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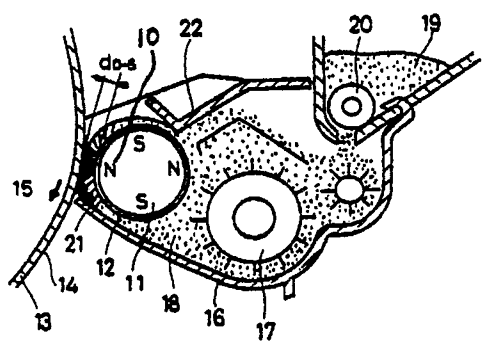
(54) Developing method using two-component type developer.

(57) In a developing method comprising delivering a two-component type developer comprising a magnetic carrier and a toner and developing an electrostatic latent image on a photosensitive drum, the developing conditions are set so that the degree (R) of substitution of the developer, which is the ratio of substitution of the volume of the developing zone by a fresh carrier/toner aggregate (developer) during the developing time, is within a specific range of from 16.00 to 33.00%. According to this developing method, in the reproduction of multiple fine lines, the line width is kept constant in each line and front end lacking or rear end lacking can be prevented, and an image having a high density and a high quality can be formed with an excellent image reproducibility.

Fig. 5



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DEVELOPING METHOD USING TWO-COMPONENT TYPE DEVELOPER

Background of the Invention

(1) Field of the Invention

The present invention relates to a developing method using a two-component type developer. More particularly, the present invention relates to a developing method in which a high reproducibility of letters can be attained and in reproduction of multiple fine lines, the width of each line is constant and occurrence of so-called front end lacking or rear end lacking is prevented.

(2) Description of the Related Art

A two-component type developer comprising a magnetic carrier and a toner is widely used in commercial electro-photographic copying machines, and at the development of a charge image, a magnetic brush of this developer is formed on a developing sleeve having magnetic poles disposed therein and the magnetic brush is brought into sliding contact with a photosensitive material having a charge image formed thereon to form a toner image.

Many proposals have been made on conditions adopted for this development. For example, Japanese Unexamined Patent Publication No. 59-172660 teaches that an image having a high density and an excellent gradation can be obtained by using a two-component type developer comprising a ferrite carrier and an electroscopic toner and adjusting the toner concentration, the photosensitive drum/developing sleeve peripheral speed radio and the angle of the main pole in the developing sleeve within predetermined ranges. Furthermore, Japanese Unexamined Patent Publication No. 61-118767 teaches that in the development using a two-component type developer, a high-quality image having no image unevenness can be obtained by adjusting the surface potential, the distance D-S (between the photosensitive material drum and the developing sleeve) and the resistance value of the magnetic carrier.

Recently, Japanese Unexamined Patent Publication No. 63-208867 discloses a developing method using a two-component type developer comprising a magnetic carrier and a toner, in which dispersions of the image density can be eliminated by adjusting the developer packing ratio (PD) of the developing zone, defined by the following formula, to 20 to 50%:

$$PD = M/(\rho \times Ds) \times 100$$

wherein M represents the amount (g/cm^2) of the developer on the sleeve after passage through the brush height-regulating portion, ρ represents the true specific gravity (g/cm^3) of the developer, and Ds represents the distance between the developing sleeve and the electrostatic latent image recorder.

In each of the two former proposals, the characteristics of the developer and the developing conditions are independently defined but the actual developing operations are not comprehensively grasped, and the characteristics of the developers are defined only under static conditions, not under practical dynamic conditions. Therefore, the defined developing method is not satisfactorily matched to practical conditions in a copying machine.

The latter proposal is significant in that the packing ratio of the developer in the developing zone is taken into account. However, the contact state between the magnetic brush of the developer and the surface of the photosensitive material under practical developing conditions, that is, under dynamic conditions, is not satisfactorily defined, and the defined method is not well in agreement with the practical development method.

Summary of the Invention

We found that in a developing method using a two-component type developer, the substitution degree of the developer in the developing zone has significant influences on the reproducibility of fine lines irrespectively of various developing conditions, the kind of the developer and the kind of the photosensitive material.

It is a primary object of the present invention to provide a developing method in which in the reproduction of multiple fine lines, the width of each line is constant and front end lacking or rear end lacking is prevented, and a high-density and high-quality image can be formed.

Another object of the present invention is to provide a developing method in which the reproducibility of Chinese characters and the reprodubility in the repeated reproduction from obtained copies are improved.

In accordance with the present invention, there is provided a developing method comprising delivering a two-component type developer comprising a magnetic carrier and a toner by a sleeve and developing an electrostatic latent image on a photosensitive drum, wherein developing conditions are set so that the substitution degree (R) of the developer, defined by the following formula:

$$R(\%) = \frac{X \cdot T}{V} \left[\left(\frac{1}{\rho t} - \frac{1}{\rho c}\right)A + \frac{1}{\rho c}\right] \times 100 \qquad (1)$$

x represents the delivery quantity (g/sec) of the two-component type developer, T represents the developing time (sec), V represents the volume (mm^3) of the developing zone, ρt represents the density (g/mm^3) of the toner, ρc represents the density (g/mm^3) of the carrier, and A represents the weight ratio of the toner in the developer,

is 16.00 to 33.00%.

It is preferred that in the above-mentioned formula, the delivery quantity x be 40 to 250 g/sec, the developing time T be 0.025 to 0.28 second, and the volume V of the developing zone be 1.15×10^2 to 28.00×10^2 mm^3.

