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

(11) **EP 4 818 810 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.10.2026 Bulletin 2026/41

(21) Application number: **26165315.8**

(22) Date of filing: **17.03.2026**

(51) International Patent Classification (IPC):
G03G 9/10 *(2006.01)* ***G03G 9/08*** *(2006.01)*
G03G 9/113 *(2006.01)* *G03G 9/107* *(2006.01)*

(52) Cooperative Patent Classification (CPC):
G03G 9/10; G03G 9/08; G03G 9/1136; G03G 9/1139; G03G 9/108

(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:
GE KH LA MA MD TN

(30) Priority: **24.03.2025 JP 2025048537**

(71) Applicant: **KYOCERA Document Solutions Inc.**
Osaka-shi, Osaka 540-8585 (JP)

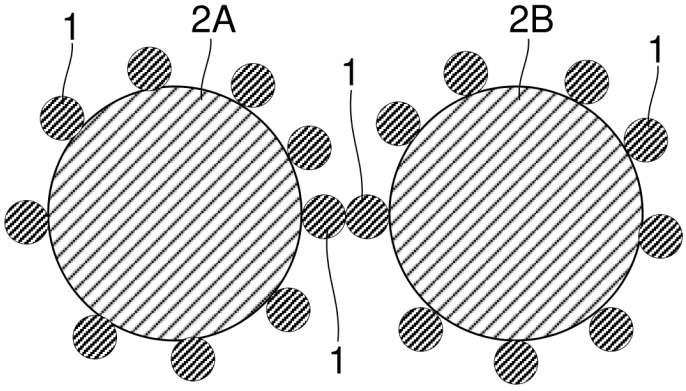
(72) Inventors:
- **SHIMIZU, Tamotsu**
  Osaka-shi, Osaka, 540-8585 (JP)
- **IKEMURA, Ayano**
  Osaka-shi, Osaka, 540-8585 (JP)
- **YAMAGISHI, Yoshihiro**
  Osaka-shi, Osaka, 540-8585 (JP)

(74) Representative: **Heuer, Wilhelm**
Beetz & Partner mbB
Patentanwälte
Prinzregentenstraße 54
80538 München (DE)

(54) **TWO-COMPONENT DEVELOPER, DEVELOPING DEVICE, AND IMAGE FORMING APPARATUS**

(57) A two-component developer (DP) has a variation width of a shear friction coefficient of 0.02 or less, within a range where a surface coverage of toner particles (1) with respect to one carrier particle (2) in the two-component developer (DP) is 20% or more and 45% or less.

FIG.6



second state (toner coverage: 20% to 45%)

EP 4 818 810 A1

Description

BACKGROUND

[0001] The present disclosure relates to a two-component developer, a developing device, and an image forming apparatus.

[0002] Conventionally, a developing device is known, which uses a two-component developer so as to perform development.

[0003] The conventional developing device stirs the developer in its casing, carries the developer on a developing roller, and supplies toner from the developing roller to an electrostatic latent image. In this way, the electrostatic latent image is developed into a toner image. After that, the developer remaining on the developing roller is separated from the developing roller, is mixed and stirred into the developer stored in the casing, and is carried again on the developing roller.

SUMMARY

[0004] A two-component developer according to a first aspect of the present disclosure is a two-component developer containing toner particles and carrier particles, in which a variation width of a shear friction coefficient of the two-component developer is 0.02 or less, within a range where a surface coverage of the toner particles with respect to one carrier particle is 20% or more and 45% or less.

[0005] A developing device according to a second aspect of the present disclosure includes a developer carrying member having a developer carrying surface configured to carry the two-component developer described above, and the developing device supplies toner in the two-component developer carried by the developer carrying surface to an electrostatic latent image at a development position, so as to develop the electrostatic latent image. The developer carrying member includes a shaft, a magnet, and a development sleeve. The shaft extends in a predetermined direction. The magnet is fixed to an outer peripheral surface of the shaft, and has a plurality of magnetic poles in a circumferential direction of the shaft. The development sleeve is a cylindrical member in which the shaft is inserted, and it has an outer peripheral surface of the cylindrical member as the developer carrying surface, and is supported in a rotatable manner about the shaft. The magnet has at least a first magnetic pole and a second magnetic pole as magnetic poles. The first magnetic pole is disposed on a downstream side of the development position in a rotation direction of the development sleeve. The second magnetic pole is disposed on a downstream side of the first magnetic pole in the rotation direction of the development sleeve, and has the same polarity as the first magnetic pole. The developer carrying member has a part from the first magnetic pole to the second magnetic pole on the downstream side in the rotation direction of the development sleeve, as a developer separating part for separating the two-component developer from the developer carrying surface. The developer carrying member has a magnetic force reversal region, in which a resultant force of a vertical magnetic force and a horizontal magnetic force of the developer separating part increases as separating from the developer carrying surface in the normal direction, on the downstream side of a position on the developer carrying surface, at which the resultant force of the vertical magnetic force and the horizontal magnetic force of the first magnetic pole has a peak, in the rotation direction of the development sleeve from a position. When a position on the developer carrying surface, at which the resultant force of the vertical magnetic force and the horizontal magnetic force of the first magnetic pole has a peak, is referred to as a position A, and a position on the developer carrying surface at which the magnetic force reversal region starts is referred to as a position B, then the distance from the position A to the position B on the downstream side in the rotation direction of the development sleeve is 1.1 mm or more and 4.0 mm or less.

[0006] An image forming apparatus according to a third aspect of the present disclosure includes the developing device described above, an image carrier, and a transfer unit. The image carrier carries an electrostatic latent image to be developed by the developing device. The transfer unit transfers the image developed by the developing device onto a sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a schematic diagram of an image forming apparatus according to an embodiment.
FIG. 2 is a schematic diagram of a developing device and its vicinity according to the embodiment.
FIG. 3 is a schematic diagram of the developing device and its vicinity (including a replenishment unit) according to the embodiment.
FIG. 4 is a schematic diagram of a two-component developer according to the embodiment.
FIG. 5 is a schematic diagram illustrating a state of the developer illustrated in FIG. 4, when a toner coverage is less than 20%.

FIG. 6 is a schematic diagram illustrating a state of the developer illustrated in FIG. 4, when the toner coverage is 20% to 45%.

FIG. 7 is a schematic diagram illustrating a state of the developer illustrated in FIG. 4, when the toner coverage is more than 45%.

FIG. 8 is a graph showing a relationship between a shear friction coefficient and a toner coverage of the two-component developer according to the embodiment.

FIG. 9 is a graph showing a magnetic force distribution of a developing roller of the developing device according to the embodiment.

FIG. 10 is a graph showing the magnetic force distribution of the developing roller of the developing device according to the embodiment.

FIG. 11 is a schematic diagram of images printed in an experiment for checking effects of the present disclosure.

DETAILED DESCRIPTION

< 1. Image Forming Apparatus >

[0008] Hereinafter, with reference to FIG. 1, an image forming apparatus PR of this embodiment is described. The image forming apparatus PR is a printer.

[0009] The image forming apparatus PR uses a developer DP (see FIG. 4) so as to perform electrophotographic printing on a sheet S as a recording medium. Note that the developer DP is a two-component developer, and it contains toner (an aggregate of toner particles 1) and carrier (an aggregate of carrier particles 2).

[0010] The image forming apparatus PR has a conveying path. In FIG. 1, the conveying path is shown by a broken line arrow. The image forming apparatus PR supplies the sheet S stored in a cassette to the conveying path, and conveys the sheet S along the conveying path. In this way, the sheet S passes through a transfer position and a fixing position in this order, and then it is discharged onto a discharge tray ET. At the transfer position, a transferring process is performed on the sheet S. At the fixing position, a fixing process is performed on the sheet S.

[0011] The image forming apparatus PR includes four image forming units P corresponding to four colors, i.e., cyan, magenta, yellow, and black colors. Each of the image forming units P forms an image using toner of the corresponding color. Hereinafter, one of the image forming units P is noted and a structure thereof is described. The image forming units P have the same basic structure. Therefore, descriptions of structures of other image forming units P are omitted by citing the following description.

[0012] The image forming unit P includes developing device 3. The developing device 3 is connected to a replenishment unit 4 (see FIG. 3). In addition, the image forming unit P includes photosensitive drum 5. The photosensitive drum 5 corresponds to an "image carrier".

[0013] The photosensitive drum 5 has an outer peripheral surface 5S that functions as a toner carrying surface. An electrostatic latent image is formed on the outer peripheral surface 5S of the photosensitive drum 5, and the toner is supplied to the electrostatic latent image. The photosensitive drum 5 carries the supplied toner on the outer peripheral surface 5S. In the following description, the outer peripheral surface 5S of the photosensitive drum 5 is referred to as the drum outer peripheral surface 5S.

[0014] The image forming unit P further includes a charging device 51 and a cleaning device 52. The photosensitive drum 5 constitutes one unit together with the charging device 51 and the cleaning device 52. Note that the image forming unit P includes an exposure device 50. The single exposure device 50 is shared by the image forming units P.

[0015] When the image forming unit P forms an image, the photosensitive drum 5 rotates. The charging device 51 is applied with a charging voltage from a not-shown charging voltage power supply. The charging device 51 charges the photosensitive drum 5. In this way, the drum outer peripheral surface 5S is charged at a predetermined potential. The exposure device 50 exposes the drum outer peripheral surface 5S, so as to form an electrostatic latent image on the drum outer peripheral surface 5S. The developing device 3 supplies the toner to the electrostatic latent image on the drum outer peripheral surface 5S, so as to develop the electrostatic latent image into a toner image. The replenishment unit 4 replenishes the developer DP to the developing device 3. The cleaning device 52 removes residual toner on the drum outer peripheral surface 5S.

[0016] The image forming apparatus PR includes a transfer unit 6. The transfer unit 6 transfers the toner image on the drum outer peripheral surface 5S of each photosensitive drum 5 to the sheet S. In other words, the transfer unit 6 transfers the images developed by the developing devices 3 to the sheet S.

[0017] The transfer unit 6 includes an intermediate transfer belt 60. The intermediate transfer belt 60 is an endless belt. The intermediate transfer belt 60 contacts the drum outer peripheral surface 5S of each photosensitive drum 5, and in this state, moves (rotates) in the direction shown by an arrow D.

[0018] The transfer unit 6 includes primary transfer rollers 61. There are a plurality of the primary transfer rollers 61, which are allotted to the cyan, magenta, yellow, and black colors, respectively. The primary transfer rollers 61 are disposed

on an inner peripheral side of the intermediate transfer belt 60. Each of the primary transfer rollers 61 is disposed to face the drum outer peripheral surface 5S of the photosensitive drum 5 carrying the toner image of the corresponding color, via the intermediate transfer belt 60 between them.

[0019] In addition, the image forming apparatus PR includes one secondary transfer roller 62. The secondary transfer roller 62 is pressed to contact the outer peripheral surface of the intermediate transfer belt 60 at the transfer position. A transfer nip is formed between the secondary transfer roller 62 and the intermediate transfer belt 60. In other words, the transfer nip is formed at the transfer position.

[0020] In a print job, the sheet S is conveyed to the transfer position (i.e., the transfer nip). The sheet S that is being conveyed passes through the transfer nip.

[0021] The intermediate transfer belt 60 receives primary transfer of toner images from the photosensitive drums 5. The intermediate transfer belt 60 rotates while carrying the toner images on the outer peripheral surface. When the sheet S is passing through the transfer nip, the sheet S contacts the outer peripheral surface of the intermediate transfer belt 60. In this way, the toner images are secondarily transferred to the sheet S that is passing through the transfer nip.

[0022] The image forming apparatus PR includes a fixing unit F. The fixing unit F includes a heating roller and a pressure roller. The heating roller includes a heater inside. The pressure roller is pressed to contact the heating roller. The heating roller and the pressure roller contact each other with pressure so as to form a fixing nip at the fixing position.

[0023] In the print job, the sheet S after the transferring process passes through the fixing nip. In other words, the sheet S is sandwiched between the heating roller and the pressure roller at the fixing nip. The fixing unit F heats the sheet S that is passing through the fixing nip. At the fixing nip, the sheet S is pressed. The fixing unit F heats and presses the sheet S after the transferring process, so as to fix the toner image to the sheet S. After the fixing process, the sheet S is discharged onto the discharge tray ET.

