



EUROPEAN PATENT SPECIFICATION

Date of publication of patent specification :
21.12.94 Bulletin 94/51

Int. Cl.⁵ : **G03G 15/09**

Application number : **91308055.2**

Date of filing : **03.09.91**

Developing process.

Priority : **04.09.90 JP 232396/90**

Date of publication of application :
11.03.92 Bulletin 92/11

Publication of the grant of the patent :
21.12.94 Bulletin 94/51

Designated Contracting States :
DE FR GB IT

References cited :
DE-A- 3 014 849
US-A- 4 018 187
PATENT ABSTRACTS OF JAPAN vol. 14, no.
104 (P-1013)26 February 1990 & JP-A-1 307 783
PATENT ABSTRACTS OF JAPAN vol. 9, no.
195 (P-379)13 August 1985 & JP-A-60 061 776

Proprietor : **MITA INDUSTRIAL CO., LTD.**
2-28, 1-chome, Tamatsukuri
Chuo-ku
Osaka 540 (JP)

Inventor : **Nishino, Toshio**
1-56-101 Tsurumai,
Higashimachi
Nara-shi, Nara-ken (JP)
Inventor : **Tomita, Shoji**
313-101 Naka-machi 2-chome,
Onji
Yao-shi, Osaka-fu (JP)

Representative : **Senior, Alan Murray et al**
J.A. KEMP & CO.,
14 South Square,
Gray's Inn
London WC1R 5LX (GB)

EP 0 474 460 B1

Note : Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

Description

Background of the Invention

(1) Field of the Invention

The present invention relates to a developing process having an excellent image reproducibility in the electrophotography. More particularly, the present invention relates to a developing process in which in the reproduction of multiple fine lines, a high-quality image can be formed without shortening the life of a developing device or a developer while preventing occurrence of so-called front end lacking or rear end lacking and keeping the width of each line uniform.

(2) Description of the Related Art

A two-component developer comprising a magnetic carrier and a toner is widely used in commercial electrophotographic copying machines. On the development of a charged image, a magnetic brush of this developer is formed on a developing sleeve having magnetic poles arranged in the interior thereof, and this magnetic brush is brought into sliding contact with a photosensitive material having the charged image.

Many proposals have been made on setting of developing conditions and the like. For example, Japanese Unexamined Patent Publication No. 59-172660 discloses a process in which a two-component developer comprising a ferrite carrier and an electroscopic toner is used and the photosensitive drum/developing sleeve peripheral speed ratio and the angle of the main pole in the developing sleeve are set within specific ranges, whereby an image having a high density and an excellent gradation can be obtained. Furthermore, Japanese Unexamined Patent Publication No. 61-118767 teaches that in the development using a two-component developer, by setting the surface voltage, the distance D-S (the distance between the photosensitive drum and the developing sleeve) and the electric resistance value of the magnetic carrier, a uniform image having a high quality can be obtained.

Recently, Japanese Unexamined Patent Publication No. 63-208867 discloses a developing process using a two-component developer, in which dispersion of the image density is prevented by setting the developer packing ratio (PD), defined by the following formula, in the developing zone within a range of 20 to 50%:

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

wherein M represents the amount (g/cm²) of the developer after the passage through the brush height-regulating zone on the sleeve, ρ represents the true specific gravity (g/cm³) of the developer, and DS represents the distance (cm) between the devel-

oping sleeve and the electrostatic latent image-recording member.

In previously filed Japanese Patent Application No. 01-107331, the present inventors have found that at the practical development, the state of the contact between a magnetic brush of a developer and a photosensitive surface can be easily known by adding collodion to this magnetic brush to fix the magnetic brush and photographing the fixed magnetic brush by using a scanning electron microscope, an image having a high quality can be obtained by setting the frequency (k) defined by the product of the contact number of the carrier per unit area of the photosensitive material (n, number per mm²) and the developing length (L), determined by the above-mentioned method, within a specific range, and an image having a high quality can be obtained by adjusting the revolution number of the developing sleeve, the saturation magnetization of the magnetic carrier and the flux density of magnetic poles in the developing sleeve so that a specific relation is established, and preferably by setting, at the practical development, the frequency (k) defined by the product of the contact number of the carrier per unit area of the photosensitive material (n, number per mm²) and the developing length (L), determined by adding collodion to this magnetic brush to fix the magnetic brush and photographing the fixed magnetic brush by using a scanning electron microscope, within a specific range.

Each of the former two proposals defines the characteristics of the developer and the developing conditions, independently, but the practical developing operation is not comprehensively grasped. Since the characteristics of the developer and carrier are defined under static conditions but not defined under practical dynamic conditions, a good applicability to the practical development in a copying machine is not attained.

The latter proposal is significant in that the packing ratio of the developer in the developing zone is noted, but the state of the contact 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 defined, and therefore, a good applicability to the practical development in a copying machine is not attained.

The above proposal made by the present inventors is significant in the finding that an image having a high quality can be obtained by setting the frequency (k) defined by the product of the contact number of the carrier per unit area of the photosensitive material (n, number per mm²) and the developing length (L), in the practical contact state between the magnetic carrier and the surface of the photosensitive material, within a specific range. However, in order to obtain an optimum value of the above parameter, the earing length of the magnetic brush should be considerably

reduced, which results in occurrence of another new problem.