The specific volume (v/M) of the two-component type developer, which is represented by the following formula:

$$\frac{v}{M} = \left(\frac{1}{\rho T} - \frac{1}{\rho C}\right)A + \frac{1}{\rho C}$$

is preferably 1.5×10^2 to 3.75×10^2 mm^3/g.

Furthermore, it is preferred that the density ρc of the magnetic carrier be 3.50×10^{-3} to 6.50×10^{-3} g/mm^3, the density ρt of the toner be 1.00×10^{-3} to 1.40×10^{-3} g/mm^3, and the weight ratio A of the toner in the developer be 0.03 to 0.06.

Brief Description of the Drawings

Fig. 1 is a diagram showing the relation between the distance in the feed direction and the image density of congregated fine lines, which illustrates front end lacking or rear end lacking caused in the development of congregated lines.

Fig. 2 is a graph showing the relation between the substitution degree R of the developer and the deviation (δ) of the line width, which is observed when the value R is changed.

Fig. 3 is a graph showing the relation between the value R and the image density (ID), observed when the value R is changed.

Fig. 4 is a graph showing the relation between the weight ratio A of the toner and the ratio (v/M) of the total volume (v) of one carrier particle and the toner present around one particle of the carrier to the total weight (M) of one carrier particle and the toner present around one particle of the carrier.

Fig. 5 is a diagram illustrating the developing method of the present invention.

Detailed Description of the Preferred Embodiments

The present invention is based on the finding that if the substitution degree (R) of the developer, defined by the above-mentioned formula (1), is maintained within the range of from 16.00 to 33.00%, especially from 18.75 to 32.05%, a copied image having a high quality and an excellent reproducibility of Chinese characters at a high image density can be obtained. Chinese characters are constructed by congregated fine lines. According to the present invention, in the development of congregated fine lines, the line width is kept constant in each line and front end lacking or rear end lacking can be prevented, and a copied image having a high image quality can be obtained.

Referring to Fig. 1 illustrating front end lacking or rear end lacking caused in the development of congregated fine lines, the distance in the feed direction is plotted on the abscissa and the reflection image density of a copied image of congregated fine lines, measured by a microdensitometer, is plotted on the ordinate, to show the relation between them. Curve (i) in Fig. 1 shows a copied image in which the line width is constant in each line and front end lacking or rear end lacking is not caused, curve (ii) in Fig. 1

shows a copied image in which front end lacking is conspicuous, and curve (iii) shows a copied image in which rear end lacking is conspicuous. The deviation (δ) of the line width in the feed direction in the reproduction of fine lines is given by the following formula:

$= \frac{B+C}{A+B} \times 100$ (2)

wherein A, B and C represent image densities of respective peaks appearing in order in the feed direction. If the value of δ is 100 or close thereto, the width is constant in each line. If the value of δ is larger 100, this indicates occurrence of front end lacking, and if the value of δ is smaller than 100, this indicates occurrence of rear end lacking.

In Fig. 2, the relation between the value of the substitution degree R of the developer defined by the formula (1) and the deviation (δ) of the line width, observed when the value of R is changed, is plotted, and in Fig. 3, the relation between the value of R and the image density (ID), observed when the value R is changed, is plotted. From the results shown in Figs. 2 and 3 it is understood that if the developing conditions are set so that the value of R is within the range specified in the present invention, the deviation of the line width can be maintained at a level of about 100% while maintaining the image density at such a high level as 1.3 or more. In general, if R exceeds the above range, the reproducibility of a line image is degraded, thickening of the line width, especially the thickening of the front end, is readily caused, and the image density tends to decrease slightly. If R is below the above-mentioned range, a blur is readily formed in the line image, front end lacking is readily caused, and the image density tends to decrease. On the other hand, if R is within the above-mentioned range, an optimum combination of the image density and the image quality can be obtained in a copied image of multiple fine lines.

The substitution degree (R) of the developer, referred to in the present invention, is a dimensionless number and has the following meaning. Namely, the developing time is the time required for the electrostatic latent image to pass through the volume V of the developing zone and therefore, the value of term xT represents the delivery weight of the two-component type developer fed into the volume of the developing zone within the developing time T. For convenience, supposing that M is the total weight (g) of one carrier particle and the toner present around one particle of the carrier and v is the total volume (mm^3) of one carrier particle and the toner present around one particle of the carrier, the value of the term v/M represents the specific volume of the carrier/toner aggregate. Accordingly, the product of both the values, that is, xT/•v/M, represents the volume of the carrier/toner aggregate fed into the volume of the developing zone during the developing time T. The value R obtained by dividing this value by the volume V of the developing zone and multiplying the obtained value by 100, which is represented by the following formula:

$R = \frac{xT}{V} \cdot \frac{v}{M} \times 100$ (1-A)

indicates the ratio of the substitution of the volume of the developing zone by a fresh carrier/toner aggregate (developer) within the developing time T.

