type includes two or more internal electrodes different in polarity. When a web to be attracted is grounded, charges (current) leak to the ground, and electrostatic attraction force becomes unstable. In the present invention, the internal electrode layer 3 is of the monopolar type. The internal electrode layer 3 is continuously uniformly provided over a range wider than a width of a web 7 in the axis direction of the backing roll 1, and over an entire circumference of the backing roll 1 in the rotation direction of the backing roll 1. In a case where the internal electrode 3 has a comb blade shape, a belt shape, or a spiral shape, shape irregularity occurs on a coating layer. Note that, at both end parts of a cylindrical surface of the backing roll 1 outside the supporting range of the web 7, the internal electrode layer 3 may not be formed.

[0034] The outermost layer 4 is made of a high-resistance ceramic material, and the volume-specific resistance value of the outermost layer 4 is $10^7\ \Omega$cm to $10^{13}\ \Omega$cm and more preferably $10^8\ \Omega$cm to $10^{12}\ \Omega$cm at a temperature of 25°C to 100°C.

In a "field for handling static electricity", a substance having a volume-specific resistance value of 10^{13} Ωcm or more is classified into an insulator because static electricity hardly moves. A material having a volume-specific resistance value of less than 10^{6} Ωcm is referred to as an electrostatic conductor, allows static electricity to easily move, and becomes equipotential when a voltage is applied. A material having a volume-specific resistance value of 10^{7} Ωcm to 10^{13} Ωcm is classified into an intermediate region between a conductor and an insulator, and is classified into "electrostatic semiconductor". It is known that, when a voltage is applied to such material, a minute current flows, and free charges move to a surface to charge the material as with the conductor. The charge amount of the free charges depends on the application voltage. Unlike a surface of a conductive metal, on a surface of such a high-resistance semiconductor ceramic material, only a minute current of about 0.001 μA/cm^2 to about 10 μA/cm^2 locally flows even when a high voltage of 3.5 kV to 6 kV is applied. Therefore, discharge by the free charges on the surface become minute corona without being developed to arc discharge, and spark discharge toward peripheral devices does not occur.

[0035] In the present invention, as illustrated in Figure 2, when a DC voltage is applied to the internal electrode layer 3, the free charges 17 having the same polarity as that of the internal electrode 3 move to and charge the surface of the outermost layer 4. When a second surface 13 (rear-side surface) of the web 7 comes into contact with the surface of the outermost layer 4, dipoles 18 inside the web 7 are coordinated by directing poles opposite to the free charges 17 toward the surface of the outermost layer 4 owing to dielectric polarization caused by an electric field of the internal electrode. Further, the web 7 adheres to the surface of the outermost layer 4 by electrostatic force between the charges 17 on the surface of the outermost layer 4 and the reverse charges of the dipoles coordinated on the second surface 13 of the web 7. At this time, a first surface 12 (front-side surface) of the web as a coating surface is polarized and charged to the same polarity as that of the internal electrode by an electrostatic field of the internal electrode 3. By the "polar charges", a coating liquid is attracted to the first surface 12 of the web 7 under rotational transfer, and a uniform coating layer 11 can be formed on the first surface 12 of the web 7 without making the accompanying air layer intrude between the coating liquid 9 and the first surface 12 of the web 7. When the voltage applied to the internal electrode 3 is higher, the amount of polar charges on the first surface 12 deposited by dielectric polarization of the web 7 is increased, and the electric field thereof is intensified. This makes it possible to largely increase the coating speed.

[0036] (2) Figures 4 and 5 are side views illustrating an example of a method according to a modification of the present invention. Figure 5 schematically illustrates a charge distribution state in a portion B illustrated in Figure 4.

[0037] The method according to the modification of the present invention is a method in which, in the same apparatus configuration as in the method according to the present invention, a space assistance electrode 14 is additionally installed at a position on an upstream of the coating point, a high voltage of a polarity opposite to the polarity of the internal electrode 4 is applied to generate corona discharge, thereby charging the first surface 12 of the web 7 with free charges 19 of a polarity opposite to the polarity of the internal electrode layer 3.

[0038] The withstand voltage of the outermost layer 4 of the backing roll 1 is up to 6 kV, and the volume-specific resistance value is 10^{7} Ωcm to 10^{13} Ωcm. Therefore, even when a pinhole or a portion with weak insulation resistance is present on the web charged with the charges 19, generation of a short-circuit current from the coating liquid to the backing roll 1 at these defect portions is prevented. Therefore, by increasing the corona discharge potential of the external assistance electrode 14 installed in a space on the upstream side of the coating point as necessary, the charge amount of the free charges 19 with respect to the first surface 12 of the web 7 can be increased, and the coating speed by electrostatic assistance can be further largely increased. A sufficient effect can be achieved by applying the DC voltage of (-)3.5 kV to 6 kV to the external assistance electrode, and when the external assistance electrode is installed while an appropriate distance relative to the peripheral devises is maintained, spark discharge does not occur.

[0039] Further, by the electrostatic force between the charges 17 on the surface of the outermost layer 4 and the charges 19 charged on the first surface of the web, the web 7 more firmly adheres to the surface of the outermost layer 4, which makes it possible to completely prevent intrusion of the accompanying air flow to the rear side of the web 7. Accordingly, the web conveyance speed can be largely increased as necessary with increase in coating speed.

[0040] (3) The web 7 to be attracted according to the present invention has flexibility. Therefore, it is necessary to eliminate a non-adhesion portion on an entire contact surface between the web 7 and the backing roll 1, and uniform strong adhesion force is necessary. The voltage applied to the internal electrode layer 3 sufficient to obtain electrostatic force necessary for electrostatic adhesion of the web 7 is generally a DC voltage of (+)0.3 kV to 3.5 kV. An electrostatic assistance effect is enhanced as the application voltage is higher, and the electrostatic force is insufficient when the application voltage is 0.3 kV or less. Since the withstand voltage of the outermost layer 4 is up to 6 kV or more, spark discharge does not occur even when the DC voltage of +3.5 kV is applied.

[0041] (4) At least one of the insulating layer 4, the internal electrode layer 3, and the outermost layer 2 of the backing roll 1 is a layer member formed by a thermal spraying method or a layer member using either one of an inorganic binder or an organic binder, and at least one thereof is subjected to sealing treatment.

[0042] The thermal spraying used herein is a coating technique in which a coating material is melted or softened by heating and is turned into particles, the particles are accelerated to collide with a surface of an object to be coated, and the particles crushed flat are solidified and deposited to form a coating. The thermal spraying includes various methods that are classified based on a used material, a type of a heat source, and the like. In the present invention, an atmospheric plasma spraying method is particularly suitable.