< 2. Developing Device >

[0024] Hereinafter, with reference to FIG. 2 and FIG. 3, the developing device 3 of this embodiment is described. Note that FIG. 3 also illustrates the replenishment unit 4 connected to the developing device 3.

[0025] The developing device 3 uses the developer DP (see FIG. 4), so as to develop the electrostatic latent image. A development method of the developing device 3 is a trickle development method. The developing device 3 receives replenishment of the developer DP from the replenishment unit 4. In other words, the image forming apparatus PR includes the replenishment units 4 in addition to the developing devices 3. The replenishment unit 4 may be one component of the developing device 3.

[0026] The developing device 3 includes a development casing 30. The developer DP is stored in the development casing 30 in advance. The developing device 3 uses the developer DP stored in the development casing 30 so as to perform development. Here, the developer DP stored in the development casing 30 is referred to as "developer currently in use". On the other hand, the developer DP replenished from the replenishment unit 4 into the development casing 30 is referred to as "replenishment developer".

[0027] The developing device 3 includes a developing roller 31 as illustrated in FIG. 2. The developing roller 31 corresponds to a "developer carrying member". The developing roller 31 has its outer peripheral surface 31S as a developer carrying surface. In the following description, the outer peripheral surface 31S of the developing roller 31 is referred to as the developer carrying surface 31S.

[0028] The developing roller 31 is disposed inside the development casing 30 and is supported in a rotatable manner. The developer carrying surface 31S of the developing roller 31 is partially exposed from inside to outside of the development casing 30. Specifically, the development casing 30 has an opening at a position facing the drum outer peripheral surface 5S. From this opening, the developer carrying surface 31S is partially exposed to the outside. In this way, the developer carrying surface 31S and the drum outer peripheral surface 5S face each other. The developer carrying surface 31S faces the drum outer peripheral surface 5S at a development position Pd with a predetermined space between them. In other words, development position Pd is a position at which the developer carrying surface 31S and the drum outer peripheral surface 5S face each other with a predetermined space between them.

[0029] The developing roller 31 carries the developer currently in use on the developer carrying surface 31S, and supplies toner in the developer currently in use to the electrostatic latent image on the drum outer peripheral surface 5S, at the development position Pd. Note that, in this case, the developing roller 31 and the photosensitive drum 5 rotate individually. In FIG. 2 and FIG. 3, a rotation direction of the developing roller 31 is shown by an arrow Dr1, and a rotation direction of the photosensitive drum 5 is shown by an arrow Dr2.

[0030] The developing device 3 includes a regulating blade 32. The regulating blade 32 is attached to the development casing 30. The regulating blade 32 has a distal end part disposed close to the developer carrying surface 31S. The distal end part of the regulating blade 32 is disposed on an upstream side of the development position Pd in the rotation direction of the developing roller 31 (specifically, on an upstream side of a development sleeve 310 described later in the rotation direction).

[0031] The developing device 3 includes two stirring screws 33. Each of the stirring screws 33 is disposed inside the development casing 30 and is supported in a rotatable manner. Each of the stirring screws 33 has a structure in which a helical blade is disposed on a rotation shaft. Each of the stirring screws 33 rotates so as to stir and convey the developer currently in use, while the toner in the developer currently in use is charged.

[0032] During rotation of the developing roller 31, the carrier carrying the toner in the developer currently in use is attracted to the developer carrying surface 31S, by a magnetic force of the developing roller 31 (specifically, a magnetic force of a magnet 312 described later), and a magnetic brush containing the toner and the carrier is formed on the developer carrying surface 31S. When the magnetic brush passes through between the developing roller 31 and the regulating blade 32, the magnetic brush is regulated to have a constant layer thickness. Then, the magnetic brush on the developer carrying surface 31S contacts the drum outer peripheral surface 5S.

[0033] In addition, the developing roller 31 is supplied with a development voltage including a DC voltage from a not-shown development voltage power supply. The development voltage is a voltage in which an AC voltage is superimposed on the DC voltage. When the development voltage is applied between the developing roller 31 and the photosensitive drum 5, a potential difference is generated between the developing roller 31 and the photosensitive drum 5. This potential difference allows the toner in the magnetic brush to move from the developing roller 31 to the photosensitive drum 5. The photosensitive drum 5 carries the toner moved from the magnetic brush on the developer carrying surface 31S, on the drum outer peripheral surface 5S. The toner is supplied to the electrostatic latent image on the drum outer peripheral surface 5S (to parts whose potentials are decreased by exposure). In this way, the electrostatic latent image on the drum outer peripheral surface 5S is developed into the toner image.

[0034] The developing roller 31 includes the development sleeve 310. The development sleeve 310 is a cylindrical member having a central axis extending in a predetermined direction. A direction parallel to the rotation axis of the photosensitive drum 5 is the predetermined direction. The development sleeve 310 has its outer peripheral surface as the developer carrying surface 31S. The development sleeve 310 is supported in a rotatable manner about the central axis.

[0035] The developing roller 31 includes a shaft 311. The shaft 311 is a round bar extending in a predetermined direction. The shaft 311 has a D-cut surface on one side end in the axial direction, and the D-cut surface is held so as to be fixed and unable to rotate. The shaft 311 is inserted in the development sleeve 310. **In** other words, the development sleeve 310 is supported in a rotatable manner about the shaft 311. The development sleeve 310 rotates in the direction shown by the arrow Dr1.

[0036] Although not illustrated, each end of the development sleeve 310 is fixed to a flange. Each flange is supported by the shaft 311 in a rotatable manner. For instance, a bearing inner ring is fixed to the shaft 311, while an outer ring of the bearing is fixed to the flange. In addition, one of the flanges is linked to a motor. When the motor is driven, the development sleeve 310 rotates.

[0037] The developing roller 31 includes the magnet 312. The magnet 312 is fixed to an outer peripheral surface of the shaft 311, so as to be disposed inside the development sleeve 310. The magnet 312 has a plurality of magnetic poles in a circumferential direction of the shaft 311. Hereinafter, described are arrangement positions of the magnetic poles viewed from the axial direction of the development sleeve 310 (the predetermined direction).

[0038] A first magnetic pole S1 having a predetermined polarity is disposed on the downstream side of the development position Pd, in the rotation direction of the development sleeve 310. Specifically, the first magnetic pole S1 is disposed on the downstream side of the line connecting the rotation center of the development sleeve 310 and the development position Pd, in the rotation direction of the development sleeve 310.

[0039] A second magnetic pole S2 having the same polarity as the first magnetic pole S1 is disposed on the downstream side of the first magnetic pole S1, in the rotation direction of the development sleeve 310. The second magnetic pole S2 is disposed at a position facing the regulating blade 32. The second magnetic pole S2 faces the regulating blade 32 via the development sleeve 310. The second magnetic pole S2 works as a pump-up pole, which forms a magnetic field for pumping up the developer currently in use to the developer carrying surface 31S. Further, the second magnetic pole S2 works as a regulation pole, which forms a magnetic field for regulating a layer thickness of the developer currently in use on the developer carrying surface 31S, together with the regulating blade 32.

[0040] A main pole N1 having a polarity different from that of the first magnetic pole S1 is disposed at the development position Pd. Specifically, the main pole N1 is disposed on the straight line connecting the rotation center of the development sleeve 310 and the development position Pd. An electric field is formed between the main pole N1 and the drum outer peripheral surface 5S. In this way, the toner is supplied from the developer carrying surface 31S to the drum outer peripheral surface 5S.

[0041] A conveying pole S3 having a polarity opposite to that of the main pole N1 is disposed on the downstream side of the main pole N1, in the rotation direction of the development sleeve 310, and on the further downstream side in the rotation direction of the development sleeve 310, a conveying pole N2 having the same polarity as the main pole N1 is disposed. Then, the developer currently in use that was not used for development is conveyed from the main pole N1 to the conveying pole S3 and to the conveying pole N2 sequentially on the developer carrying surface 31S.

[0042] Here, the developing roller 31 has a developer separating part. The developing roller 31 allows the developer

currently in use, which is being conveyed on the developer carrying surface 31S, to separate and drop from the developer carrying surface 31S at the developer separating part. The developer currently in use that separates and drops from the developer carrying surface 31S is stirred and pumped up to the developer carrying surface 31S again.

[0043] The developer separating part is at least a part of the area from the first magnetic pole S1 to the second magnetic pole S2 on the downstream side in the rotation direction of the development sleeve 310. In the developer separating part, because the first magnetic pole S1 and the second magnetic pole S2 have the same polarity, the developer currently in use separates and drops from the developer carrying surface 31S. In other words, the developer separating part is constituted of the first magnetic pole S1 and the second magnetic pole S2.

[0044] In addition, as illustrated in FIG. 3, the developing device 3 includes a discharge path 34. The discharge path 34 connects the inside of the development casing 30 and a collection box 300. In this way, excessive developer currently in use flows into the discharge path 34, flows along the discharge path 34, and reaches the collection box 300. In other words, the collection box 300 stores the excessive developer currently in use.

[0045] The replenishment unit 4 includes a container 41 and a replenishment member 42. The container 41 stores replenishment developer. The replenishment member 42 replenishes the replenishment developer stored in the container 41 to the developing device 3. For instance, the replenishment member 42 includes a screw shaft. When the screw shaft rotates, the replenishment developer is replenished from the container 41 to the inside of the development casing 30.

[0046] Note that the image forming apparatus PR includes a controller unit CON (see FIG. 1). The developing device 3 is equipped with a T/C sensor. The T/C sensor is connected to the controller unit CON. The T/C sensor detects a mixing ratio between the toner and the carrier in the developer currently in use. On the basis of an output of the T/C sensor, the controller unit CON controls replenishment of the replenishment developer from the replenishment unit 4 to the developing device 3. In other words, the controller unit CON controls the replenishment member 42 (to rotate and stop the screw shaft).

[0047] The T/C sensor is a magnetic permeability sensor and outputs a value corresponding to a magnetic permeability of the developer currently in use. As the ratio of the carrier in the developer currently in use is higher, the magnetic permeability of the developer currently in use is higher. Utilizing this fact, the mixing ratio between the toner and the carrier in the developer currently in use is detected. Further, a toner remaining amount in the developer currently in use can be detected from the detected mixing ratio.

[0048] When starting to use the developing device 3, the development casing 30 already stores initial developer inside. The initial developer is the developer DP stored inside the development casing 30 when the image forming apparatus PR is shipped (before a user uses the image forming apparatus PR). In other words, when starting to use the developing device 3, the developer currently in use contains only the initial developer.

[0049] After starting use of the developing device 3, when the print job is performed, the developer currently in use is consumed and decreased. In other words, the initial developer is decreased inside the development casing 30. For this reason, after starting use of the developing device 3, the replenishment developer is replenished from the replenishment unit 4 to the developing device 3. The developer DP stored in the container 41 is the replenishment developer.

[0050] While the image forming apparatus PR continues the print job, the replenishment developer is replenished into the development casing 30 while the developer currently in use is discharged from the inside of the development casing 30. In this way, inside the development casing 30, the developer currently in use is gradually changed, i.e., the initial developer is gradually replaced by the replenishment developer. In other words, the initial developer and the replenishment developer are mixed as the developer currently in use.

< 3. Developer >

[0051] Hereinafter, with reference to FIG. 4, the developer DP of this embodiment is described. The developer DP is a two-component developer.

[0052] The toner of the developer DP contains toner particles 1, and the carrier of the developer DP contains carrier particles 2. The toner is an aggregate of the toner particles 1, and the carrier is an aggregate of the carrier particles 2. FIG. 4 schematically illustrates the single toner particle 1 and the single carrier particle 2.

[0053] Note that the developer DP as the initial developer and the developer DP as the replenishment developer may have the same components, mixing ratio between the toner and the carrier, production method, and the like. Alternatively, at least a part of the components, the mixing ratio between the toner and the carrier, the production method, and the like may be different between the developer DP as the initial developer and the developer DP as the replenishment developer.