Supposing that the weight ratio of the toner in the developer is A, the weight and volume of one carrier particle are Wc and Vc, respectively, and the weight and volume of one toner particle are Wt and Vt, respectively, the total weight M and total volume v of one carrier particle and the toner present around one particle of the carrier are represented by the following formulae:

$$M = Wc + \frac{AWc \cdot Wt}{(1-A)Wt} = Wc \quad \frac{1}{1-A} \qquad (3)$$

and

$$v = Vc + \frac{AWc \cdot Vt}{(1-A)Wt} \qquad (4)$$

The following term in these formulae indicates the number of toner particles present around one particle of the carrier:

$$\frac{AWc}{(1-A)Wt} \qquad (5)$$

Supposing that the specific gravities of the carrier and toners are ρc and ρt, respectively, they are represented by the following formulae:

$\rho c = \frac{Wc}{Vc}$ (6)

and

$\rho t = \frac{Wt}{Vt}$ (7)

It has value of v/M is calculated from the formulae (3), (4), (6) and (7), the following formula is derived:

$\frac{v}{M} = \frac{Vc}{Wc} - A\frac{Vc}{Wc} + \frac{Vt}{Wt} = [\frac{1}{\rho t} - \frac{1}{\rho t}]A + \frac{1}{\rho c}$ (8)

In Fig. 4, the relation between the weight ratio A or the toner and the value of v/M is the formula (8) is plotted. The weight ratio A can take any value of from 0 to 1. When A is zero, v/M is the value of $1/\rho c$ and when A is 1, v/M is the value of $1/\rho t$ (when A is an intermediate value, v/M is a value intermediate between $1/\rho c$ and $1/\rho t$). Namely, it is confirmed that this relation is well in agreement with the actual state.

In the present invention, the relations of the substitution degree (R) of the developer to various factors of the developing conditions are apparent from the above-mentioned formula (1). Namely, as the delivery quantity x of the two-component type developer, the developing time T and the parenthesized value in the formula (1), that is, v/M, increase, the substitution degree (R) of the developer increases. In contrast, as the values of x, T and v/M decrease, also the value of R decreases. On the other hand, as the volume V of the developing zone increases, the substitution degree (R) of the developer decreases, and as the volume V decreases, the value of R increases. Therefore, according to the present invention, the above-mentioned developing conditions can be set so that the substitution (R) of the developer is within the above-mentioned range.

More specifically, the delivery quantity x of the two-component type developer can be adjusted by the peripheral speed of the developing sleeve and the cut length of the magnetic brush, and the delivery quantity is selected from the range of 40.00 to 250.0 g/sec, especially 85 to 220 g/sec, so that R is in the above-mentioned range. The developing time T can be adjusted by the peripheral speed of the photosensitive drum and the width of the developing zone, and the developing time T is selected from the range of 0.025 to 0.28 second, especially 0.05 to 0.20 second, so that R is within the above-mentioned range. The volume V of the developing zone is adjusted by the width of the developing zone and the sleeve-drum distance and the volume is selected in the range of from 1.15×10^2 to 28.00×10^2 mm^3, especially 2.00×10^2 to 15.00×10^2 mm^2, so that R is in the above-mentioned range.

In the case where ρt and ρc are kept constant, increase of the weight ratio A of the toner results in increase of the substitution degree (R) of the developer. It is preferred that the parenthesized value in the formula (1), that is, the value of v/M, be 1.5×10^2 to 3.75×10^2 mm^3/g, especially 2.1×10^2 to 3.30×10^2 mm^3/g.

Developing conditions will now be described in detail.

Referring to Fig. 5 illustrating the magnetic brush developing method used in the present invention, a magnet roll 11 having many magnetic poles (N and S) 10 is contained in a developing sleeve 12 formed of a non-magnetic material such as aluminum. A photosensitive drum 15 comprising a substrate 13 and a electrophotographic photosensitive layer 14 formed thereon is disposed with a minute distance $d_{D\text{-}S}$ from the developing sleeve 12. The developing sleeve 12 and the photosensitive drum 15 are rotatably supported on a machine frame (not shown) and they are driven so that at the nip position, the moving directions of the sleeve 12 and drum 15 are the same (indicated by arrows in the drawings) (the rotating directions are opposite to each other). The developing sleeve is located at an opening of a developing device 16, and a mixing stirrer 17 for a two-component type developer (that is, a mixture of a toner and a magnetic carrier) 18 is arranged in the interior of the developing device 16. A toner supply mechanism 20 for supplying a toner 19 is arranged above the stirrer 17. The two-component type developer 18 is mixed and stirred by the stirrer 17 to frictionally charge the toner. Then, the developer is fed onto the developing sleeve 12 to form a magnetic brush 21 on the surface of the sleeve 12. The length of the magnetic brush is adjusted by a brush-cutting mechanism 22 and the magnetic brush 21 is delivered to the nip position to the electrophotographic photosensitive layer 14, and an electrostatic latent image on the photosensitive layer 14 is converted to a visible image with the toner 19.

According to the present invention, by appropriately setting in combination such conditions as the kind of the developer, the delivery quantity of the developer, the developing time and the volume of the developing zone, the requirement of the formula (1) is satisfied. This setting is accomplished, for example, in the following manner, though the present invention is not limited by the following description.

The specific volume (v/M) of the developer is preferably adjusted to 1.5×10^2 to 3.75×10^2 mm^3/g, especially preferably 2.1×10^2 to 3.30×10^2 mm^3/g, as pointed out hereinbefore.

It is preferred that the density ρc of the magnetic carrier be 3.50×10^{-3} to 6.50×10^{-3} g/mm^3, especially 4.00×10^{-3} to 5.50×10^{-3} g/mm^3, though the preferred density depends on the toner concentration. Use of a ferrite type magnetic carrier is especially preferable.