[0043] In a case where a spraying ceramic material is used for the outermost layer 4 and the outermost layer 2, at least one of the insulating layer 2, the internal electrode layer 3, and the outermost layer 4 is preferably subjected to sealing treatment. A thermally sprayed ceramic coating is an aggregation of flat thermally-sprayed particles, a minute gap is present among the thermally-sprayed particles, and interconnecting pores corresponding to 3 Vol% to 10 Vol% of the total volume of the thermally-sprayed coating are formed. In a normal atmospheric environment, air containing moisture or liquid infiltrates the pores, and water molecules are adsorbed to inner walls of the pores. Therefore, the thermally-sprayed coating is significantly low in insulation resistance and withstand voltage. When the thermally sprayed ceramic is infiltrated with an insulating sealing agent, the interconnecting pores disappear, and the volume-specific resistance value is stabilized. Thus, the ceramic material high in withstand voltage and excellent in corrosion resistance is obtained. The sealing treatment after coating of the ceramic material is performable even for a large backing roll having a diameter of 200 mm or more used in an actual machine, and is a practical method. As a material used for the sealing treatment, a liquid sealing treatment agent such as a low-viscosity silicon oligomer (for example, viscosity of 8 mPs to 40 mPs, 25°C), a low-viscosity epoxy resin (for example, viscosity of 80 mPs to 400 mPs, 25°C), a polyester resin, a lithium silicate solution forming inorganic coating, and a metal alkoxide forming inorganic sol can be used by reducing the viscosity through dilution with a solvent. In the present invention, the low-viscosity silicon oligomer and the low-viscosity epoxy resin are preferable because the low-viscosity silicon oligomer and the low-viscosity epoxy resin have excellent impregnation characteristics, insulating performance, and withstand voltage characteristics. As for the thickness range of a sealing treatment layer, the entire thermal splayed layer is preferably sealed. As described above, it is important to stabilize the volume specific resistance value and the withstand voltage characteristics of the sealing agent by infiltrating the sealing agent into the pores of the thermally-sprayed coating to seal the pores and thereafter heating to cure the sealing agent. The insulating layer 2 and the outermost layer 4 cannot be adjusted to have the inherent volume-specific resistance value and the inherent withstand voltage unless the pores inside the thermally-sprayed coating are surely sealed.

[0044] The volume-specific resistance value of the outermost layer 4 at a temperature of 25°C to 100°C after the sealing treatment is 10^7 Ωcm to 10^{13} Ωcm, preferably 10^8 Ωcm to 10^{12} Ωcm, and more preferably 10^9 Ωcm to 10^{12} Ωcm. When the volume-specific resistance value is less than 10^7 Ωcm, occurrence of a short-circuit current that flows through the web 7 coming into contact with the surface of the backing roll 1 from the coating liquid connected to the ground, or occurrence of spark discharge to the peripheral devices cannot be prevented. In other words, when the volume-specific resistance of the outermost layer 4 is 10^7 Ωcm or less, the electrostatic-assisted coating in which a high voltage of 1.5 kV or more is applied to the backing roll and the surface of the web cannot be performed, which is not preferable.

[0045] In contrast, when the volume-specific resistance value of the outermost layer 4 exceeds 10^{13} Ωcm, the outermost layer 4 becomes an insulating dielectric, and the free charges 17 do not substantially flow from the internal electrode layer 3. As a result, the surface of the outermost layer 4 cannot be charged with the free charges 17 having the same polarity as that of the internal electrode, which is not preferable. In a case where the outermost layer 4 is a dielectric having electric characteristics of insulating property, the dipoles 18 are coordinated such that the polarity of the charges on the surface of the outermost layer 4 becomes the same as the polarity of the internal electrode 3owing to dielectric polarization by the voltage of the internal electrode 3. At this time, charge of the surface of the outermost layer 4 is caused by the charges fixed to the dipoles, and cannot be eliminated by neutralization with free charges. When the web 7 is separated from the backing roll, reverse charges remain on the surface of the outermost layer 4 by separated charge. The reverse charges are trapped to fixed charges at dipole ends in the outermost layer 4 in a state where the voltage is applied to the backing roll, and the apparent charge potential is reduced but the reverse charges remain without being eliminated. When the surface of the outermost layer 4 is put into such a state, the web 7 is repelled from the surface of the outermost layer 4. In other words, when the volume-specific resistance value is higher than 10^{13} Ωcm, the outermost layer 4 becomes the insulating dielectric, and the separated charges of the web remain on the surface of the outermost layer 4 without being neutralized. Therefore, the web cannot adhere to the surface of the outermost layer 4, which causes an issue in running of the web.

[0046] (5) The outermost layer 4 is made of a ceramic material. The ceramic material is an alumina ceramic, zirconium oxide ceramic or magnesium oxide ceramic containing a compound selected from titanium oxide, chromium oxide, silicon oxide, manganese oxide, nickel oxide, and iron oxide or is an aluminum oxide ceramic containing 5 wt% to 17 wt% of titanium oxide.

[0047] The preferable material of the outermost layer 4 according to the present invention is a material having a volume-specific resistance value adjustable to 10^7 Ωcm to 10^{13} Ωcm and excellent in handleability. In terms of adhesiveness with the internal electrode layer 2, denseness, stability of the volume-specific resistance value, handleability, and the like, an aluminum oxide ceramic material layer containing 5 wt% to 17 wt% of titanium oxide, preferably 7 wt% to 15 wt% of titanium oxide, formed by the thermal spraying method is most preferable.

[0048] (6) Likewise, in the present invention, as for the outermost layer 4 and the insulating layer 2, a non-oxide ceramic material layer using an organic or inorganic binder, formed by the thermal spraying method is also preferable. As long as the volume-specific resistance value and the withstand voltage can be secured, each of the outermost layer 4 and the insulating layer 2 may be a coating layer formed by being coated with a coating material made of a ceramic material containing an organic binder such as polyimide or an inorganic binder such as aluminum phosphate, a water glass binder, and a silicon binder; at least one selected from an aluminum nitride material, a silicon carbide material, and a silicon nitride material formulated to have a volume-specific resistance value suitable for the present invention; and an organic or inorganic binder.

[0049] (7) The thickness of the outermost layer 4 is preferably 50 μm or more, and more preferably 80 μm to 500 μm. The lower limit value of the thickness is a lower limit film thickness necessary for guaranteeing that a pinhole penetrating through the outermost layer 4 up to the internal electrode layer 3 is absent, and is a film thickness that can secure the withstand voltage with respect to the minimum application voltage necessary for stable adhesion force of the web 7. The upper limit value of the thickness is set in consideration of the maximum application voltage. To obtain higher electrostatic assistance effect, a higher application voltage is necessary, and it is necessary to increase the thickness of the outermost layer 4, thereby increasing the withstand voltage. However, since sufficient effect is obtainable when the application voltage to the internal electrode layer is 3.5 kV, the withstand voltage of up to 6 kV is sufficient in consideration of the safety factor. When the thickness of the outermost layer 4 is greater than 500 μm at which the withstand voltage is obtained, the thermal spraying time is merely increased, which is not preferable.

[0050] (8) The centerline average surface roughness Ra of the outermost layer 4 of the backing roll 1 according to the present invention is 0.01 μm to 5 μm. It is difficult to obtain a smooth surface having a surface roughness of less than 0.01 μm by a practical ceramic layer polishing technique. Running of the web at high speed is stabilized as the surface roughness of the outermost layer 4 is increased, but when the surface roughness exceeds 5 μm, the surface roughness of the outermost layer 4 is transferred to the rear surface of the web, which is not preferable.