< 3-1. Toner >

[0054] The toner particle 1 has a toner mother particle 11. The toner mother particle 11 is, for example, a non-encapsulated toner mother particle without a shell layer. The toner mother particle 11 may be an encapsulated toner mother particle in which a toner core is coated with a shell layer.

[0055] The toner mother particle 11 contains binder resin, for example. As the binder resin, a thermoplastic resin such as

polyester resin may be used. The toner mother particle 11 may contain a coloring agent, a charge control agent, a mold release agent, and the like.

[0056] The toner particle 1 has external additive particles 12. The external additive particles 12 adhere to the surface of the toner mother particle 11. As the external additive particles 12, silica particles, aluminum oxide particles, or the like may be used. In addition, if necessary, resin particles, magnesium oxide particles, zinc oxide particles, or the like may be used as the external additive particles 12.

[0057] In the toner particle 1, the contained amount of the silica particles is preferably 0.1 pts. mass or more and 10.0 pts. mass or less, and more preferably 0.4 pts. mass or more and 3.0 pts. mass or less, with respect to 100.0 pts. mass of toner mother particle 11. In addition, the mean primary particle diameter of the silica particle is preferably 10 nm or more and 30 nm or less, and more preferably 15 nm or more and 25 nm or less. The silica particle may be surface treated.

[0058] The contained amount of the aluminum oxide particles in the toner particle 1 is preferably 0.05 pts. mass or more and 3.0 pts. mass or less, and more preferably 0.3 pts. mass or more and 1.5 pts. mass or less, with respect to 100.0 pts. mass of toner mother particle 11. In addition, the mean primary particle diameter of the aluminum oxide particle is preferably 200 nm or more and 600 nm or less, and more preferably 300 nm or more and 500 nm or less.

[0059] Note that the mean primary particle diameter in this specification is a mean value of equivalent circle diameters of primary particles measured using a scanning electron microscope (a Heywood diameter: a diameter of a circle having the same area as a projected area of the primary particle). The mean primary particle diameter is, for example, a mean value of equivalent circle diameters of 100 primary particles. For measuring the mean primary particle diameter, a field emission type scanning electron microscope ("JSM-7600F" manufactured by Japan Electron Optics Laboratory Co., Ltd.) can be used.

< 3-2. Carrier >

[0060] The carrier particle 2 has a carrier core 21. The carrier core 21 contains magnetic material. The carrier core 21 may contain only one type of magnetic material, or may contain two or more types of magnetic materials. As the magnetic material, it is possible to use a metal oxide such as ferrite, magnetite, or maghemite. Note that the ferrite has high flowability and chemical stability tendency. Therefore, it is preferred that the carrier core 21 contain ferrite. As an example of the ferrite, there is Ba ferrite, Mn ferrite, Mn-Zn ferrite, Ni-Zn ferrite, Mn-Mg ferrite, Ca-Mg ferrite, Li ferrite, and Cu-Zn ferrite. The shape of the carrier core 21 is not particularly limited, and it may be an irregular shape or a spherical shape.

[0061] An average particle size of the carrier cores 21 is 20 μm or more and 60 μm or less. If the average particle size of the carrier cores 21 is less than 20 μm, carrier development tends to occur in which the carrier adheres to the photosensitive drum 5. If the carrier development occurs, the carrier moves from the photosensitive drum 5 to the intermediate transfer belt 60, which causes transfer voids. Further, when the carrier is moved to a cleaning member of the intermediate transfer belt 60, insufficient cleaning may occur. On the other hand, if the average particle size of the carrier cores 21 is more than 60 μm, the magnetic brush on the developing roller 31 becomes rough, and image quality is deteriorated. For this reason, it is preferred that the average particle size of the carrier cores 21 be 20 μm or more and 60 μm or less.

[0062] A saturation magnetization of the carrier core 21 is 65 emu/g or more and 90 emu/g or less. If the saturation magnetization of the carrier core 21 is low, the carrier development occurs, and image quality is deteriorated. For this reason, it is preferred that the saturation magnetization of the carrier core 21 be 65 emu/g or more and 90 emu/g or less. If the carrier core 21 contains Mn ferrite, as the Mn content is higher, the saturation magnetization of the carrier core 21 tends to be lower. If the carrier core 21 contains Mn-Mg ferrite, as the Mg content is higher, the saturation magnetization of the carrier core 21 tends to be lower. Note that in this specification, the saturation magnetization is a value measured using a sensitive vibrating sample magnetometer ("VSM-P7" manufactured by Toei Industry Co., Ltd.) under the condition of an external magnetic field of 3,000 (Oe).

[0063] The carrier particle 2 has a coat layer 22. The coat layer 22 coats the surface of the carrier core 21. For instance, the entire surface of the carrier core 21 is coated with the coat layer 22. A main component of the coat layer 22 is silicone resin. In other words, a principal component of the coat layer 22 in mass base is silicone resin. The coat resin constituting the coat layer 22 contains only silicone resin. The coat resin constituting the coat layer 22 may further contain a resin other than silicone resin.

[0064] As a preferred example of the silicone resin, there is silicone resin having a methyl group, and epoxy modified silicone resin. An example of the silicone resin having a methyl group is a silicone resin that has a methyl group but does not have a phenyl group. Another example of the silicone resin having a methyl group is a silicone resin that has a methyl group and a phenyl group.

[0065] The coat layer 22 contains barium titanate particles. The barium titanate particles have different characteristics depending on a production method. For instance, barium titanate particles produced by a hydrothermal synthesis method have voids inside, and hence have a small true specific gravity, and also the particle diameter distribution thereof is sharp. For this reason, the barium titanate particles produced by the hydrothermal synthesis method have better dispersibility in

the coat resin than barium titanate particles produced by other method, and uniform dispersion can be achieved. Therefore, the barium titanate particles produced by the hydrothermal synthesis method is suitable for use because chargeability of the carrier is also uniformed.

[0066] The mean primary particle diameter of the barium titanate particles is preferably 100 nm or more and 500 nm or less. If the mean primary particle diameter of the barium titanate particles is less than 100 nm, a relative dielectric constant of the barium titanate particle is rapidly decreased, and hence the effect of the relative dielectric constant is decreased. On the other hand, if the mean primary particle diameter of the barium titanate particles is more than 500 nm, uniform dispersion is difficult. Therefore, the coat layer 22 contains the barium titanate particles having a mean primary particle diameter of 102 nm.

[0067] A contained amount of the barium titanate particle is preferably 5 pts. mass or more and 45 pts. mass or less with respect to 100 pts. mass of the coat resin. If the contained amount of the barium titanate particles is less than 5 pts. mass, a ferroelectric effect is deteriorated. On the other hand, if the contained amount of the barium titanate particles is more than 45 pts. mass, the barium titanate particles cannot be contained in the coat resin, and hence the barium titanate particles are released from the coat resin. Therefore, the coat layer 22 contains 10 pts. mass of the barium titanate particles with respect to 100 pts. mass of the coat resin.

[0068] The coat layer 22 contains carbon black particles. Because the carbon black particles are electric conductive, when the coat layer 22 contains the carbon black particles, charges move smoothly from the carrier particles 2 to the toner particle 1. As a result, the toner particles 1 can be charged to a desired charge amount. In this way, an image having little fogging can be formed. In addition, even if the toner concentration in the developer DP changes, a change in the toner charge amount can be small, and an image having a desired density can be stably formed.

[0069] The contained amount of the carbon black particles is preferably 2 pts. mass or more and 6 pts. mass or less with respect to 100 pts. mass of the coat resin. It is because if the contained amount of the carbon black particles is less than 2 pts. mass, the resistance is increased, and the charge cannot move sufficiently. On the other hand, if the contained amount of the carbon black particles is more than 6 pts. mass, the resistance is decreased, and leakage tend to occur.

[0070] The coat layer 22 contains a ferroelectric material (the barium titanate particles) and a conductive material (the carbon black particles). In this way, the following effect can be obtained.

[0071] A ferroelectric material has high charge retention capability, and can provide sufficient charge to the toner particles 1. The conductive material can allow the charge to move smoothly from the carrier particles 2 to the toner particles 1. By synergy of these two effects, even if the toner concentration in the developer DP (corresponding to a toner coverage described later) is increased, so that the number of toner particles 1 to be charged is increased, the charge can be provided up to a saturation charge amount level of the toner particles 1.

[0072] Note that, because the charge cannot usually be provided up to a saturation charge amount level of the toner particles 1, the charge amount is decreased along with an increase of the toner concentration in the developer DP. However, by using a dielectric material and a conductive material together, charge providing ability is improved, and the charge amount is hardly decreased even if the toner concentration in the developer DP increases. For this reason, it is preferred to constitute the coat layer 22 using the coat resin in which the ferroelectric material (the barium titanate particles) and the conductive material (the carbon black particles) are added.

< 4. Toner Concentration in Developer >

[0073] The developing device 3 allows the developer DP, which was carried on the developing roller 31 (i.e., the developer carrying surface 31S) but was not used for development, to separate from the developing roller 31. The developer DP separated from the developing roller 31 drops into the development casing 30, and is carried again on the developing roller 31 by the magnetic force of the developing roller 31. In this way, the developer DP, which was carried on the developing roller 31 but was not used for development, is used again for development.

[0074] In printing of an image that consumes much toner (such as a solid image), much toner moves from the developing roller 31 to the photosensitive drum 5, and hence a toner consumption amount increases. For this reason, when performing an image that consumes much toner, the toner concentration in the developer DP, which was carried on the developing roller 31 but was not used for development is decreased. In other words, the toner concentration in the developer DP that separates and drops from the developing roller 31 is decreased.

[0075] If the toner concentration in the developer DP that separates and drops from the developing roller 31 is decreased (i.e., when printing an image that consumes much toner), if the developer DP is stirred insufficiently, the developer DP carried on the developing roller 31 has different toner concentrations depending on the place, resulting in inconvenience that the image density is not uniform.

< 5. Stabilization of Separation Position of Developer from Developing Roller >

<5-1. Shear Friction Coefficient of Developer >

[0076] As a factor of insufficient stirring of the developer DP that separates and drops from the developing roller 31, there is a drop position of the developer DP. For instance, if the developer DP drops near a partition of the development casing 30, the developer DP can be carried again on the developing roller 31 with insufficient stirring. In addition, if the developer DP drops in a magnetic force range of the pump-up pole, the developer DP can be carried again on the developing roller 31 with insufficient stirring.

[0077] The separation characteristics of the developer DP from the developing roller 31 relates to a shear friction coefficient of the developer DP. Note that the shear friction coefficient in this specification is determined on the basis of a measurement result using a powder bed shear stress measurement device ("NS-S500" manufactured by Nano Seeds Corporation). This measurement is performed in accordance with JISZ8835:2016. A powder layer of the developer DP is a measuring object.

[0078] The powder bed shear stress measurement device is equipped with a shear cell constituted of an upper fixed cell and a lower movable cell. The upper fixed cell has a cylindrical shape. The lower movable cell has a recess indented from the top surface downward. The upper fixed cell is disposed on the top surface of the lower movable cell. The lower movable cell can move laterally with respect to the upper fixed cell. When filling the measuring object into the shear cell, the recess space of the lower movable cell is aligned to the inner space of the cylinder as the upper fixed cell in the up and down direction. Then, the measuring object is filled into the inner space of the cylinder of the upper fixed cell (including the recess space of the lower movable cell).

[0079] When measuring the shear friction coefficient of the developer DP, the developer DP as a sample is filled into the shear cell, and the top surface of the powder layer is flattened. After that, while moving the lower movable cell horizontally, a downward indentation load on the powder layer is changed in five steps (5N, 10N, 15N, 20N, and 25N) so as to sequentially measure a normal stress and a shear stress, and the five points are plotted on a graph, in which the vertical axis represents the shear stress while the horizontal axis represents the normal stress. Then, the approximate straight line of the five points is drawn on the graph, and a value of a gradient tan θ of the straight line is determined as the shear friction coefficient of the developer DP.