Sintered ferrite particles composed of at least one member selected from the group consisting of zinc iron oxide ($ZnFe_2O_4$), yttrium iron oxide ($Y_3Fe_5O_{12}$), cadmium iron oxide ($CdFe_2O_4$), gadolinium iron oxide ($Gd_3Fe_5O_{12}$), copper iron oxide ($CuFe_2O_4$), lead iron oxide ($PbFe_{12}O_{19}$), nickel iron oxide ($NiFe_2O_4$), neodium iron oxide ($NdFeO_3$), barium iron oxide ($BaFe_{12}O_{19}$), magnesium iron oxide ($MgFe_2O_4$), manganese iron oxide ($MnFe_2O_4$) and lanthanum iron oxide ($LaFeO_3$) are conventionally used. Soft ferrites comprising at least one metal component, preferably at least two metal components, selected from the group consisting of Cu, Zn, Mg, Mn and Ni, for example, copper/zinc/magnesium ferrite, are especially used. Among these ferrites, those satisfying the foregoing conditions are used in the present invention.

It is preferred that the saturation magnetization of the carrier be 40 to 65 emu/g, especially 45 to 56 emu/g. Ferrite carriers, especially spherical ferrite carriers, satisfying the above conditions, are preferably used as the magnetic carrier. It is preferred that the particle size of the magnetic carrier be 20 to 140μm, especially 50 to 100μm.

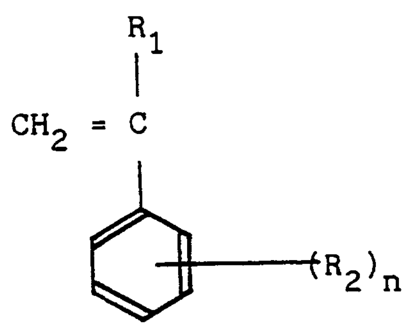
Of course, the electric resistance of the ferrite carrier varies according to the chemical composition thereof, and the electric resistance of the ferrite carrier further depends on the particulate structure, the preparation process and the kind and thickness of the coating. It is generally preferred that the volume resistivity of the carrier be 1×10^{10} to 5×10^{11} Ω-cm, especially 4×10^{10} to 1×10^{11} Ω-cm.

A toner having a density ρt of 1.00×10^{-3} to 1.40×10^{-3} g/mm³, especially 1.10×10^{-3} to 1.20×10^{-3} g/mm³, is used in the present invention, though the preferred density depends on the density of the magnetic carrier and the toner concentration.

The toner used in the present invention is prepared by incorporating a colorant and a charge-controlling agent, optionally together with known additives to toners, into a fixing resin medium. It is preferred that the volume resistivity of the toner used in the present invention be 1×10^8 to 3×10^9 Ω-cm, especially 2×10^8 to 8×10^9 Ω-cm, as measured by the method described in detail hereinafter. It is preferred that the dielectric constant of the toner be 2.5 to 4.5, especially 3.0 to 4.0.

A fixing resin medium for the toner, a colorant, a charge-controlling agent and other additives to the toner are selected and combined so that the above-mentioned characteristics can be obtained. As the fixing resin medium, a styrene resin, an acrylic resin and a styrene/acrylic copolymer resin are generally used.

As the styrene monomer used for these resins, there can be mentioned monomers represented by the following formula:



(I)

wherein R_1 represents a hydrogen atom, a lower alkyl group having up to 4 carbon atoms, or a halogen atom, R_2 represents a substituent such as a lower alkyl group or a halogen atom, and n is an integer of up to 2, including zero,

such as styrene, vinyltoluene, α-methylstyrene, α-chlorostyrene and vinylxylene, and vinylnaphthalene. Among these monomers, styrene is especially preferable.

As the acrylic monomer, there can be mentioned monomers represented by the following formula:

$$CH_2 = \underset{\substack{|\\ C - O - R_4 \\ \| \\ O}}{\overset{\substack{R_3\\ |}}{C}} \qquad \text{(II)}$$

wherein R_3 represents a hydrogen atom or a lower alkyl group, and R_4 represents a hydrogen atom or an alkyl group having up to 18 carbon atoms,
such as ethyl acrylate, methyl methacrylate, butyl acrylate, butyl methacrylate, 2-ethylhexyl acrylate, 2-ethylhexyl methacrylate, acrylic acid and methacrylic acid. Instead of these monomers, ethylenically unsaturated carboxylic acids and anhydrides thereof, such as maleic anhydride, fumaric acid, maleic acid, crotonic acid and itaconic acid, can be used as the acrylic monomer.

A styrene/acrylic copolymer resin is one of preferable resin media, and in this copolymer, it is preferred that the styrene monomer (A)/acrylic monomer (B) weight ratio be from 50/50 to 90/10, especially from 60/40 to 85/15. In general, the resin used has preferably an acid value of 0 to 25. In view of the fixing property, a resin having a glass transition temperature (Tg) is preferably used.

Inorganic and organic pigments and dyes are used singly or in the form of a mixture of two or more of them as the colorant to be incorporated into the resin. For example, there can be mentioned carbon blacks such as furnace black and channel black, iron black such as triiron tetroxide, rutile type titanium dioxide, anatase type titanium dioxide, Phthalocyanine Blue, Phthalocyanine Green, Cadmium Yellow, Molybdenum Orange, Pyrazolone Red, Fast Violet B and the like.