[0051] (9) As for the material of the internal electrode layer 3, a baking conductive paste of tungsten, molybdenum, high-performance activated carbon, copper, silver, and the like can be used, but a thermally sprayed coating of tungsten or molybdenum formed by a plasma spraying method is preferable because of high conductivity and handleability.

[0052] (10) Since the volume-specific resistance value of the outermost layer 4 is as high as 10^7 Ωcm to 10^{13} Ωcm, even in a state where a high voltage of 6 kV is applied to the internal electrode, the total current flowing from the internal electrode to the surface of the web is extremely small, for example, several mA or less. Therefore, it is sufficient for the internal electrode layer 3 to have a thickness of 5 μm to 50 μm, and the internal electrode layer 3 is preferably thin as much as possible in order to smooth boundaries of the internal electrode 3 at the both end parts of the roll.

[0053] (11) As for the high-insulating material for the insulating layer 2, a ceramic sprayed film made of high-purity alumina having a purity of 99.6% or more or alumina containing 2 wt% to 4 wt% of titanium oxide, or a coating material containing a ceramic material selected from a magnesium oxide ceramic material, a beryllium oxide (BeO) ceramic material, an aluminum nitride (AlN) ceramic material, a silicon nitride (Si3N4) ceramic material, and the like is preferable. Further, a polymer resin selected from polyimide, polyphenylene oxide, polytetrafluoroethylene (Teflon(R)), polytrifluorochloroethylene, polyethylene, polypropylene, polystyrene, and the like, an SiO2 glass film such as porcelain and enamel, or the like may be used; however, in the present invention, a ceramic sprayed coating made of high-purity alumina having a purity of 99.6% or more or alumina containing 2 wt% to 4 wt% of titanium oxide is most preferable in terms of insulating performance, heat conductivity, handleability, cost, and the like.

[0054] (12) The volume-specific resistance value of the insulating layer 2 which is the innermost layer in contact with the core metal 16 of the backing roll 1 according to the present invention is preferably 10^{13} Ωcm or more. This is to reduce a leakage current from the internal electrode layer 3 to the core metal 16 through the insulating layer 2, to an uninfluential level.

[0055] (13) The thickness of the insulating layer 2 is preferably 50 μm to 500 μm. If the thickness is less than 50 μm, the withstand voltage for enabling application of the minimum voltage 0.3 kV to the internal electrode layer 3 in order to obtain necessary adhesion force is insufficient. To enable voltage application up to 6 kV to the internal electrode layer, the withstand voltage of the insulating layer 3 is desirably 6 kV or more, but the sufficient thickness necessary for the withstand voltage is 500 μm.

[0056] (14) Examples of the web used in the present invention include paper, plastic film, resin-coated paper, and synthetic paper. Examples of the material of the plastic film include polyolefin such as polyethylene and polypropylene, a vinyl polymer such as polyvinyl acetate, polyvinyl chloride, and polystyrene, polyamide such as 6,6-nylon and 6-nylon, polyester such as polyethylene terephthalate and polyethylene-2,6-naphthalate, polycarbonate, and cellulose acetate such as polycarbonate, cellulose triacetate, and cellulose diacetate. As a resin used for the resin-coated paper, polyolefin such as polyethylene is representative, but is not limited thereto. The web can include one or some layers previously coated.

[0057] (15) The "coating liquid" includes various liquid compositions depending on application, and can be used for forming, for example, a photosensitive emulsion layer of a photographic sensitive material, an undercoat layer, a protection layer, a backing layer, an antistatic layer, an anti-halation layer, and the like. In a case of an inkjet receiving medium, the "coating liquid" can be used for forming an ink absorbing layer. Further, the "coating liquid" can be used for a magnetic layer of a magnetic recording medium, an undercoat layer, a lubricating layer, a protection layer, a back layer, an adhesion layer, a colored layer, a rustproof layer, and the like. The coating liquid can contain a water-soluble binder or an organic binder.

[0058] (16) Surface tension and coating suitability of the coating liquid can be modified using a surfactant. As the surfactant, a nonionic surfactant such as polyalkylene oxide and water-soluble glysidol-alkylphenol adduct, an anionic surfactant such as alkylaryl polyether sulphate and sulfonate, an amphoteric surfactant such as arylalkyl taurine, N-alkyl and N-acyl β-amino propionate, saponin, alkyl ammonium sulfonic acid betaine, and the like can be used.

[0059] (17) A thickener can be used for the coating liquid in order to adjust viscosity.

[0060] (17) A coating applicator to which the present invention is applicable is a bead coating applicator, a curtain coating applicator, an extrusion coating applicator, and a slide-extrusion coating applicator.

[Measurement Method]

[0061] The method of measuring a physical property value used in the present invention is as follows.

1. Centerline Average Roughness Ra

[0062] In measurement of the surface roughness of the backing roll, in a case where measurement was performable in a roll state, the average roughness Ra of the surface was measured by a portable surface roughness meter. The measurement instrument complied with JIS B 0651, a sensing pin that had a conical shape with a vertex angle of 60 degrees and had a radius of curvature at a spherical chip of 2 μm was used, the measurement method complied with JIS B 0601-2013, measurement was performed under a condition of a cutoff value of 0.8 mm, and the centerline average roughness Ra was determined. The measurement was performed using, as the measurement instrument, Surfcoder SE1700α manufactured by Kosaka Laboratory Ltd.

2. Volume-Specific Resistance Value

[0063] The volume-specific resistance value of the outermost layer 4 on the surface of the backing roll 1 was measured according to the testing method of ceramic insulators for electrical and electronic applications defined in JIS C 2141-1992. A main electrode having an outer diameter of 26 mm and a guard electrode having an outer diameter of 48 mm and an inner diameter of 38 mm were cut out from a conductive adhesion sheet, and were concentrically attached to a curved surface of the outermost layer 4 so as to meet the three terminal method of JIS C 2141. A conductor wire in which a terminal of the conductor wire is attached with conductive adhesion tape was used for contact on surfaces of the main electrode and the guard electrode. As a counter electrode, the internal electrode layer 3 of the backing roll was used. In the measurement, a value after one minute from measurement start was adopted. As a measurement instrument, a super megohmmeter R-503 manufactured by Kawaguchi Electric Works Co., Ltd. was used. A DC voltage of 500 V was applied between the guard electrode and both the main electrode and the internal electrode layer 3, the volume resistance R_v (= V/I) was determined from the current value I (A) flowing through the main electrode and the counter electrode (internal electrode layer 3) at that time, and the volume-specific resistance value ρ_v was calculated by the following expression.

$$\rho_v\ (\Omega cm) = R_v \times A/d$$

$$A = \pi \times D^2/4$$

where

V: application voltage (V),
R_v: volume resistance (Ω),
ρ_v: volume-specific resistance value (Ωcm),
A: main electrode area (cm^2),
D: main electrode outer diameter (cm), and d: outermost layer thickness (cm).