[0080] If the shear friction coefficient of the developer DP is large, a conveying power of the developing roller 31 to convey the developer DP is increased, and the developer DP is hardly separated from the developing roller 31. On the other hand, if the shear friction coefficient of the developer DP is small, the conveying power of the developing roller 31 to convey the developer DP is decreased, and the developer DP is easily separated from the developing roller 31.

[0081] In this way, if a variation width of the shear friction coefficient of the developer DP is large, a separation position of the developer DP from the developing roller 31 varies, and a difference occurs in a mixed state of the developer DP stirred in the development casing 30. In this case, the image density becomes not uniform.

< 5-2. Adhesion of Toner Particles to Carrier Particle >

[0082] Adhesion of the toner particles 1 to the carrier particle 2 causes a difference of behavior of the toner particles 1. This difference affects the shear friction coefficient of the developer DP.

[0083] If the adhesion of the toner particles 1 to the carrier particle 2 is relatively weak, the toner particles 1 can move on the carrier particle 2. In this case, the toner particles 1 work like lubricant. For this reason, as the toner coverage is higher, the shear friction coefficient of the developer DP is smaller.

[0084] If the adhesion of the toner particles 1 to the carrier particle 2 is strong, the toner particles 1 are fixed to the carrier particle 2. In this case, the toner particles 1 allows the carrier particle 2 to have an irregular shape. For this reason, as the toner coverage is higher, the shear friction coefficient of the developer DP is larger.

< 5-3. Toner Particle Coverage with Respect to Carrier Particle >

[0085] The toner coverage of the developer DP is a surface coverage of the toner particles 1 with respect to one carrier particle 2. As the number of the toner particles 1 existing on the surface of the carrier particle 2 and its vicinity is larger, the toner coverage is higher, while the number of the toner particles 1 existing on the surface of the carrier particle 2 and its vicinity is smaller, the toner coverage is lower. In other words, the toner coverage of the developer DP corresponds to the toner concentration. The toner coverage of the developer DP affects the shear friction coefficient of the developer DP.

[0086] Note that, when a volume average particle diameter of the toner particle 1 is r, a volume average particle diameter of the carrier particle 2 is R, and the number of toner particles 1 with respect to one carrier particle 2 is n, the toner coverage is calculated by the following equation (1).

$$\text{toner coverage } (\%) = (nr^2)/(4R^2) \times 100 \ldots (1)$$

[0087] A state of the developer DP can be classified into three, i.e., a first state, a second state, and a third state, in accordance with a difference of the toner coverage. The first to the third states are schematically illustrated in FIGS. 5 to 7, respectively. In this description, for convenience's sake, in order to discriminate between one and the other of the neighboring carrier particles 2, each carrier particle 2 is denoted by suffix A or B. In addition, in FIG. 5 to FIG. 7, for convenience's sake, only some of the toner particles are denoted by 1.

[0088] The state illustrated in FIG. 5 is the first state, in which the toner coverage is less than 20%. In the first state, there is a region where the toner particle 1 on one carrier particle 2A contacts the other carrier particle 2B directly.

[0089] The state illustrated in FIG. 6 is the second state, in which the toner coverage is 20% or more and 45% or less. In the second state, there is always a region where the toner particle 1 on one carrier particle 2A contacts the toner particle 1 on the other carrier particle 2B.

[0090] The state illustrated in FIG. 7 is the third state, in which the toner coverage is more than 45%. In the third state, there is the toner particle 1 that is not held on the carrier particle 2 but is floating.

[0091] Note that, according to the calculation, when the particles are arranged in square, the toner coverage is 78.5%. However, in fact, because the toner particles are charged at the same polarity, the toner coverage does not reach 78.5% but has a limitation of approximately 50%. In other words, in actual use, it becomes the second state (see FIG. 6).

< 5-4. Coat Material of Carrier Particle >

[0092] In this embodiment, a coat material is silicone resin. In other words, the coat layer 22 is made of silicone resin. In this way, in the range where the surface coverage of the toner particles 1 with respect to one carrier particle 2 (i.e., the toner coverage of the developer DP) is 20% or more and 45% or less, the variation width of the shear friction coefficient of the developer DP is set to 0.02 or less. In other words, in the range where toner coverage is 20% or more and 45% or less, an absolute value of a difference between a maximum value and a minimum value of the shear friction coefficient of the developer DP is 0.02 or less.

[0093] More preferably, in the range where the toner coverage is 20% or more and 45% or less, the variation width of the shear friction coefficient of the developer DP is 0.01 or less. In other words, in the range where the toner coverage is 20% or more and 45% or less, the absolute value of the difference between the maximum value and the minimum value of the shear friction coefficient of the developer DP is 0.01 or less.

[0094] If the coat layer 22 is made of polyimide resin and fluorocarbon resin, the variation width of the shear friction coefficient of the developer DP is more than 0.02. In other words, if the coat layer 22 is made of polyimide resin and fluorocarbon resin, the variation width of the shear friction coefficient of the developer DP is larger than that in the case where the coat layer 22 is made of silicone resin.

[0095] Here, a relationship between the shear friction coefficient and the toner coverage of the developer is shown in FIG. 8. In the graph shown in FIG. 8, the vertical axis represents the shear friction coefficient of the developer, while the horizontal axis represents the toner coverage of the developer.

[0096] In the graph, a broken line indicates a relationship between the shear friction coefficient and the toner coverage of the developer using silicone resin as the coat resin (i.e., the developer DP in this embodiment). On the other hand, a solid line in the graph indicates a relationship between the shear friction coefficient and the toner coverage of the developer using polyimide resin and fluorocarbon resin as the coat resin. Note that the true specific gravity of the carrier in each developer is 4.8 g/cm^3, and the particle diameter of the carrier is 38 μm. The true specific gravity of the toner in each developer is 1.2 g/cm^3, and the particle diameter of the toner is 6.7 μm.

[0097] In the developer using silicone resin as the coat resin (i.e., the developer DP in this embodiment), as shown by the broken line in the graph, in the second state where the toner coverage is 20% to 45%, the shear friction coefficient is in the range of 0.58 to 0.6, and the variation width thereof is 0.02 or less (specifically, 0.01 or less). On the other hand, In the developer using polyimide resin and fluorocarbon resin as the coat resin, as shown by the solid line in the graph, in the second state, the maximum value of the shear friction coefficient is approximately 0.6 while the minimum value is approximately 0.56, and the variation width thereof is more than 0.02.

[0098] In the developer using silicone resin as the coat resin, adhesion of the toner particle to the carrier particle is neither too weak nor too strong, i.e., it is an appropriate adhesion, and hence it can be said that the variation width of the shear friction coefficient of the developer is small even if the toner coverage changes within the range of 20% to 45%. On the other hand, in the developer using polyimide resin and fluorocarbon resin as the coat resin, the adhesion of the toner particle to the carrier particle is strong, and hence it can be said that the shear friction coefficient of the developer increases along with an increase of the toner coverage.

[0099] Note that in the first state where the toner coverage is less than 20%, the number of the toner particles is small. For this reason, the shear friction coefficient of the developer depends on whether or not the adhesion of the toner particle to the carrier particle is weak. In other words, the shear friction coefficient of the developer depends on whether the toner particles move on the carrier particle so as to work as lubricant, or the toner particles are fixed onto the carrier particle.

[0100] In the third state where the toner coverage is more than 45%, a sufficient number of the toner particles adhere

onto the carrier particle, and floating toner particles occur. Then, the floating toner particles work like lubricant. In this way, regardless of the type of the coat resin, the shear friction coefficient of the developer is decreased.

[0101] Therefore, when the coat layer 22 is made of silicone resin, within the range where the toner coverage of the developer DP is 20% or more and 45% or less, it can be said that the variation width of the shear friction coefficient of the developer DP can be 0.02 or less. In other words, it can be said that it is preferable that the coat layer 22 be made of silicone resin.

[0102] Because the variation width of the shear friction coefficient of the developer DP is 0.02 or less (i.e., the variation width of the shear friction coefficient of the developer DP is small), it is possible to suppress a variation in the separation position of the developer DP from the developing roller 31. In other words, the developer DP drops from the developing roller 31 at a desired position. In this way, the mixed state of the developer DP that is stirred inside the development casing 30 is stabilized, and it is possible to prevent the image density from being not uniform.

< 6. Uniformalization of Toner Concentration in Developer on Developing Roller >

[0103] The developing roller 31 has the developer separating part for separating the developer DP from the developer carrying surface 31S. A part of the developing roller 31, from the first magnetic pole S1 to the second magnetic pole S2 on the downstream side in the rotation direction of the development sleeve 310, is the developer separating part. In the developer separating part of the developing roller 31, when the attraction of the developer DP after passing the first magnetic pole S1 to the developer carrying surface 31S is decreased, the developer DP is separated from the developer carrying surface 31S.

[0104] Specifically, with respect to a position on the developer carrying surface 31S, where a resultant force of a vertical magnetic force and a horizontal magnetic force of the first magnetic pole S1 has a peak, on the downstream side in the rotation direction of the development sleeve 310, there is a magnetic force reversal region in which the resultant force of the vertical magnetic force and the horizontal magnetic force of the developer separating part increases, as separating from the developer carrying surface 31S in the normal direction. The magnetic force reversal region of the developer separating part is described with reference to FIG. 9 and FIG. 10. FIG. 9 and FIG. 10 are graphs showing magnetic force distributions of the developing roller 31.

[0105] In FIG. 9 and FIG. 10, the horizontal axis represents an angle of the magnetic pole (see FIG. 2), and the left vertical axis represents a magnetic force (mT). In addition, a solid line in the graph (noted as "vertical magnetic force (0.05)") indicates measurement values at a position apart from the developer carrying surface 31S by 0.05 mm in the normal direction. A coarse broken line in the graph (noted as "resultant force (0.05 mm)") indicates the resultant force of the vertical magnetic force and the horizontal magnetic force at the position apart from the developer carrying surface 31S by 0.05 mm in the normal direction. A fine broken line in the graph (noted as "resultant force (0.5 mm)") indicates the resultant force of the vertical magnetic force and the horizontal magnetic force at a position apart from the developer carrying surface 31S by 0.5 mm in the normal direction.

[0106] In addition, the right vertical axis in FIG. 10 represents a ratio of the resultant force of the vertical magnetic force and the horizontal magnetic force at a position apart from the developer carrying surface 31S by 0.5 mm in the normal direction, to the resultant force of the vertical magnetic force and the horizontal magnetic force at the position apart from the developer carrying surface 31S by 0.05 mm in the normal direction. The ratio of the resultant force is indicated by a two-dot-dash line (noted as "resultant force ratio (0.5/0.05)") in the graph. In the following description, the ratio of the resultant force of the vertical magnetic force and the horizontal magnetic force at the position apart from the developer carrying surface 31S by 0.5 mm in the normal direction, to the resultant force of the vertical magnetic force and the horizontal magnetic force at the position apart from the developer carrying surface 31S by 0.05 mm in the normal direction, is simply referred to as the ratio of the resultant force.

[0107] Normally, the resultant force at the position apart by 0.5 mm is smaller than the resultant force at the position apart by 0.05 mm in the normal direction from the developer carrying surface 31S, and the ratio of the resultant force is less than 1. However, in the developer separating part, there is a region where the resultant force at the position apart by 0.5 mm is larger than the resultant force at the position apart by 0.05 mm in the normal direction from the developer carrying surface 31S (a region where the ratio of the resultant force is 1 or more). In other words, there is a region where the resultant force is increased as separating from the developer carrying surface 31S in the normal direction. This region is the magnetic force reversal region, which is the region where the developer DP is easily separated from the developer carrying surface 31S.

[0108] Here, a position on the developer carrying surface 31S, at which the resultant force of the vertical magnetic force and the horizontal magnetic force of the first magnetic pole S1 has a peak, is referred to as a position A. The resultant force of the vertical magnetic force and the horizontal magnetic force in the developer separating part decreases first toward the downstream side in the rotation direction of the development sleeve 310, along with separating from the developer carrying surface 31S in the normal direction. After that, the resultant force of the vertical magnetic force and the horizontal magnetic force in the developer separating part starts to increase, toward the downstream side in the rotation direction of the development sleeve 310, along with separating from the developer carrying surface 31S in the normal direction, and the

ratio of the resultant force becomes 1. The position at which the ratio of the resultant force becomes 1 (a position closer to the position A) is a start position of the magnetic force reversal region. Here, a start position of the magnetic force reversal region, on the downstream side of the position A on the developer carrying surface 31S in the rotation direction of the development sleeve 310, is referred to as a position B.