Known charge-controlling agents can be optionally used as the charge-controlling agent in the present invention. For example, there can be used oil-soluble dyes such as Nigrosine Base (CI 50415), Oil Black (CI 26150) and Spilon Black, 1:1 type and 2:1 type metal complex salt dyes, metal salts of naphthenic acid, fatty acids, soaps and resin acid soaps.

Preferably, the particle size of toner particles is 8 to 14 μm, especially 10 to 12 μm, as the volume median particle size measured by Coulter Counter. The shape of the toner particles can be an indeterminate shape as formed by the melt-kneading and pulverizing method or a spherical shape as formed by the dispersion or suspension polymerization method.

The weight ratio A of the toner in the developer is preferably 0.03 to 0.06, especially preferably 0.035 to 0.055.

In order to attain the objects of the present invention, it is preferred that the resistivity of the developer as a whole be 5×10^9 to 5×10^{10} Ω-cm, especially 1×10^{10} to 4×10^{10} Ω-cm.

As pointed out hereinbefore, it is preferred that the delivery quantity x of the developer be 40.00 to 250.00 g/sec, especially 85 to 220 g/sec. For this purpose, it is preferred that the flux density of the magnetic field of the magnetic poles of the developing sleeve be 500 to 1000 G, especially 650 to 850 G, and that the peripheral speed of the developing sleeve be 60 to 800 cm/sec, especially 90 to 450 cm/sec. The cut length of the magnetic brush depends on the flux density, but it is preferred that the cut length of the magnetic brush be 0.6 to 1.6 mm, especially 0.8 to 1.4 mm.

As pointed out hereinbefore, the developing time T is preferably 0.025 to 0.28 second, especially preferably 0.05 to 0.20 second. The developing time T can be adjusted by changing the peripheral speed of the photosensitive drum or changing the nip width to the developer. The peripheral speed of the photosensitive drum is selected from the range of 60 to 200 cm/sec, especially 90 to 150 cm/sec, and the nip width is selected from the range of 5 to 17 cm, especially 8 to 12 cm.

As pointed out hereinbefore, the volume V of the developing zone is preferably 1.15×10^2 to 28.00×10^2 mm^3, especially preferably 2.00×10^2 to 15.00×10^2 mm^3. This volume V can be adjusted by changing the nip width or the drum/sleeve distance (D-S). Preferably, the distance (D-S) is selected from the range of from 0.6 to 1.6 mm, especially the range of from 0.8 to 1.4 mm.

All of photosensitive materials customarily used in the electrophotography, for example, a selenium photosensitive material, an amorphous silicon photosensitive material, a zinc oxide photosensitive material, a cadmium selenide photosensitive material, a cadmium sulfide photosensitive material and various organic photosensitive materials can be used as the photosensitive material in the present invention.

The bias voltage applied between the developing sleeve and the conductive substrate of the photosensitive material as another developing condition is preferably such that the average field intensity is 100 to 1000 V/mm, especially 125 to 500 V/mm.

As is apparent from the foregoing description, according to the present invention, by setting the developing conditions so that the substitution degree of the developer, defined relatively to the delivery quantity of the two-component type developer, the developing time, the volume of the developing zone, the density of the toner, the density of the carrier and the weight ratio of the toner in the developer, is within the specific range of 16.00 to 33.00%, the reproducibility of letters especially Chinese characters or aggregates of fine lines, is improved, and a copied image having a high density and a high quality can be obtained.

The effects of the present invention will now be described more clearly with reference to the following example.

Example

The relation of the substitution degree of the developer to the formed image was examined under the following developing conditions by using the developing apparatus shown in Fig. 5.

Developing Conditions

Photosensitive material (D): Se, diameter = 78 mm
Sleeve (S): diameter = 38 mm
D-S Distance: 1.0 mm
Brush-cutting clearance: 1.0 mm
Density (ρt) of toner: 1.15×10^{-3} g/mm^3
Density (ρc) of carrier: 5.00×10^{-3} g/mm^3
Weight ratio (A) of toner: 0.045

In the forward direction development where the rotation directions of the photosensitive material (D) and sleeve (S) were the same in the developing zone, a plurality of runs were carried out by changing the rotation speeds of the photosensitive material (D) and sleeve (S).

In each of these runs, the delivery quantity x (g/sec) of the developer, the developing time T (second) and the volume V (mm^3) of the developing zone were determined, and the substitution degree R (%) of the toner was calculated from these values according to the following formula (1) defining the substitution degree R (%) of the developer:

$$R(\%) = \frac{X \cdot T}{V}\left[\left(\frac{1}{\rho t} - \frac{1}{\rho c}\right)A + \frac{1}{\rho c}\right] \times 100 \qquad (1)$$

In each run, an image sample was prepared and the quality of the image was evaluated relatively to the substitution degree of the developer calculated according to the above-mentioned formula (1). For evaluation of the image quality, the image density (ID) of the first copy and the deviation (%) of the line width were determined by using a microdensitometer (Model PD5 supplied by Konica).

The obtained results are shown in Table 1.