Namely, if the earing length of the magnetic brush is thus reduced, a considerably large stress is imposed on the developing sleeve or the brush-forming developer, which results in shortening of the life of the developing device or the developer. Furthermore, if the earing length of the brush is reduced, when the peripheral speed of the developing sleeve is kept constant, the developer delivery speed per unit time is reduced and hence, the image density is degraded. In order to overcome this defect, means causing degradation of the image quality, such as increase of the earing length of the brush or increase of the distance D-S, should be adopted. Therefore the image quality is inevitably sacrificed.

US-A-4018187 discloses a developing process in which toner is transferred from a magnetic brush comprising the toner and the magnetic carrier material on to a developing sleeve on a photosensitive drum by sliding contact between the brush and the sleeve. The sleeve has axial grooves about its circumference and periodic variations in the thickness of the developing material on the sleeve resulting from these grooves. Pitch, groove width and groove depth lie in the range of 15-25, 2-3 and 1-2 carrier diameters respectively, with a carrier diameter lying in the range of 100-400 microns.

Summary of the Invention

It is therefore a primary object of the present invention to provide a developing process in which a proper frequency of the contact between the carrier and the drum can be obtained without drastically controlling the earing length of the brush or the distance D-S, whereby an image having a high quality and a high density can be obtained.

Another object of the present invention is to provide a developing process which avoids shortening the life of the developing device or the developer.

In accordance with the present invention, there is provided a developing process having an excellent reproducibility, which comprises forming a magnetic brush of a two-component developer comprising a magnetic carrier and a toner on a developing sleeve and bringing the magnetic brush into sliding contact with a photosensitive material having a charged image to form a toner image on the photosensitive material; wherein the developing sleeve has a plurality of axially extending grooves formed in the circumferential direction; wherein in advance of the sliding contact with the photosensitive material, developer sleeve portions having a high pack density of the developer are formed in the grooves and developer sleeve portions having a low pack density of the developer are formed at parts of the sleeve other than the grooves; characterized in that the depth of the grooves is 0.2

to 1.0 mm; in that the pitch of the grooves is 1.5 to 8 mm; in that the ratio of the width of the grooves to the width of the circumferential parts other than the grooves is in the range of from 1/3 to 3/1; in that the sliding contact between the magnetic brush and the photosensitive material is controlled so that the average frequency (k), defined by the formula given below, is 100 to 700:

$$K = L \cdot n \quad (1)$$

wherein n represents the contact number (per mm²) of the carrier per unit area of the photosensitive material, determined from a scanning electron microscope photo with respect to a collodion-fixed magnetic brush, and L represents the developing length defined by the following formula:

$$L = \frac{Nip}{Vd} (VS - Vd) \quad (2)$$

in which Nip represents the nip width (mm) of the developer on the surface of the photosensitive material, VS represents the moving speed (mm/sec) of the developing sleeve, and Vd represents the moving speed (mm/sec) of the surface of the photosensitive material; and in that the developing conditions are set so that the requirement represented by the following formula is satisfied:

$$15,000 \geq \frac{m \cdot H}{f} \geq 7,000 \quad (3)$$

wherein f represents the revolution rate (per second) of the developing sleeve, m represents the saturation magnetization (emu/g) of the magnetic carrier, and H represents the flux density (Gauss) of the magnetic pole in the developing sleeve.

Brief Description of the Drawings

Fig. 1 is a diagram illustrating the relation between the distance in the feed direction and the line density of congregated lines.

Fig. 2 is a diagram illustrating the relation between the contact frequency and the dispersion of the line width.

Fig. 3 is a side arrangement view illustrating the magnetic brush developing process.

Fig. 4 is a sectional view showing a grooved roll used in the present invention.

Fig. 5 is a diagram illustrating a method for measuring the resistivity of a carrier used in the present invention.

Detailed Description of the Invention

The present invention is based on the finding that if a magnetic brush of a two-component developer comprising a magnetic carrier and a toner is formed on a developing sleeve and in advance to the supply of this magnetic brush to a developing area of a photosensitive material, portions having a high pack density of the developer and portions having a low pack

density of the developer are alternately formed on the developing sleeve, a proper frequency of the contact between the carrier and the photosensitive material drum can be obtained without drastically limiting the brush-cutting length or the distance D-S.

The fact that in the present invention, the above-mentioned advantage is attained by forming portions having a high pack density and portions having a low pack density in the magnetic brush in advance to the supply of the magnetic brush to the developing area was found as a phenomenon as the result of many experiments, and the reason has not been sufficiently elucidated but it is believed that the above advantage will be attained according to the following mechanism.