[0064] The thickness d was measured by a magnetic or eddy current thickness meter. As a measurement instrument, a magnetic/eddy-current coating thickness measurement instrument DUALSCOPE FMP20 manufactured by Fischer Instruments K.K. was used.

Examples

(Example 1)

[0065] By the method illustrated in Figure 1, the web 7 was continuously conveyed to the backing roll 1, a DC voltage was applied only to the internal electrode 3 of the backing roll, and the electrostatic-assisted curtain coating by the method according to the present invention was performed.

[0066] The backing roll 1 used at this time was manufactured in the following manner.

[0067] After sandblast treatment was performed on the entire surface of a middle drum part of a cylindrical core metal 16 made of steel and having a diameter of 200 mm, an 80 wt% Ni/20 wt% Cr alloy having a thickness of 50 μm was laminated by plasma spraying, as a bonding layer for improving adhesion force of the ceramic layer. Subsequently, after aluminum oxide (alumina) (99.6 wt% Al_2O_3) as a high insulating material was laminated by 250 μm on a surface of the bonding layer by plasma spraying, sealing treatment with a low-viscosity epoxy resin was performed on the sprayed alumina layer to form the insulating layer 2 having a volume-specific resistance value of 10^{14} Ωcm or more. Tungsten (W) having a thickness of 30 μm was laminated on the insulating layer 2 by plasma spraying to form the internal electrode layer 3. At this time, masking was performed with a width of 20 mm from each end in the width direction of the backing roll 1, so that the internal electrode layer 3 was not formed within these regions. After the masks at the both ends were removed, an alumina ceramic material containing 10 wt% of titanium oxide (TiO_2) and 90 wt% of alumina (Al_2O_3) was laminated with a thickness of 400 μm as the outermost layer 4 on the both ends and the upper surface of the internal electrode layer 3, namely, over the entire cylindrical surface of the backing roll 1, by plasma spraying. Likewise, the sealing treatment with the low-viscosity epoxy resin was performed on the tungsten layer of the internal electrode layer 3 and the alumina ceramic material layer, which resulted in the outermost layer 4 having a volume-specific resistance value of 5.6×10^{10} Ωcm.

[0068] Polishing with a diamond whetstone was performed on the outermost layer 4 subjected to the sealing treatment such that the remaining thickness was 300 μm and the surface roughness Ra after polishing was 0.05 μm. To enable electric connection to the internal electrode layer 3, masking on a rectangular range of 20 mm × 30 mm was performed at an end on one side of the roll when thermal spraying of the outermost layer 4 was performed, and the internal electrode layer 3 was exposed at the end of the roll with the width of 20 mm × 10 mm after the outermost layer 4 was thermally sprayed. A slip ring 6 was connected to the exposed internal electrode layer 3. The DC high-voltage power supply 5 was connected to the slip ring 6, and a DC voltage (+)3.5 kV was applied to the internal electrode layer 3. Even when a finger touched the surface of the outermost layer 4 in a state where the voltage was applied to the internal electrode, the current felt by a human body did not flow.

[0069] The web 7 was a polyethylene terephthalate film having a thickness of 100 μm, and included a gelatin undercoat layer having a thickness of 0.3 μm. The rear surface and the front surface of the web 7 were previously alternately brought into contact with a grounded roll in a heating furnace at a temperature of 90°C to 100°C to remove the charges until the surface potential was ±50 V or less, and then, the web 7 was cooled to 25°C.

[0070] Under a condition that the curtain height of the coating liquid 9 was 10 cm, the coating angle was 30 degrees in a front direction from an apex of the roll, the tension of the web 7 was 150 N/m, and the conveyance speed of the web 7 was 400 m/min, coating of a gelatin composition was performed such that the thickness of the wet coating layer 11 was 60 μm. As the coating liquid, 15% of gelatin solution with 0.1% of sodium dodecylbenzene sulfonate was used, the low shearing viscosity was adjusted to 100 mPa·s by a thickener, and the flow velocity of the coating liquid was set to 4 cc/second per coating width of 1 cm.

[0071] The rear surface 12 of the web 7 adhered to the surface of the backing roll 1, and running of the web was stable. Coating can be continued without occurrence of coating failure caused by that air layer accompanying the surface of the web which was taken in under the coating liquid, and the wet coating layer 11 was excellent in uniformity of the thickness and had the smooth surface. Spark discharge from the backing roll to the periphery did not occur, and a short-circuit current penetrating through the web 7 from the coating liquid 9 to the surface of the roll did not occur.

(Comparative Example 1)

[0072] In a case where the voltage applied to the internal electrode 3 was set to zero and coating was performed under the same configuration condition as the configuration condition in Example 1, the accompanying air layer could not be eliminated only by the curtain of the coating liquid 9, and the surface 12 of the web 7 was not wetted with the coating liquid. Thus, uniform coating could not be performed. In addition, the web 7 floated from the backing roll. Therefore, the traction force of the web 7 by the backing roll 1 was lowered, the tension and the speed of the web 7 were varied, and running was unstable. Thus, the coating could not be continued.

(Example 2)

[0073] In the coating apparatus same as the coating apparatus in Example 1, the web 7 was conveyed to the backing roll 1 having a diameter of 200 mm, the application voltage to the internal electrode 3 was set to +3.5 kV, the tungsten line electrode 14 having a diameter of 0.5 mm was additionally installed at a position separated by a distance of 10 mm from the web as illustrated in Figure 2, a voltage of -3 kV was applied to cause negative charges (-) to adhere to the first surface of the web 7 from the electrode 14, and the electrostatic-assisted curtain coating by the method according to the modification of the present invention was performed.

[0074] The web 7 was a polyethylene-coated paper having a thickness of 100 μm, and included a gelatin undercoat layer having a thickness of 0.6 μm. The rear surface and the front surface of the web 7 were previously alternately brought into contact with a grounded roll in a heating furnace at a temperature of 90°C to 100°C, to remove the charges until the surface potential was ±50 V or less, and then, the web 7 was cooled to 25°C.

[0075] Under a condition that the curtain height was 10 cm, the coating angle was 30 degrees in the front direction from the apex of the roll, the tension of the web 7 was 150 N/m, and the conveyance speed of the web was 400 m/min, coating of a gelatin composition was performed such that the thickness of the wet coating layer was 35 μm. As the coating liquid 9, 12% of gelatin solution with 0.1% of sodium dodecylbenzene sulfonate was used, the low shearing viscosity was adjusted to 21 mPa·s by a thickener, and the flow velocity of the coating liquid was set to 2.3 cc/second per coating width of 1 cm. The second surface 13 of the web 7 adhered to the surface of the backing roll 1, and running of the web was stable. Coating can be continued stably without occurrence of coating failure caused by that air layer accompanying the first surface 12 of the web 7 which was taken in under the coating liquid, and the wet coating layer 11 was excellent in uniformity of the thickness and had the smooth surface. Spark discharge from the backing roll to the periphery and glow discharge did not occur, and a short-circuit current penetrating through the web 7 from the coating liquid 9 to the surface of the roll did not occur.