Table 1

Run No.	Delivery Quantity x (g/sec) of Developer	Developing Time T (second)	Volume V (mm^3) of Developing Zone	Substitution Degree R (%) of Developer	Image		
					I.D.	Deviation	Reproduction of Letters and Lines
1	27.55	0.033	3.75×10^2	10.51	1.21	88	×
2	40.55	0.058	5.51×10^2	18.75	1.25	90	Δ
3	61.50	0.067	8.37×10^2	21.60	1.31	92	O
4	70.55	0.078	9.59×10^2	25.16	1.35	94	O
5	78.95	0.090	10.75×10^2	28.66	1.37	98	O
6	87.23	0.10	11.90×10^2	32.05	1.40	90	Δ
7	90.10	0.11	12.26×10^2	34.10	1.41	87	×
8	97.38	0.11	13.24×10^2	35.89	1.41	75	×
9	106.32	0.12	14.41×10^2	39.11	1.43	69	×

Note : O: good, Δ: fair, ×: bad,

Claims

1. A developing method comprising delivering a two-component type developer comprising a magnetic carrier and a toner by a sleeve and developing an electrostatic latent image on a photosensitive drum, wherein developing conditions are set so that the substitution degree (R) of the developer, defined by the following formula:

$$R(\%) = \frac{X \cdot T}{V}\left[\left(\frac{1}{\rho t} - \frac{1}{\rho c}\right)A + \frac{1}{\rho c}\right] \times 100$$

x represents the delivery quantity (g/sec) of the two-component type developer, T represents the developing time (sec), V represents the volume (mm^3) of the developing zone, ρt represents the density (g/mm^3) of the toner, ρc represents the density (g/mm^3) of the carrier, and A represents the weight ratio of the toner in the developer,
is 16.00 to 33.00%.

2. A developing method according to claim 1, wherein the delivery quantity x is 40 to 250 g/sec, the developing time T is 0.025 to 0.28 second, and the volume V of the developing zone is 1.15×10^2 to 28.00×10^2 mm^3.

3. A developing method according to claim 1, wherein the specific volume (v/M) of the developer represented by the following formula:

$$\frac{v}{M} = \left(\frac{1}{\rho t} - \frac{1}{\rho c}\right)A + \frac{1}{\rho c}$$

wherein v represents the total volume of one carrier particle and the toner present around one particle of the carrier, M represents the total weight of one carrier particle and the toner present around one particle of the carrier, and ρt, ρc and A are as defined in claim 1.

4. A developing method according to claim 3, wherein the density ρc of the magnetic carrier is 3.50×10^{-3} to 6.50×10^{-3} g/mm^3, the density ρt of the toner is 1.00×10^{-3} to 1.40×10^{-3} g/mm^3, and the weight ratio A of the toner in the developer is 0.03 to 0.06.

FIG. 1

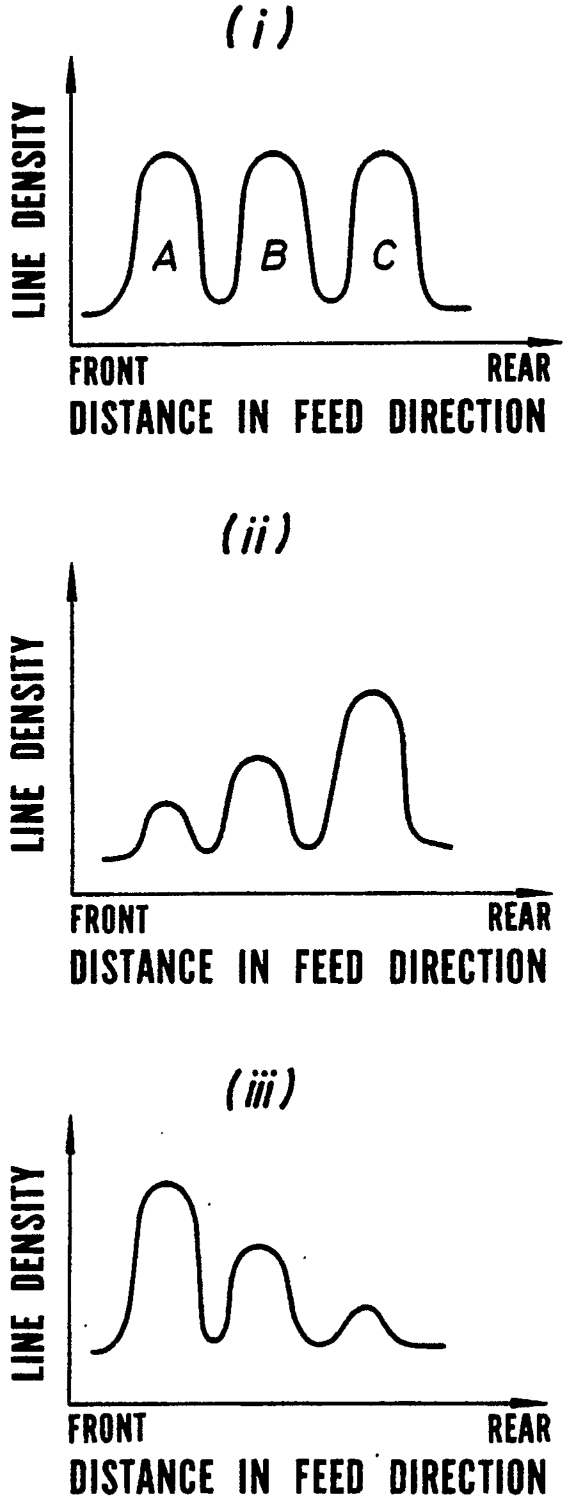

(i)
LINE DENSITY
A
B
C
FRONT
REAR
DISTANCE IN FEED DIRECTION
(ii)
LINE DENSITY
FRONT
REAR
DISTANCE IN FEED DIRECTION
(iii)
LINE DENSITY
FRONT
REAR
DISTANCE IN FEED DIRECTION