[0109] At the position A, the magnetic force is stronger at a position closer to the developer carrying surface 31S in the normal direction. On the other hand, after passing the position B to the downstream side in the rotation direction of the development sleeve 310, the magnetic force is stronger as separating from the developer carrying surface 31S in the normal direction. For this reason, in a region M from the position A to the position B, the developer DP gathers on the developer carrying surface 31S, and separates from the developer carrying surface 31S. Then, also in the region M, the developer DP is stirred.

[0110] In this way, if the region M from the position A to the position B is large to some extent, an accumulation amount of the developer DP is increased, and the stirring power of the developer DP is increased. As a result, the toner concentration on the developing roller 31 can be uniformed. In other words, the image density can be more uniform.

[0111] However, if the region M from the position A to the position B is too large, the accumulation amount of the developer DP is increased, and a driving torque of the developing roller 31 is increased. In addition, if the region M from the position A to the position B is too large, a stress is continuously applied to the developer DP on the developer carrying surface 31S, and the developer DP is deteriorated.

[0112] Therefore, in this embodiment, a distance from the position A to the position B on the downstream side in the rotation direction of the development sleeve 310 is set to 1.1 mm or more and 4.0 mm or less. Preferably, the distance from the position A to the position B on the downstream side in the rotation direction of the development sleeve 310 is 1.4 mm or more and 4.0 mm or less. In this way, the image density can be uniformed (in other words, unevenness of image density can be suppressed).

< 7. Confirmation Experiment >

[0113] Hereinafter, an experiment is described, which was performed for checking the above effects of this embodiment. In the confirmation experiment, printing was actually performed, and states of printed images were checked.

< 7-1. Preparation of Toner >

[0114] The toner of the developer to be used for the confirmation experiment was prepared by the following method.

< 7-1-1. Synthesis of Amorphous Polyester Resin >

[0115] A reaction container, equipped with a thermometer (thermocouple), a dewatering conduit, a nitrogen gas introduction conduit, and a stirring device (stirring blade), was set in an oil bath. Then, 1,575 g of bisphenol A propylene oxide additive (BPA-PO), 163 g of bisphenol A ethylene oxide additive (BPA-EO), 377 g of fumaric acid, and 4 g of catalyst (dibutyltin oxide) were put into the reaction container.

[0116] After creating a nitrogen atmosphere in the reaction container, the temperature inside the reaction container was raised to 220 degrees Celsius while stirring the contents. Under the conditions of the nitrogen atmosphere and the temperature of 220 degrees Celsius, polymerization reaction of the contents in the reaction container was performed for 8 hours while removing by-product water. Next, the pressure inside the reaction container is reduced, and under the conditions of the reduced pressure atmosphere (pressure: 7,999 Pa) and the temperature of 220 degrees Celsius, the polymerization reaction of the contents in the reaction container was performed for more and 1 hour. In addition, the temperature inside the reaction container was reduced to 210 degrees Celsius, and then 336 g of trimellitic anhydride was added into the reaction container. Then, under the conditions of the reduced pressure atmosphere (pressure: 7,999 Pa) and the temperature of 210 degrees Celsius, reaction of the contents in the reaction container was performed. After that, the reaction product was taken out from the reaction container and was cooled, and hence the amorphous polyester resin having the following physical properties was obtained. Note that the polyester resin obtained in this way did not clearly show its endothermic peak in the endothermic curve measured using a differential scanning calorimeter, and its clear melting point was not able to be measured, and thus it was determined to be amorphous.

softening point (Tm): 100 degrees Celsius
glass transition point (Tg):50 degrees Celsius
mass average molecular weight (Mw):30,000
acid value: 15 mgKOH/g
hydroxyl value: 30 mgKOH/g

< 7-1-2. Preparation of Toner Mother Particles >

[0117] Using an FM mixer ("FM-10B" manufactured by Nippon Coke & Engineering Co., Ltd.), 100 pts. mass of binder resin, 4 pts. mass of coloring agent, 1 pts. mass of charge control agent, and 5 pts. mass of mold release agent were mixed, so that the mixture was obtained. As the binder resin, the amorphous polyester resin described above was used. As the coloring agent, copper phthalocyanine blue pigment (C.I. Pigment Blue 15:3) was used. As the charge control agent, quaternary ammonium salt ("BONTRON (registered trademark) P-51" manufactured by Orient Chemical Industries Co., Ltd.) was used. As the mold release agent, carnauba wax ("Special Carnauba Wax 1st" manufactured by S. KATO & CO.) was used.

[0118] Next, using a twin-screw extruder ("PCM-30 type" manufactured by Ikegai Co., Ltd.), the mixture was melted and kneaded, so that the melted and kneaded material was obtained. In addition, using a mechanical pulverizer ("Turbo Mill" manufactured by Freund-Turbo Corporation), the melted and kneaded material was pulverized, so that the pulverized material was obtained. Then, using a classifier ("Elbow Jet" manufactured by Nittetsu Mining Co., Ltd.), the pulverized material was classified. In this way, powder-like toner mother particles having a volume median diameter of 6.8 μm were obtained. Note that the volume median diameter (D_{50}) is a median diameter measured using a laser diffraction/scattering type particle size distribution measurement device ("LA-950" manufactured by HORIBA, Ltd.).

< 7-1-3. External Addition to Toner Mother Particles >

[0119] Using the FM mixer ("FM-10B" manufactured by Nippon Coke & Engineering Co., Ltd.), 100.0 pts. mass of the toner mother particle described above, 1.0 pts. mass of the silica particles (mean primary particle diameter: 20 nm), and 0.75 pts. mass of aluminum oxide particles ("AEROXIDE (registered trademark) Alu C805" manufactured by Nippon Aerosil Co., Ltd., BET specific surface area: 75 to 105 m^2/g) were mixed for 5 minutes under the condition of 4,000 rpm, so that the mixture was obtained. Note that the mean primary particle diameter of the aluminum oxide particles is more than 300 nm. Then, using a sieve of 200 mesh (aperture of 75 μm), the mixture was sieved, and the toner shown in Table 1 was obtained. In the following description, the toner is shown by "T".

[Table 1]

toner (T)			
mother particle	external additive particle		
	alumina particle	silica particle	
pts. mass	pts. mass	pts. mass	diameter (nm)
100	0.75	1	20

< 7-2. Preparation of Carrier >

[0120] The carrier of the developer to be used for the confirmation experiment was prepared by the following method.

< 7-2-1. Preparation of Coating Liquid >

[0121] Coat resin solution, at least one of the barium titanate particles and the carbon black particles, and toluene were put into a stainless steel container. Then, using a homogenizer, the contents in the stainless steel container were mixed, so that the coating liquid was obtained. As the barium titanate particles, "BT-01" manufactured by Sakai Chemical Industry Co., Ltd. (mean primary particle diameter: 304 nm) was used. As the carbon black particle, "Ketjenblack (registered trademark) EC300J" manufactured by LION SPECIALTY CHEMICALS CO., Ltd. (mean primary particle diameter: 39.5 nm), which is conductive carbon black, was used.

< 7-2-2. Preparation of Carrier Particles >

[0122] Using a fluid bed coating machine ("FD-MP-01 D type" manufactured by Powrex Corporation), 5,000 g of the carrier cores were allowed to flow, while the coating liquid was sprayed to the carrier cores. In this way, the carrier cores coated with the coating liquid were obtained. In this case, as the carrier cores, manganese ferrite cores (manufactured by DOWA IP Creation Co., Ltd., volume median diameter: 40 μm) were used. Next, using an electric furnace, the carrier cores coated with the coating liquid were fired at 200 degrees Celsius for 1 hour, so that the coat layer was formed on the surface of the carrier core. In this way, the carrier particles were obtained.

[0123] Here, in the confirmation experiment, carriers C1, C2, and C3, i.e., three types were used. In other words, three types of developers were used. Characteristics of the carriers C1 to C3 are shown in Table 2. Note that each toner of the developers is the toner T described above. In addition, the toner coverage of each developer (i.e., toner concentration) is 20% or more and 45% or less.

[Table 2]

carrier						
type	particle diameter (μ m)	saturation magnetization (emu/g)	coat resin	coat resin internal additive (pts. mass)		shear friction coefficient variation width
C1	40	80	Si	CB (4)	BT (10)	0.009
C2	36	70	Si	CB (3)	BT (10)	0.020
C3	36	70	PI+FEP	CB (2)		0.037

[0124] As illustrated in Table 2, a carrier particle diameter of the carrier C1 is 40 μm, and the saturation magnetization of the carrier core of the carrier C1 is 80 emu/g. A carrier particle diameter of the carrier C2 is 36 μm, and the saturation magnetization of the carrier core of the carrier C2 is 70 emu/g. A carrier particle diameter of the carrier C3 is 36 μm, and the saturation magnetization of the carrier core of the carrier C3 is 70 emu/g.

[0125] **In** addition, a contained amount of the carbon black particles (CB) in the coat layer of the carrier C1 is 4 pts. mass with respect to 100 pts. mass of the coat resin, and a contained amount of the barium titanate particles (BT) in the coat layer of the carrier C1 is 10 pts. mass with respect to 100 pts. mass of the coat resin. A contained amount of the carbon black particles (CB) in the coat layer of the carrier C2 is 3 pts. mass with respect to 100 pts. mass of the coat resin, and a contained amount of the barium titanate particles (BT) in the coat layer of the carrier C2 is 10 pts. mass with respect to 100 pts. mass of the coat resin. A contained amount of the carbon black particles (CB) in the coat layer of the carrier C3 is 2 pts. mass with respect to 100 pts. mass of the coat resin. Note that the coat layer of the carrier C3 does not contain barium titanate particles.

[0126] In addition, in the carrier C1, the coat layer was made of silicone resin (Si). In the same manner for the carrier C2, the coat layer was made of silicone resin (Si). As the silicone resin, "KR-255" manufactured by Shin-Etsu Chemical Co., Ltd. (solid content: methylphenyl silicone resin, solid content concentration: 50 mass %) was used. On the other hand, in the carrier C3, the coat layer was made of polyimide resin (PI) and fluorocarbon resin (FEP).

[0127] The carriers C1 to C3 have different contained amounts of the carbon black particles. In addition, between the carrier C3 and the carrier C1 or C2, there is a difference whether or not the barium titanate particles are contained. Further, between the carrier C3 and the carrier C1 or C2, there is a difference whether or not the coat resin is silicone resin.

[0128] In this way, the developers using the carriers C1 to C3, respectively, had different variation widths of the shear friction coefficient within the range where the toner coverage is 20% or more and 45% or less. In the developer using the carrier C1, the variation width of the shear friction coefficient was 0.009, within the range where the toner coverage is 20% or more and 45% or less. In the developer using the carrier C2, the variation width of the shear friction coefficient was 0.020, within the range where the toner coverage is 20% or more and 45% or less. In the developer using the carrier C3, the variation width of the shear friction coefficient was 0.037, within the range where the toner coverage is 20% or more and 45% or less.

[0129] In other words, in the developer using the carrier C1, the variation width of the shear friction coefficient was 0.01 or less, within the range where the toner coverage is 20% or more and 45% or less. In the developer using the carrier C2, the variation width of the shear friction coefficient was 0.02 or less, within the range where the toner coverage is 20% or more and 45% or less. In the developer using the carrier C3, the variation width of the shear friction coefficient was more than 0.02, within the range where the toner coverage is 20% or more and 45% or less. Note that measurement conditions of the shear friction coefficient are as follows.

sample amount: 15 g
sampling frequency: 10 Hz
device configuration identification symbol: BF82XB
upper fixed cell inner diameter: 30 mm
lower movable cell depth: 5 mm
shear speed: 10 μm/sec
shear band thickness: 0.2 mm

compression speed: 0.2 m/sec

< 7-3. Developing Roller of Developing Device >

[0130] In the confirmation experiment, six types of the developing devices, i.e., developing devices D1, D2, D3, D4, D5 and D6 are prepared. Characteristics of the developing devices (developing rollers) D1 to D6 are shown in Table 3. Note that in Table 3, "A-B distance" means a distance from the position A of the developing roller to the position B on the downstream side in the rotation direction of the development sleeve, in a circumferential direction (a circumferential direction of a circle around the rotation center of the developing roller).