(Comparative Example 2)

[0076] In a case where the voltage applied to the internal electrode 3 was set to zero and coating was performed under the same configuration condition as the configuration condition in Example 2, the wet coating layer 11 adhering to the entire first surface 12 of the web could be formed by the coating liquid 9. However, the accompanying air layer intruded between the rear surface 13 of the web and the backing roll, and the web 7 floated. Thus, the tension and the speed of the web 7 were unstable, the web 7 was swung, running of the web 7 was unstable, and the wet coating layer 11 having the smooth surface could not be continuously formed.

Reference Signs List

[0077]

1 Backing roll
2 Insulating layer
3 Internal electrode (+)
4 Outermost layer
5 DC high-voltage power supply (for internal electrode)
6 Slip ring
7 Belt-shaped support (web)
8 Applicator (coating head)
9 Curtain of coating liquid
10 Coating liquid contact line portion (coating point)
11 Wet coating layer
12 First surface (front surface) of web
13 Second surface (rear surface) of web
14 Space assistance electrode (-)
15 DC high-voltage power supply (for space assistance electrode)
16 Roll core metal
17 Free charge (+)
18 Dipole inside web
19 Surface charge (-)

Claims

1. A coating method of coating a first surface of a continuously moving flexible plastic web including the first surface and a second surface opposing to each other with a coating liquid composed of a liquid composition by causing the coating liquid to flow out from a grounded applicator, the method comprising:

   conveying the web to a backing roll for coating along a path and causing the web to pass through a coating point while causing the second surface of the web to adhere to a part of a surface of the backing roll to which a DC voltage is applied and which is rotating by means of an electrostatic field of the backing roll to support the web; and attracting, at the coating point, the coating liquid by electrostatic force generated due to configuration of charges of the same polarity as that of the DC voltage applied to the baking roll on the first surface of the web to coati the first surface of the web with the coating liquid,
   wherein the backing roll includes an outermost layer to which the web adheres, a conductive monopolar internal electrode layer adjacent to an inside of the outermost layer, and an insulating layer adjacent to an inside of the internal electrode layer, wherein the backing roll is configured to enable application of a predetermined voltage to the internal electrode layer, wherein the outermost layer is a ceramic material layer having a volume-specific resistance value of 10^7 Ωcm to 10^{13} Ωcm at a temperature of 25°C to 100°C, wherein in a state where the predetermined voltage is applied to the internal electrode layer, the surface of the backing roll charges the outermost layer with charges of the same sign as that of the voltage applied to the internal electrode layer, the second surface of the web coming into contact with the outermost layer by electrostatic force of the charges is caused to adhere to the outermost layer and is rotationally transferred, and the coating liquid is attracted to and brought into contact with the first surface of the web under rotational transfer to be deposited on the first surface of the web.

2. The coating method according to claim 1, wherein, before the coating liquid comes into contact with the web under rotational transfer, charges of a polarity opposite to that of the DC voltage applied to the internal electrode layer are applied to the first surface on a side opposite to the second surface of the web.

3. The coating method according to claim 1, wherein the DC voltage applied to the internal electrode layer is 0.3 KV to 6.0 KV.

4. The coating method according to claim 1, wherein the backing roll has a diameter of 100 mm or more.

5. The coating method according to claim 1, wherein at least one of the insulating layer, the internal electrode layer, and the outermost layer is a layer member formed by a thermal spraying method or a layer member using either one of an inorganic binder and an organic binder, and at least one of the insulating layer, the internal electrode layer, and the outermost layer of the backing roll is subjected to sealing treatment.

6. The coating method according to claim 1, wherein the outermost layer is made of a ceramic material, and the ceramic material is an alumina ceramic, a zirconium oxide ceramic or a magnesium oxide ceramic containing a compound selected from titanium oxide, chromium oxide, silicon oxide, manganese oxide, nickel oxide, and iron oxide or is an aluminum oxide ceramic containing 5 wt% to 17 wt% of titanium oxide.

7. The coating method according to claim 1, wherein the outermost layer is made of a ceramic material, and the ceramic material contains at least one selected from an aluminum nitride material, a silicon carbide material, and a silicon nitride material and contains an organic or inorganic binder.

8. The coating method according to claim 1, wherein the outermost layer has a thickness of 50 μm to 500 μm.

9. The coating method according to claim 1, wherein the outermost layer of the backing roll has a centerline average surface roughness Ra of 0.01 μm to 5 μm.

10. The coating method according to claim 1, wherein the internal electrode layer is made of a conductive material containing tungsten or molybdenum.

11. The coating method according to claim 1, wherein the internal electrode layer has a thickness of 5 μm to 50 μm.

12. The coating method according to claim 1, wherein the insulating layer comprises at least one high-insulating material

selected from aluminum oxide, an aluminum oxide ceramic material containing 2 wt% to 4 wt% of titanium oxide, a magnesium oxide ceramic material, a beryllium oxide ceramic material, an aluminum nitride ceramic material, a ceramic material containing silicon nitride, porcelain, and enamel.

13. The coating method according to claim 1, wherein the insulating layer has a volume-specific resistance value of 10^{13} Ωcm or more.