FIG. 2

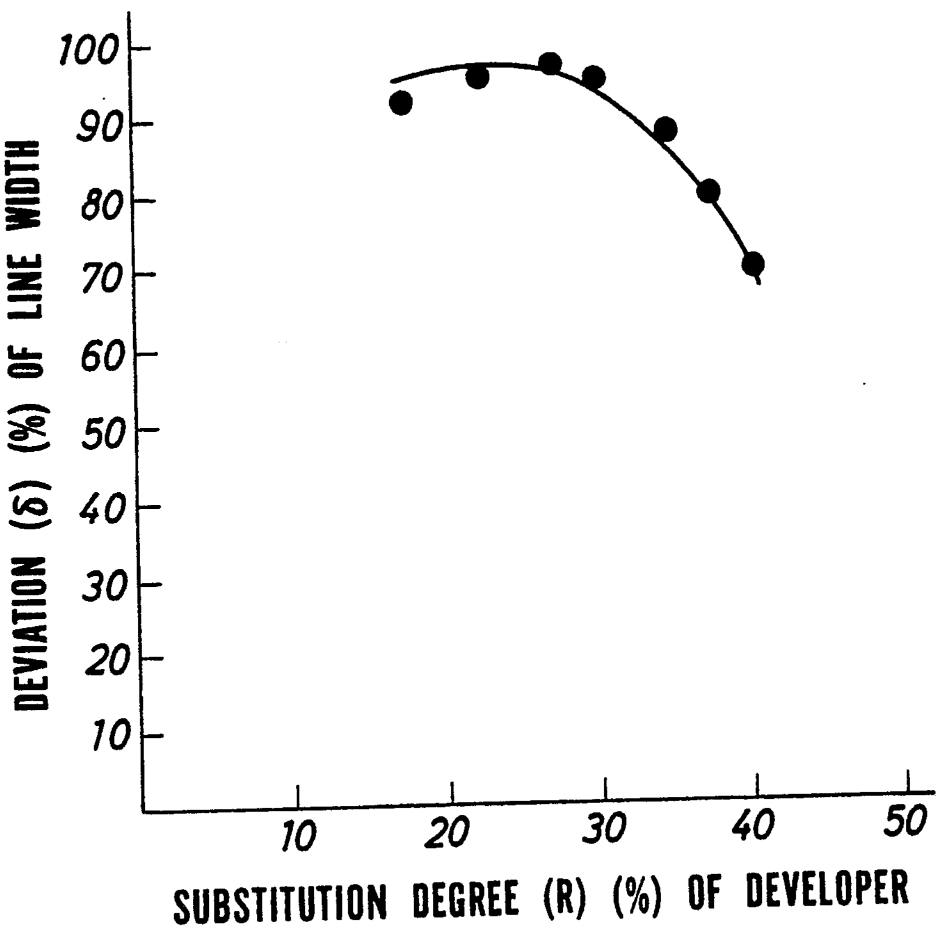

100
90
80
70
60
50
40
30
20
10
DEVIATION (δ) (%) OF LINE WIDTH
10
20
30
40
50
SUBSTITUTION DEGREE (R) (%) OF DEVELOPER

FIG. 3

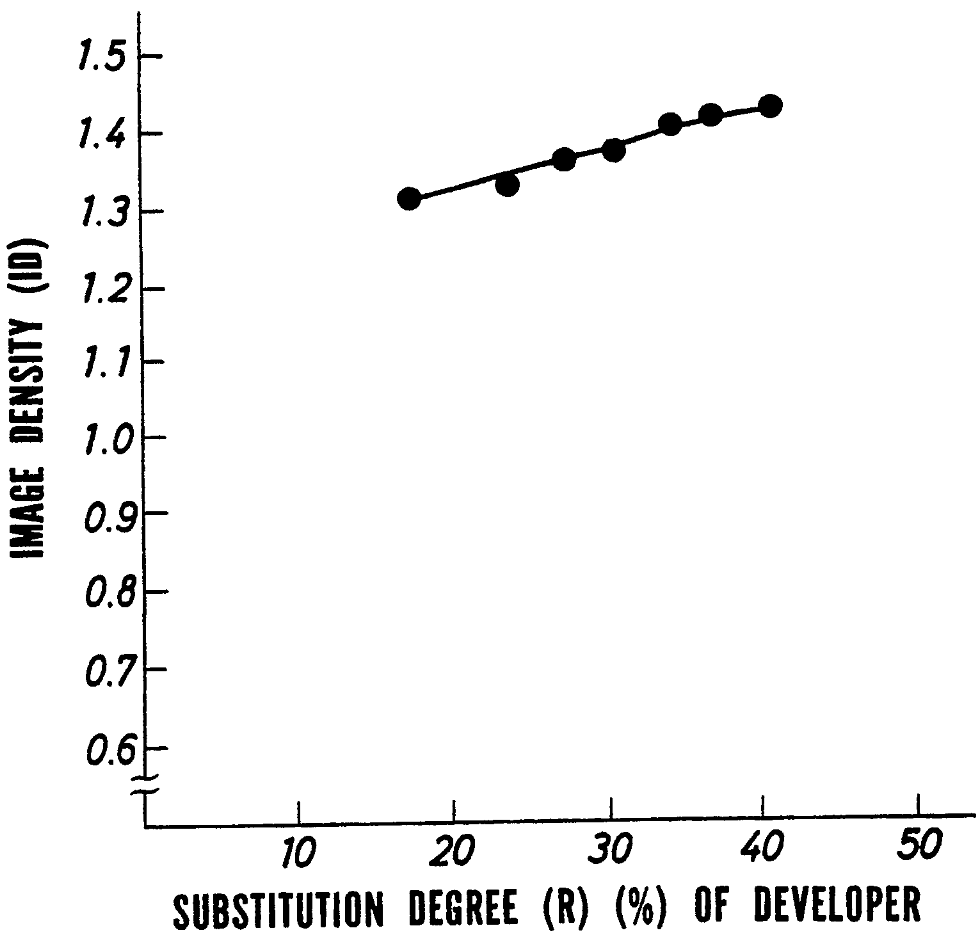

1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
IMAGE DENSITY (ID)
10
20
30
40
50
SUBSTITUTION DEGREE (R) (%) OF DEVELOPER