[Table 3]

developing device			
type	roller diameter (mm)	A-B angle (degrees)	A-B distance (mm)
D1	20	23.0	4.0
D2	20	18.3	3.2
D3	16	16.9	2.4
D4	16	13.5	1.9
D5	16	10.0	1.4
D6	16	8.1	1.1

[0131] In the developing device D1, the A-B distance of the developing roller is 4.0 mm. In the developing device D2, the A-B distance of the developing roller is 3.2 mm. In the developing device D3, the A-B distance of the developing roller is 2.4 mm. In the developing device D4, the A-B distance of the developing roller is 1.9 mm. In the developing device D5, the A-B distance of the developing roller is 1.4 mm. In the developing device D6, the A-B distance of the developing roller is 1.1 mm. In other words, in the developing devices D1 to D6, the A-B distance of the developing roller is 1.1 mm or more and 4.0 mm or less. In particular, in the developing devices D3 to D5, the A-B distance of the developing roller is 1.4 mm or more and 2.4 mm or less.

< 7-4. Evaluation >

[0132] In order to check image density unevenness, Experiments 1 to 18 were performed. As the evaluation machine, an image forming apparatus (Taskalfa3554ci) manufactured by KYOCERA Document Solutions Inc. was used. Evaluation results are shown in Table 4.

[Table 4]

No.	carrier	developing device	maximum value of luminance deviation/average luminance evaluation	evaluation
1	C1	D1	0.027	B
2	C1	D2	0.024	B
3	C1	D3	0.022	A
4	C1	D4	0.022	A
5	C1	D5	0.023	A
6	C1	D6	0.024	B
7	C2	D1	0.031	C
8	C2	D2	0.028	C
9	C2	D3	0.026	B
10	C2	D4	0.026	B
11	C2	D5	0.027	B
12	C2	D6	0.028	C

(continued)

No.	carrier	developing device	maximum value of luminance deviation/average luminance evaluation	evaluation
13	C3	D1	0.038	E
14	C3	D2	0.035	D
15	C3	D3	0.033	D
16	C3	D4	0.034	D
17	C3	D5	0.035	D
18	C3	D6	0.036	E

[0133] The developing devices D1 to D6 were used in the confirmation experiments 1 to 6, respectively, and the developing devices D1 to D6 were used in the confirmation experiments 7 to 12, respectively, and the developing devices D1 to D6 were used in the confirmation experiments 13 to 18, respectively. Further, the carrier C1 was used in the confirmation experiments 1 to 6, the carrier C2 was used in the confirmation experiments 7 to 12, and the carrier C3 was used in the confirmation experiments 13 to 18.

[0134] In addition, in each of the confirmation experiments 1 to 18, an experiment printing was performed, in which an evaluation target image including a solid vertical stripe pattern and a following half image (image density 25%) was printed on ten successive sheets, and density unevenness of the half image in the evaluation target image was measured. The image that was printed in the confirmation experiments is illustrated in FIG. 11. The image denoted by G1 is a schematic diagram of the solid vertical stripe pattern, and the image denoted by G2 is a schematic diagram of the half image.

[0135] In the measurement of density unevenness of the half image, the evaluation target image was taken in image analysis software ("ImagePro" manufactured by MediaCybernetics Company) and is converted into grayscale, and then the image was processed by a low-pass filter, so as to remove fine noise. After that, the processed half image is divided into 500 (10×50) regions. In addition, luminance deviation and average luminance were measured for each of the 500 regions, and a value of luminance deviation/average luminance was calculated. Then, a maximum value of the values of luminance deviation/average luminance was calculated for each sheet of each experiment printing, and a mean value of the maximum values of luminance deviation/average luminance of ten sheets was calculated.

[0136] In each confirmation experiment, the experiment printing was repeated five times, in each of which the evaluation target image was printed on ten sheets. In addition, for each confirmation experiment, a mean value of the maximum values of luminance deviation/average luminance of the experiment printing for five times was calculated, as a value indicating density unevenness of each confirmation experiment. Then, evaluation of five steps, i.e., Evaluation A, B, C, D or E, was performed as follows. Note that if the maximum value of luminance deviation/average luminance is smaller, it means that a degree of image density unevenness is lower (better). Evaluation A indicates best, Evaluation B indicates good, and Evaluation C indicates a level having no problem. On the other hand, Evaluation D indicates a level having a problem, and Evaluation E indicates a worst level (a level having a problem).

A: The maximum value of luminance deviation/average luminance is 0.023 or less.

B: The maximum value of luminance deviation/average luminance is 0.024 or more and 0.027 or less.

C: The maximum value of luminance deviation/average luminance is 0.028 or more and 0.031 or less.

D: The maximum value of luminance deviation/average luminance is 0.032 or more and 0.035 or less.

E: The maximum value of luminance deviation/average luminance is more than 0.036.

[0137] First, in each of Experiments 1 to 6 using the carrier C1, the image density unevenness was a level having no problem. In each of Experiments 7 to 12 using the carrier C2, too, the image density unevenness was a level having no problem. On the other hand, in each of Experiments 13 to 18 using the carrier C3, the image density unevenness was a level having a problem.

[0138] From this result, it was confirmed that the image density unevenness can be reduced, by using the developer in which the variation width of the shear friction coefficient is 0.02 or less within the range where the toner coverage is 20% or more and 45% or less. In other words, it was confirmed that the image density can be uniform, by using the developer in which the variation width of the shear friction coefficient is 0.02 or less within the range where the toner coverage is 20% or

more and 45% or less.

[0139] Note that in each of Experiments 1 to 6 using the carrier C1, the evaluation was "B" or better. On the other hand, in some of Experiments 7 to 12 using the carrier C2, the evaluation was "C". From this fact, it can be said that it is preferable to use the developer in which the variation width of the shear friction coefficient is smaller within the range where the toner coverage is 20% or more and 45% or less. In other words, it can be said that it is more preferable that the variation width of the shear friction coefficient of the developer be 0.01 or less, within the range where the toner coverage of the developer is 20% or more and 45% or less.

[0140] In addition, in Experiments 1 to 12, the A-B distance of the developing roller is 1.1 mm or more and 4.0 mm or less. In particular, in Experiments 3 to 5 in which the evaluation is "A", the A-B distance of the developing roller is 1.4 mm or more and 2.4 mm or less. From this fact, it was confirmed that the image density can be uniform, by using the developer in which the variation width of the shear friction coefficient was 0.01 or less within the range where the toner coverage is 20% or more and 45% or less, and by using the developing roller having the A-B distance of 1.1 mm or more and 4.0 mm or less. Further, it was confirmed that the image density can be more uniform, by suing the developing roller having the A-B distance of 1.4 mm or more and 2.4 mm or less.

Claims

1. A two-component developer (DP) containing toner particles (1) and carrier particles (2), wherein
a variation width of a shear friction coefficient of the two-component developer (DP) is 0.02 or less, within a range where a surface coverage of the toner particles (1) with respect to one carrier particle (2) is 20% or more and 45% or less.

2. The two-component developer (DP) according to claim 1, wherein the variation width of the shear friction coefficient of the two-component developer (DP) is 0.01 or less, within the range where the surface coverage of the toner particles (1) with respect to one carrier particle (2) is 20% or more and 45% or less.

3. A developing device (3) comprising a developer carrying member (31) having a developer carrying surface (31S) configured to carry the two-component developer (DP) according to claim 1 or 2, the developing device (3) supplying toner in the two-component developer (DP) carried by the developer carrying surface (31S) to an electrostatic latent image at a development position (Pd), so as to develop the electrostatic latent image, wherein

the developer carrying member (31) includes

a shaft (311) extending in a predetermined direction,
a magnet (312) fixed to an outer peripheral surface of the shaft (311), so as to have a plurality of magnetic poles in a circumferential direction of the shaft (311), and
a development sleeve (310) as a cylindrical member in which the shaft (311) is inserted, the development sleeve (310) having an outer peripheral surface of the cylindrical member as the developer carrying surface (31S), so as to be supported in a rotatable manner about the shaft (311),

the magnet (312) includes, as magnetic poles, at least

a first magnetic pole (S1) disposed on a downstream side of the development position (Pd) in a rotation direction of the development sleeve (310), and
a second magnetic pole (S2) disposed on a downstream side of the first magnetic pole (S1) in the rotation direction of the development sleeve (310), the second magnetic pole (S2) having the same polarity as the first magnetic pole (S1),

the developer carrying member (31) has a part from the first magnetic pole (S1) to the second magnetic pole (S2) on the downstream side in the rotation direction of the development sleeve (310), as a developer separating part for allowing the two-component developer (DP) to separate from the developer carrying surface (31S),
the developer carrying member (31) has a magnetic force reversal region on a downstream side of a position on the developer carrying surface (31S), at which a resultant force of a vertical magnetic force and a horizontal magnetic force of the first magnetic pole (S1) has a peak, in the rotation direction of the development sleeve (310),
the resultant force of the vertical magnetic force and the horizontal magnetic force in the magnetic force reversal region being increased as separating from the developer carrying surface (31S) in the normal direction, and
when the position on the developer carrying surface (31S), at which the resultant force of the vertical magnetic

force and the horizontal magnetic force of the first magnetic pole (S1) has a peak, is referred to as a position A, and a start position of the magnetic force reversal region on the developer carrying surface (31S) is referred to as a position B, then a distance from the position A to the position B on the downstream side in the rotation direction of the development sleeve (310) is 1.1 mm or more and 4.0 mm or less.

4. The developing device (3) according to claim 3, wherein the distance from the position A to the position B on the downstream side in the rotation direction of the development sleeve (310) is 1.4 mm or more and 2.4 mm or less.

5. An image forming apparatus (PR) comprising:

the developing device (3) according to claim 3 or 4;
an image carrier (5) configured to carry an electrostatic latent image to be developed by the developing device (3); and
a transfer unit (6) configured to transfer the image developed by the developing device (3) onto a sheet (S).