14. The coating method according to claim 1, wherein the insulating layer has a thickness of 50 μm to 500 μm.

Fig. 1

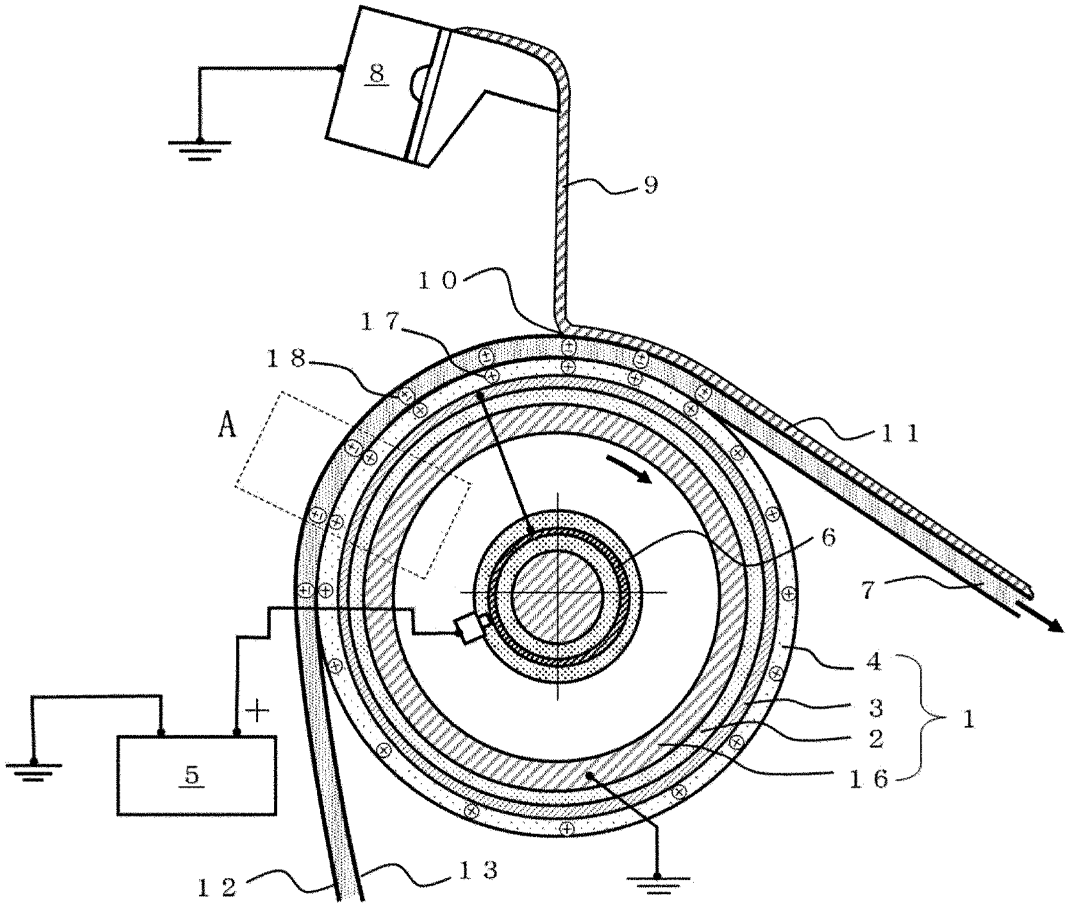
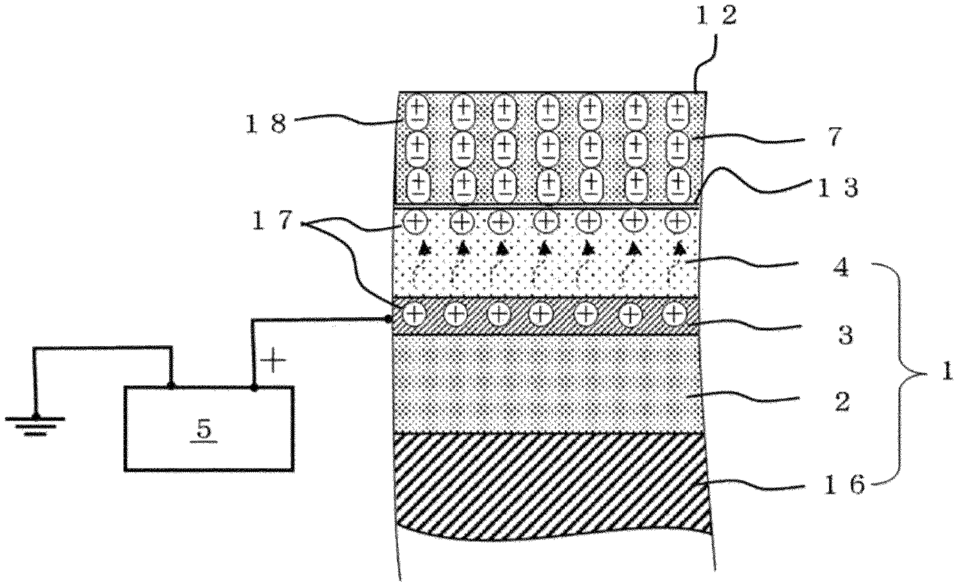