FIG. 4

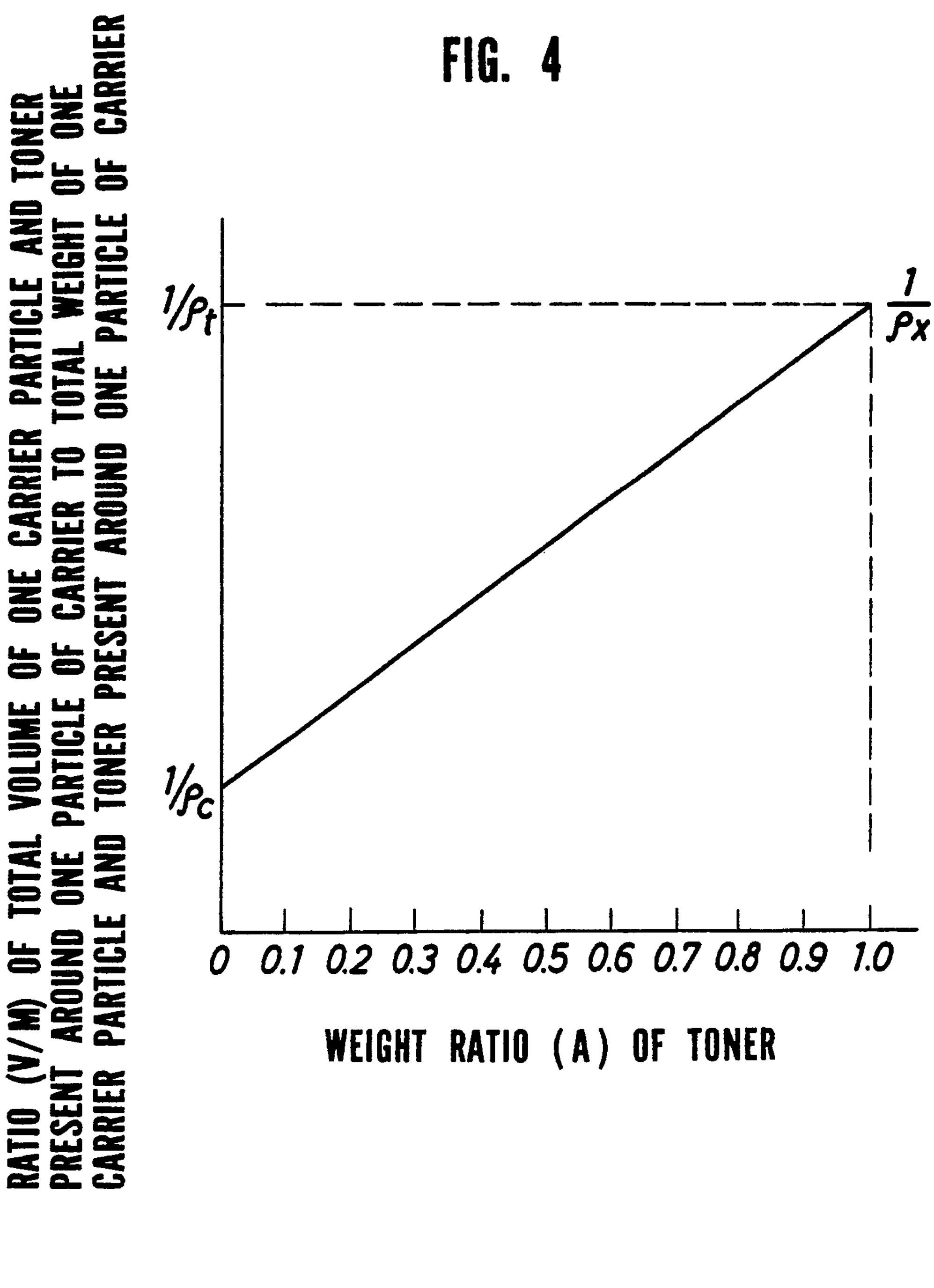

RATIO (V/M) OF TOTAL VOLUME OF ONE CARRIER PARTICLE AND TONER PRESENT AROUND ONE PARTICLE OF CARRIER TO TOTAL WEIGHT OF ONE CARRIER PARTICLE AND TONER PRESENT AROUND ONE PARTICLE OF CARRIER
1/ρt
1/ρc
1/ρx
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
WEIGHT RATIO (A) OF TONER

Fig. 5