FIG.1

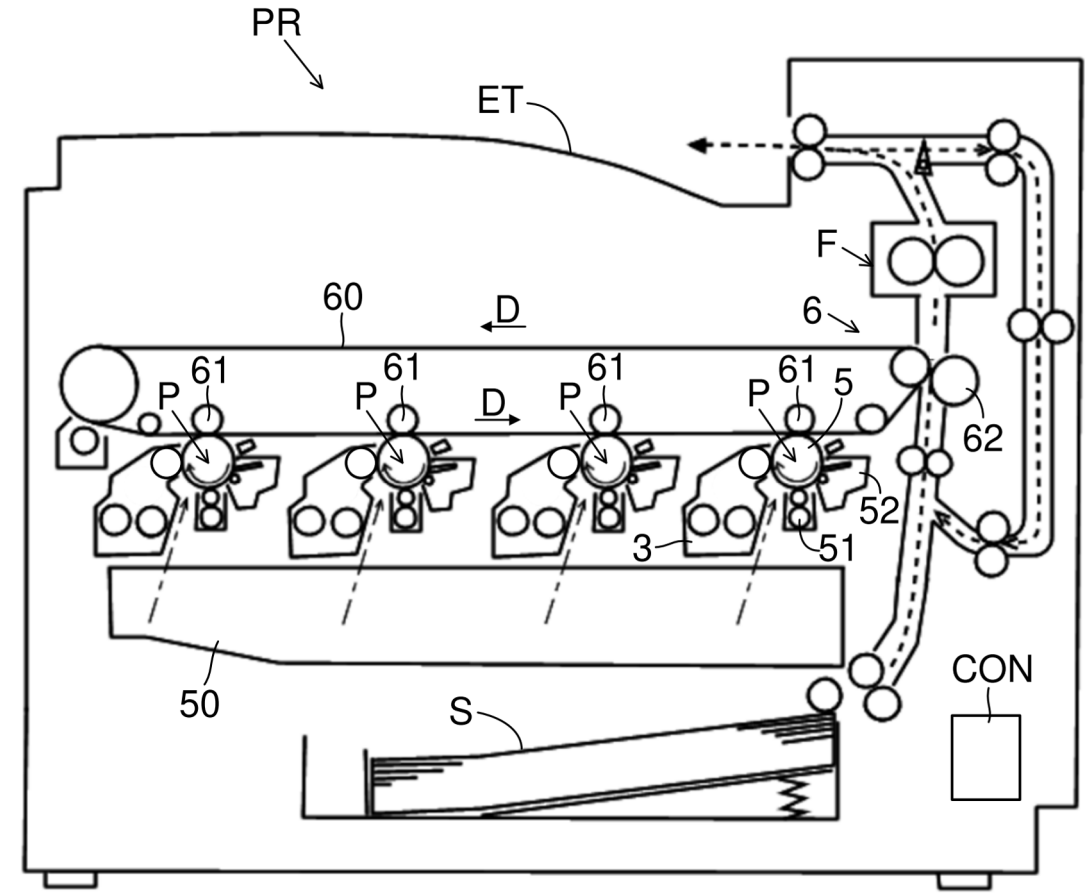


FIG.2

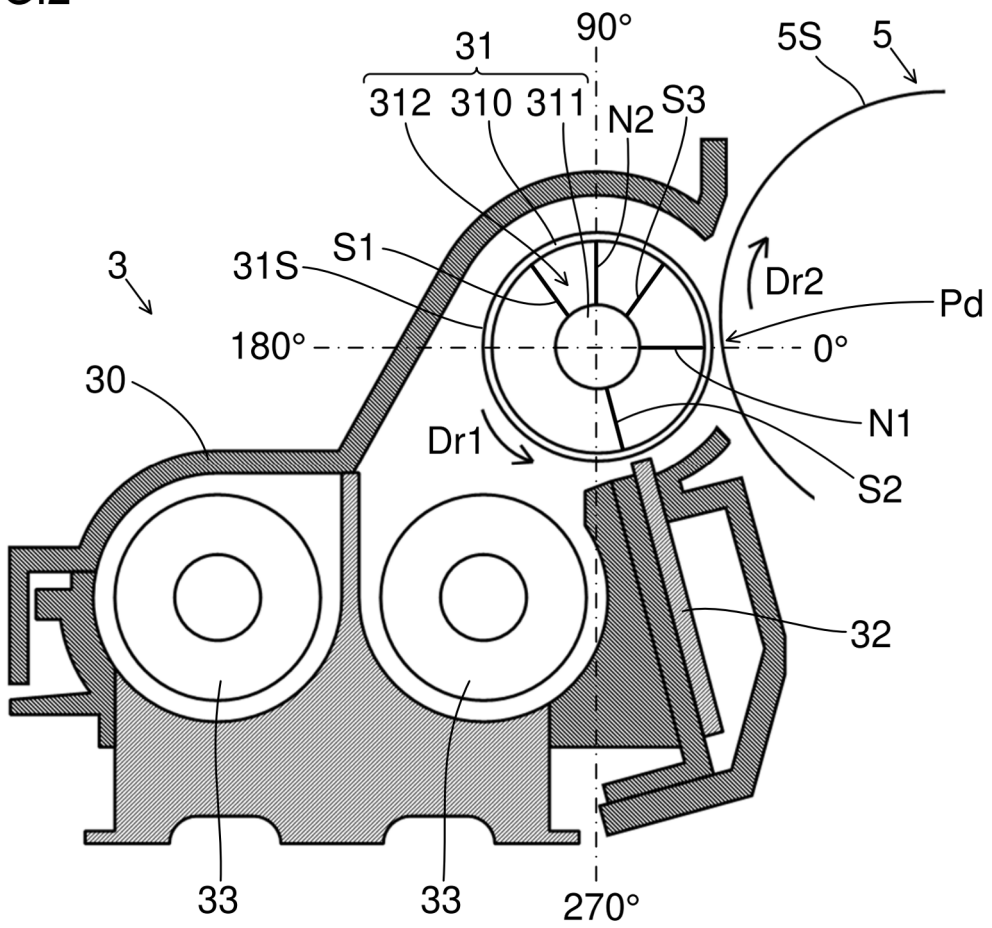

90°
31
312
310
311
N2
S3
5S
5
3
31S
S1
Dr2
Pd
180°
0°
30
N1
Dr1
S2
32
33
33
270°

FIG.3

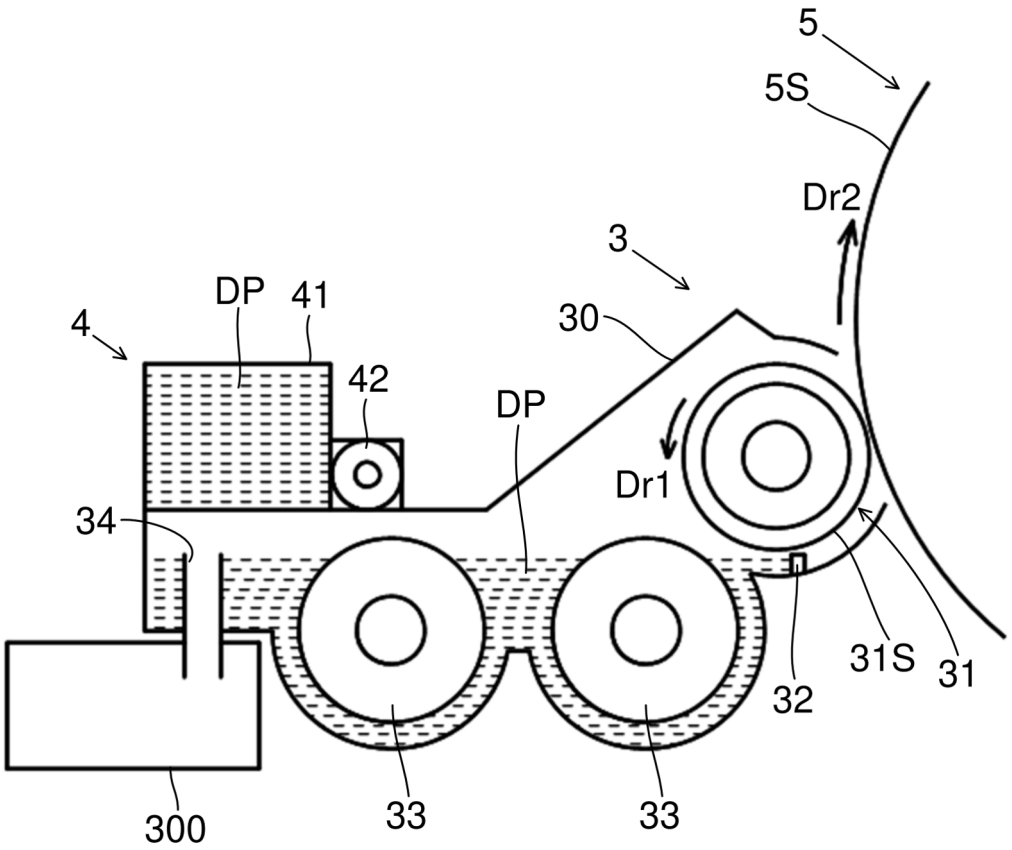


FIG.4

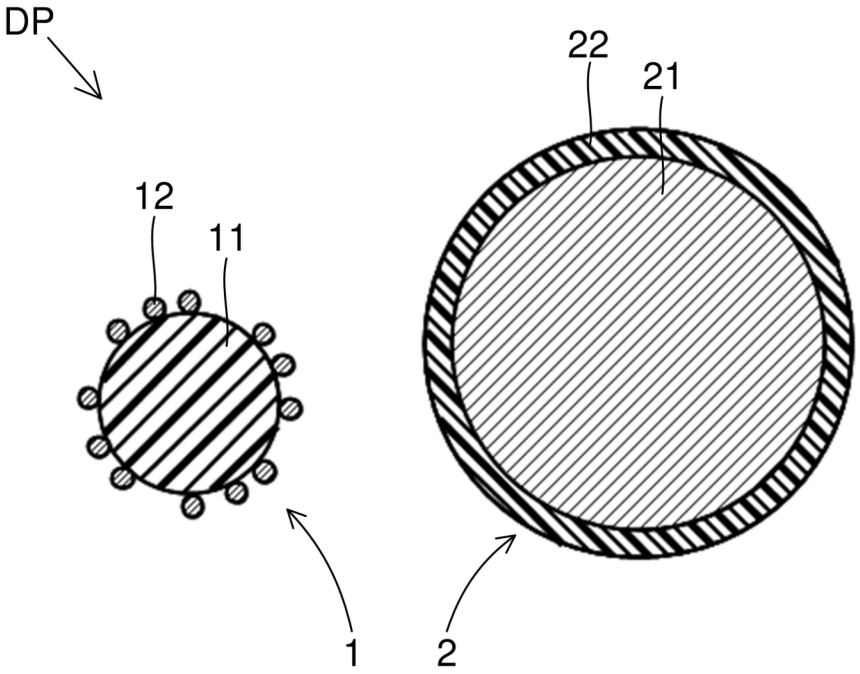
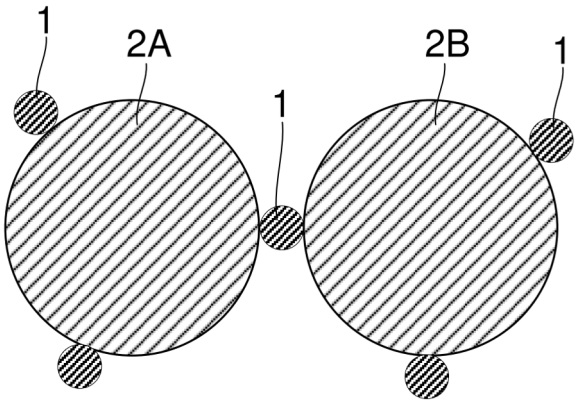
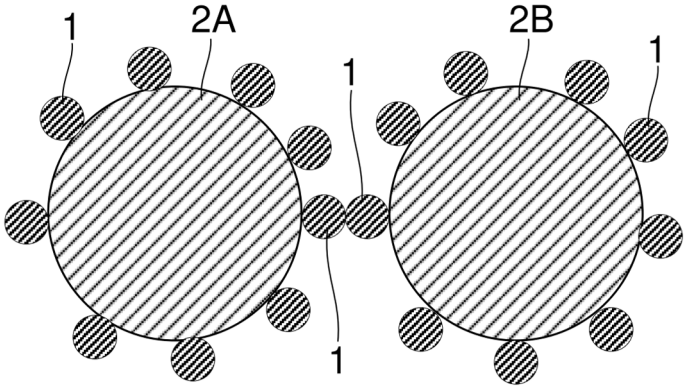


FIG.5



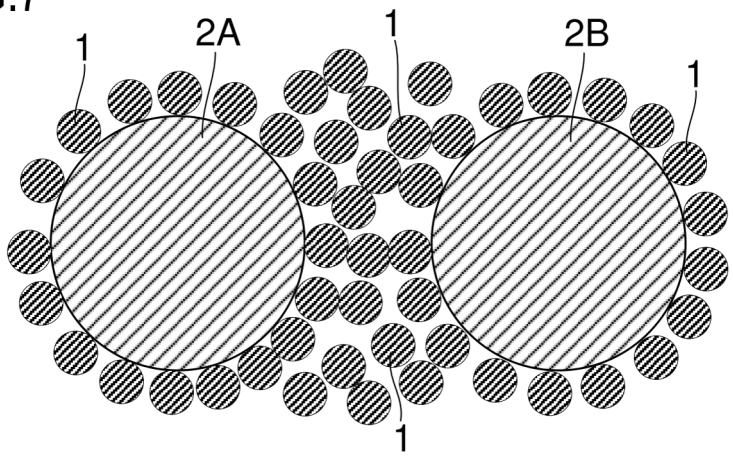
first state (toner coverage: less than 20%)

FIG.6



second state (toner coverage: 20% to 45%)

FIG.7



third state (toner coverage: more than 45%)