Fig. 2



ENLARGED VIEW OF PORTION A

Fig. 3

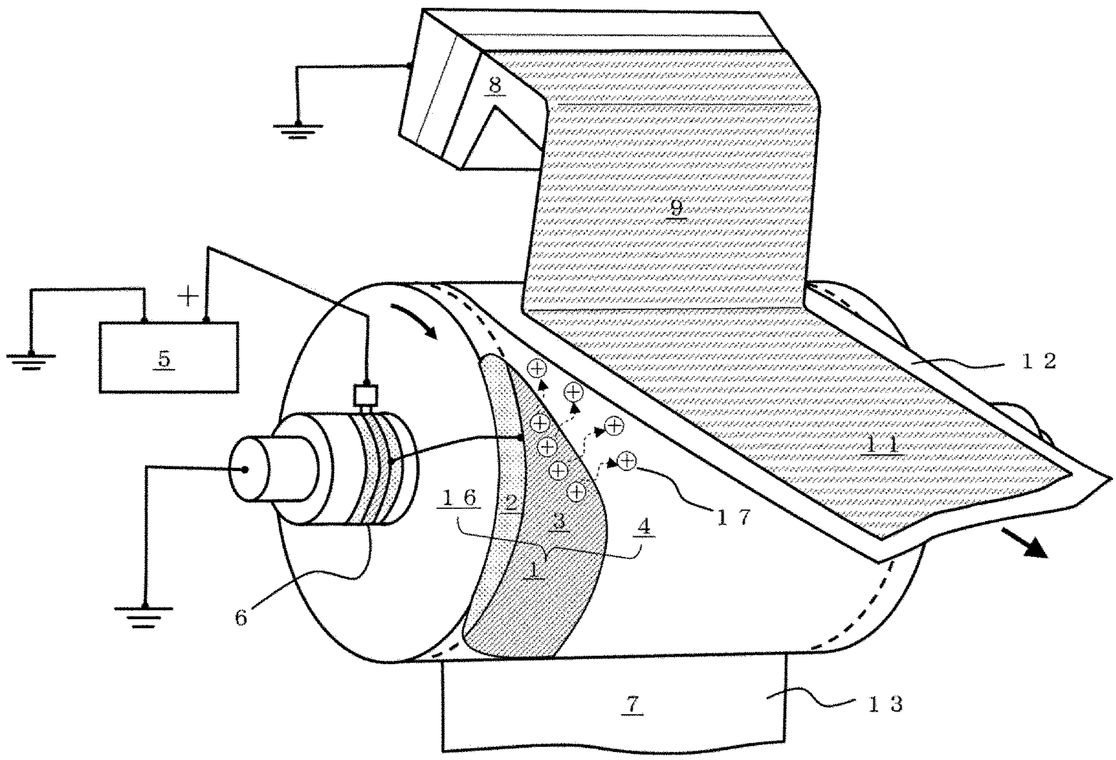


Fig. 4

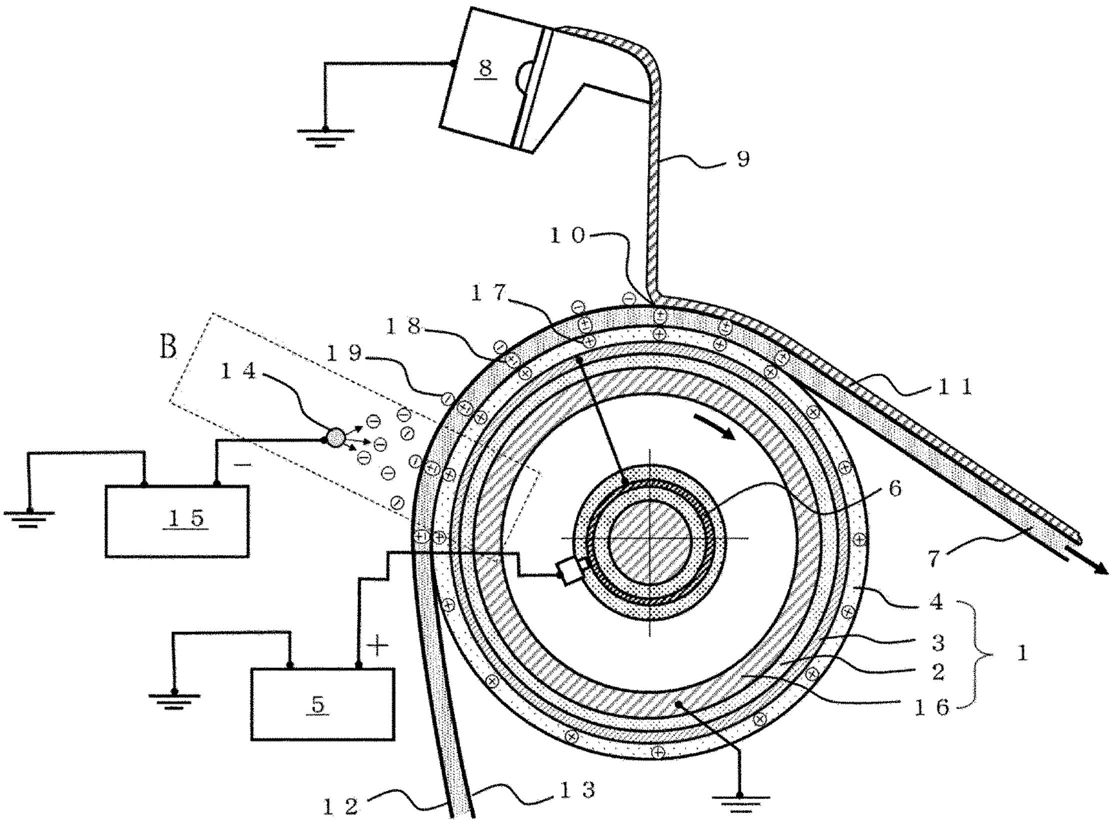
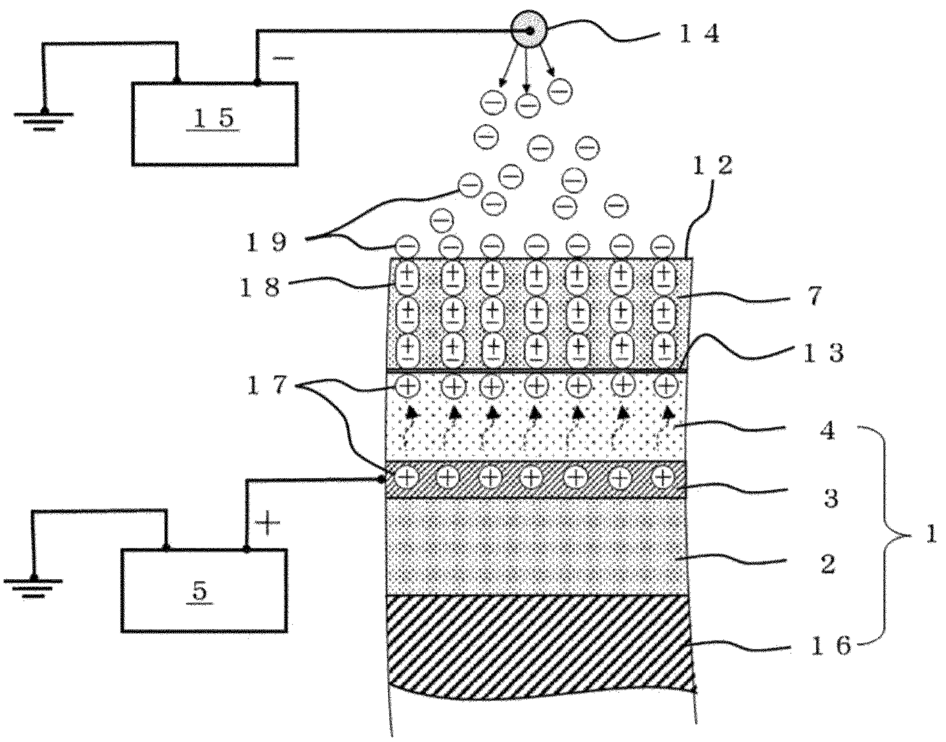


Fig. 5



ENLARGED VIEW OF PORTION B

Fig. 6

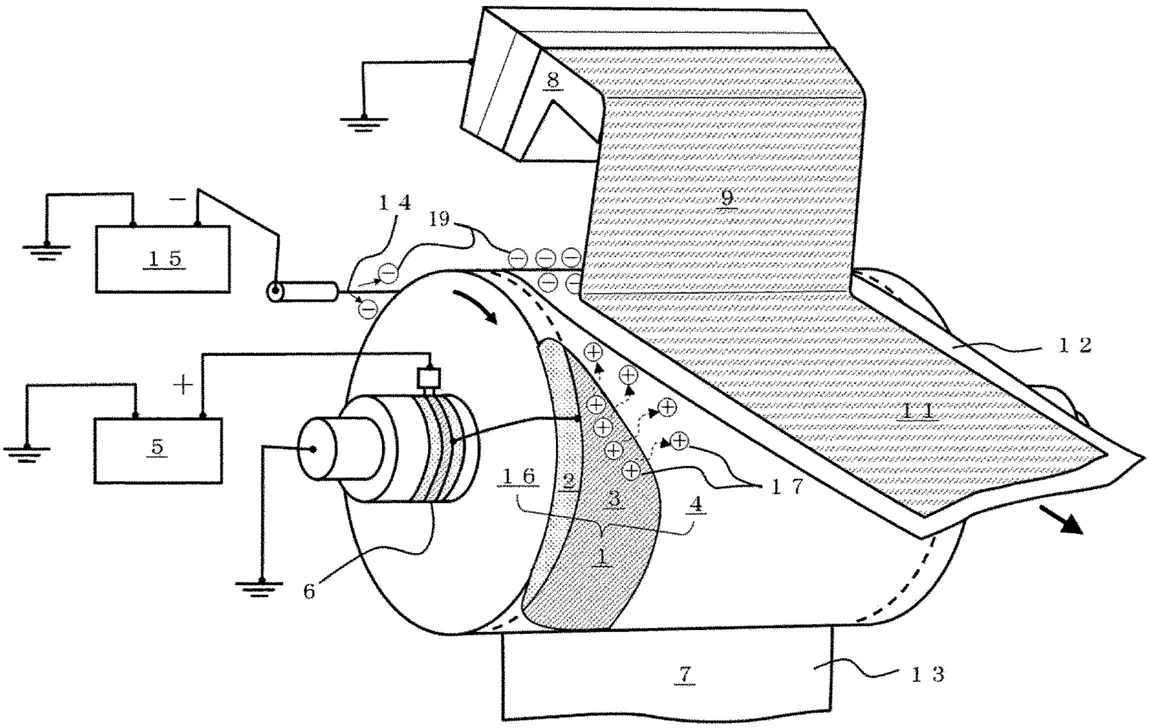


Fig. 7

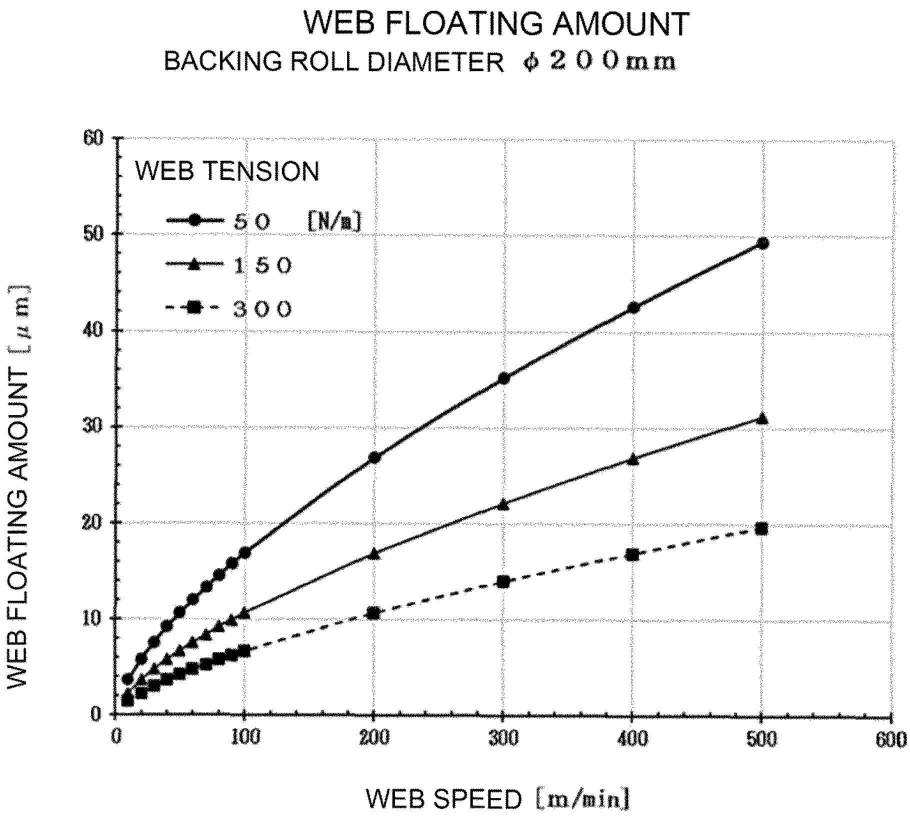
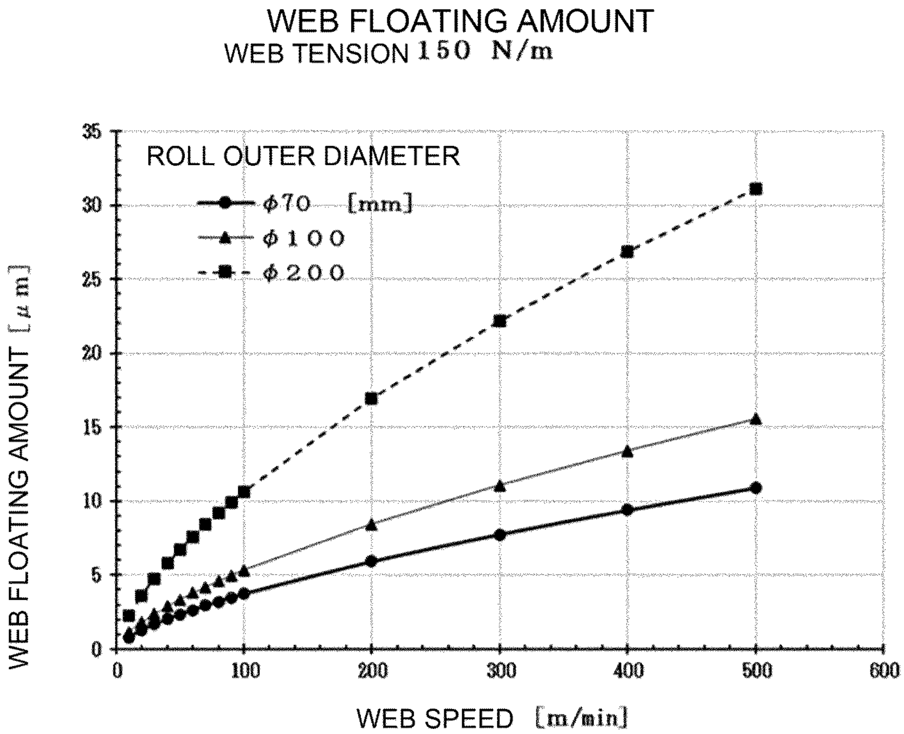

WEB FLOATING AMOUNT
BACKING ROLL DIAMETER φ200mm
WEB TENSION
50 [N/m]
150
300
WEB FLOATING AMOUNT [μm]
60
50
40
30
20
10
0
0
100
200
300
400
500
600
WEB SPEED [m/min]

Fig. 8


WEB FLOATING AMOUNT
WEB TENSION 150 N/m
ROLL OUTER DIAMETER
φ70 [mm]
φ100
φ200
WEB FLOATING AMOUNT [μm]
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
WEB SPEED [m/min]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/034039

A. CLASSIFICATION OF SUBJECT MATTER

B05D 1/30(2006.01)i; ***B05C 13/00***(2006.01)i; ***B05D 1/04***(2006.01)i; ***B05D 3/00***(2006.01)i
FI: B05D1/30; B05C13/00; B05D1/04; B05D3/00 D

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B05D1/30; B05C13/00; B05D1/04; B05D3/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2019/116600 A1 (KOKA CHROME INDUSTRY CO., LTD.) 20 June 2019 (2019-06-20) entire text	1-14
A	JP 2020-158605 A (TORAY INDUSTRIES, INC.) 01 October 2020 (2020-10-01) entire text	1-14
A	JP 2003-530215 A (3M INNOVATIVE PROPERTIES COMPANY) 14 October 2003 (2003-10-14) entire text	1-14
A	US 2003/0138572 A1 (NEUHAUS-STEINMETZ et al.) 24 July 2003 (2003-07-24) entire text	1-14

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 November 2023	**05 December 2023**

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/034039

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US 2003/0138572 A1	24 July 2003	EP 1314487 A2	
		ES 2250571 T	

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REFERENCES CITED IN THE DESCRIPTION

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- JP H08252517 A **[0018]**
- JP 2509316 B **[0018]**
- JP H06009671 B **[0018]**
- JP S46027423 A **[0018]**
- US 6177141 B **[0018]**

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- **HIROMU HASHIMOTO**. Basic Theory and Application of Web Handling. Converting Technical Institute, 73 **[0011] [0019]**