FIG.8

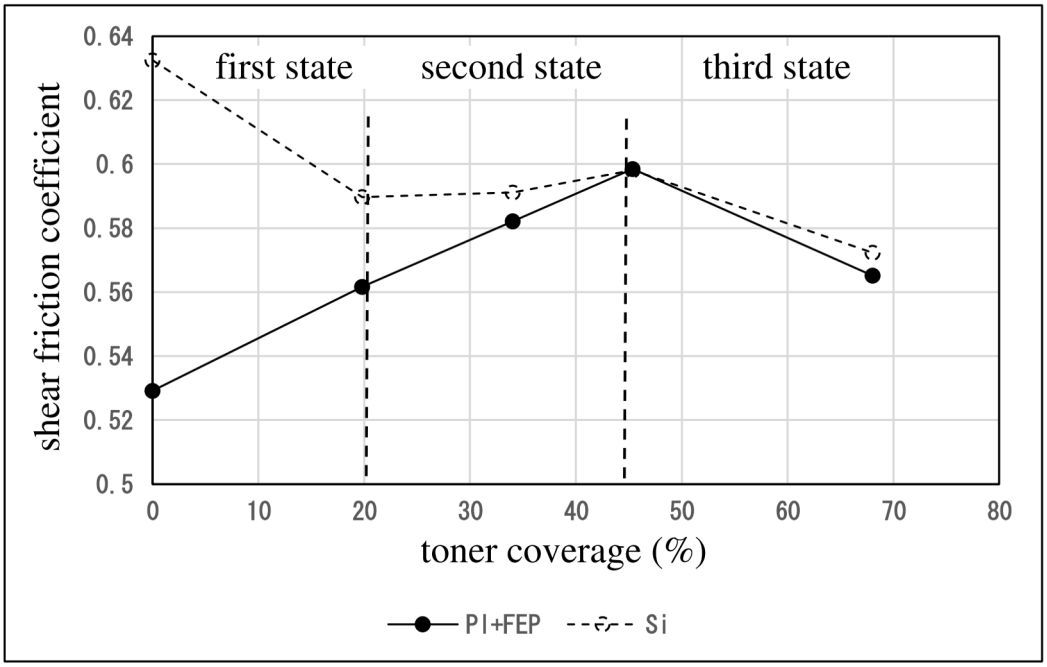

first state
second state
third state
shear friction coefficient
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0
10
20
30
40
50
60
70
80
toner coverage (%)
PI+FEP
Si

FIG.9

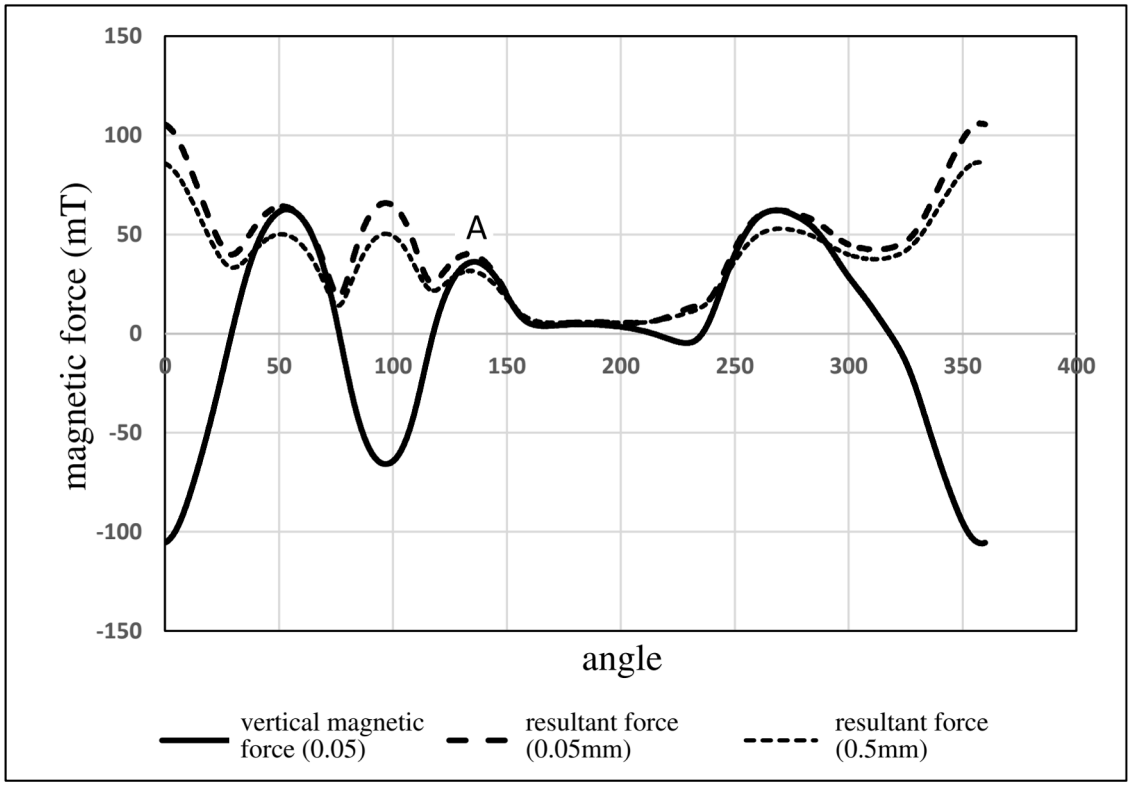

150
100
50
0
-50
-100
-150
magnetic force (mT)
0
50
100
150
200
250
300
350
400
A
angle
vertical magnetic force (0.05)
resultant force (0.05mm)
resultant force (0.5mm)

FIG.10

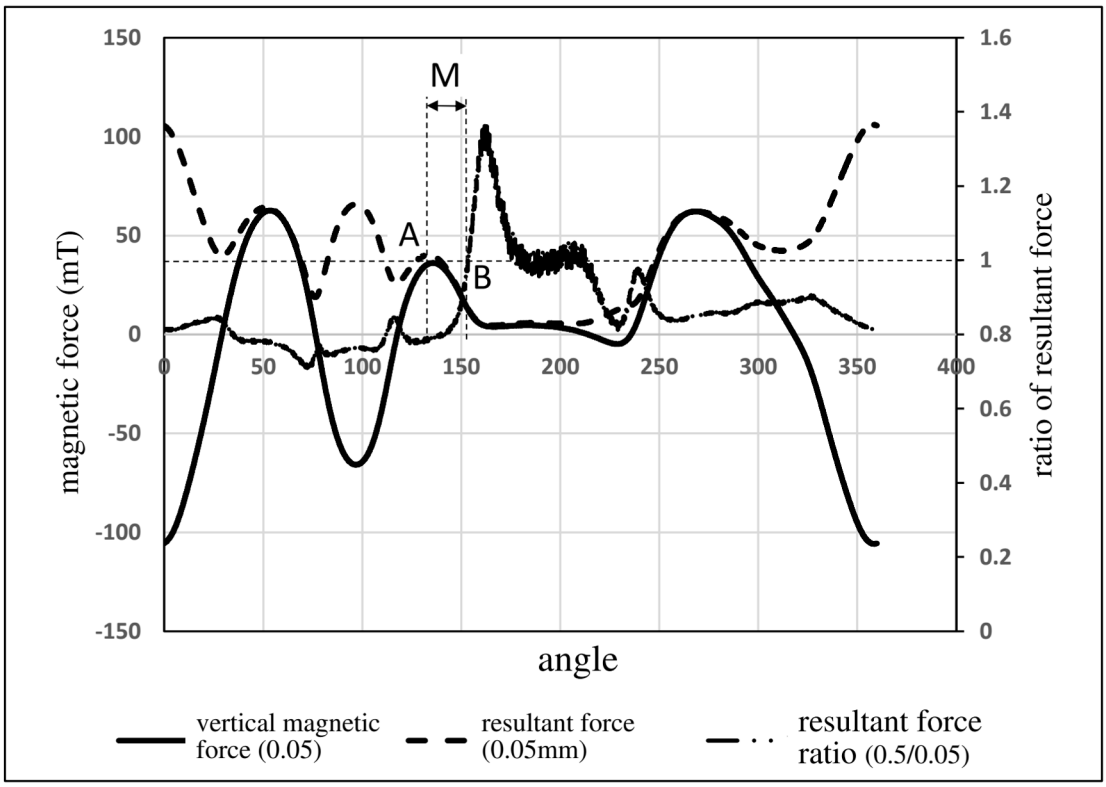
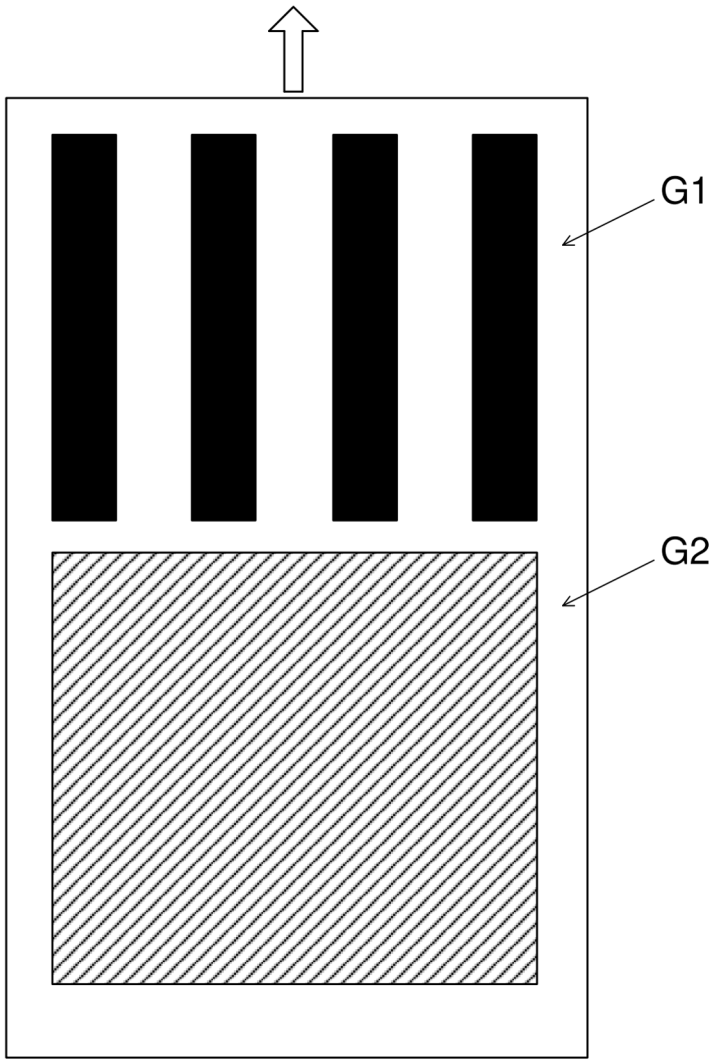

150
100
50
0
-50
-100
-150
magnetic force (mT)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ratio of resultant force
0
50
100
150
200
250
300
350
400
angle
M
A
B
vertical magnetic force (0.05)
resultant force (0.05mm)
resultant force ratio (0.5/0.05)

FIG.11



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 26 16 5315

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2024/241461 A1 (SHIMIZU TAMOTSU [JP] ET AL) 18 July 2024 (2024-07-18) * paragraph [0231]; figure 1; tables 3-8 * -----	1-5	INV. G03G9/10 G03G9/08 G03G9/113
A	JP 2011 174954 A (RICOH CO LTD) 8 September 2011 (2011-09-08) * paragraph [0103] * -----	1-5	ADD. G03G9/107

TECHNICAL FIELDS SEARCHED (IPC)

G03G

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 August 2026	Stabel, Andreas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 26 16 5315

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

20-08-2026

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2024241461 A1	18-07-2024	CN 117716299 A	15-03-2024
		JP 7690988 B2	11-06-2025
		JP WO2023281881 A1	12-01-2023
		US 2024241461 A1	18-07-2024
		WO 2023281881 A1	12-01-2023
JP 2011174954 A	08-09-2011	JP 5424118 B2	26-02-2014
		JP 2011174954 A	08-09-2011

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82