More specifically, in the developing process using a two-component developer, the problem of the life of the developer or the developing device is most serious at a brush-cutting part where the developer and the developing sleeve are most strongly rubbed with each other. As described in detail hereinafter, as the parameter having influences on the developing condition with respect to the reproducibility of fine lines or letters, there can be mentioned the carrier contact frequency (k), and as the factor having influences on this contact frequency, there can be mentioned the distance D-S and the delivery speed of the developer. The delivery speed of the developer depends on the brush-cutting length and the speed of the sleeve, but since the change of the speed of the sleeve is naturally restricted, the brush-cutting length is generally changed. However, if the brush-cutting length is shortened, friction between the developer and the sleeve inevitably increases, resulting in shortening of the life of the developer or the sleeve. In contrast, if portions having a high pack density and portions having a low pack density are formed in the magnetic brush according to the present invention, cutting of the magnetic brush is effected alternately in coarse portions and dense portions, and therefore, the degree of the friction is halved. Furthermore, because of the presence of convexities and concavities on the developing sleeve, a short earing length is obtained in coarse portions of the magnetic brush and a long earing length is obtained in dense portions of the magnetic brush, with the result that the degree of the friction is considerably reduced. Moreover, if portions having a high pack density and portions having a low pack density are alternately formed in the magnetic brush before the supply to the developing area, the supply of the developer to the developing area can be performed smoothly and sufficiently, rendering it possible to form a high-density image. Furthermore, there can be attained an advantage that the contact friction of the toner-loading carrier is maintained within an optimum range and the reproducibility of fine lines or letters is surprisingly improved.

In the instant specification, the contact frequency (k, number/mm) having important influences on the

reproducibility of fine lines or letters is defined by the above-mentioned formula (1), and according to the present invention, the contact frequency can be set within a range of 100 to 700, especially 100 to 300, on the average and in the development of congregated fine lines, a copied image having a high quality can be obtained while keeping the width of each line uniform and preventing occurrence of front end lacking or rear end lacking.

Referring to Fig. 1 illustrating top end lacking or rear end lacking caused in the development of congregated fine lines, the distance in the delivery direction of the fine lines is plotted on the abscissa and the reflection image density of a copied image of congregated fine lines, determined by a micro-densitometer, is plotted on the ordinate, and the relation between the above distance and the reflection image density is illustrated. In Fig. 1, curve (i) shows the case where the width of each line is uniform and top end lacking or rear end lacking is not caused, curve (ii) shows the case where top end lacking is conspicuous, and curve (iii) shows the case where rear end lacking is conspicuous. In connection with reproduction of the width of each line, the dispersion (δ) in the feed direction is given by the following Formula:

$$\delta = \frac{B + C}{A + B} \times 100 \quad (4)$$

wherein A, B and C represent image densities of respective peaks in order in the feed direction.

If the value δ is 100 or close to 100, the width of each line is uniform and there is no substantial dispersion. If the value δ is larger than 100, top end lacking occurs and if the value δ is smaller than 100, rear end lacking occurs.

Fig. 2 is a graph on which there is plotted the relation between the contact frequency (k) and the dispersion (δ) of the line width, observed when three developers differing in the characteristics are used and developing conditions are variously changed to change the contact frequency (k) of the carrier. From the results shown in Fig. 2, it is clear that if the developer and the developing conditions are selected so that the contact frequency (k) is maintained within the above-mentioned range, the dispersion of the line width can be maintained at almost 100%. Generally speaking, if the contact frequency of the carrier (developer) is reduced, top end lacking (rear end thickening) appears, and if the contact frequency is increased, rear end lacking (top end thickening) becomes conspicuous. In contrast, by controlling the contact frequency within a specific range, appearance of these defects can be controlled. The tendencies shown in Fig. 2 are similarly observed when the contact frequency is changed by changing other developing conditions instead of the characteristics of the developer.

As is seen from the above formula (1), the contact frequency (k) of the carrier is represented by the prod-

uct of the number n of contacts of the carrier per unit area of the photosensitive material and the developing length L , and since the developing length L is naturally determined within a certain range if a developing device is decided, the freedom of the developing length L is small, and therefore, the contact number n of the carrier is preferably adjusted. Main factors having influences on the contact frequency n of the carrier are the properties of the developer, especially the magnetic carrier, and furthermore, there can be mentioned the distance $dD-S$ between the developing sleeve and the photosensitive drum, and the pack density of the developer. Generally, if $dD-S$ becomes large, the frequency n becomes small, and in contrast, if $dD-S$ becomes small, the value n becomes large. If $dD-S$ is kept constant, the value n depends on the pack density of the developer and the characteristics, especially the saturation magnetization, of the developer, especially the magnetic carrier. If the pack density or the saturation magnetization increases, the value n becomes large, and if these values decrease, the value n becomes small.

Portions having a high pack density in the magnetic brush exert a function of preventing occurrence of top end lacking and portions having a low pack density exert a function of preventing occurrence of rear end lacking, and these functions are exerted in a good balance. Thus, the value of the contact frequency of the carrier can be set within a range of from 100 to 700, especially from 100 to 300, on the average, and in the development of congregated fine lines, the width of each line can be kept uniform and a copied image having a high quality can be obtained while preventing occurrence of front edge lacking or rear end lacking. In order to obtain a good reproducibility of fine lines, it is preferred that the carrier contact frequency (k) of portions having a high pack density be at least 500 and the carrier contact frequency (k) of portions having a low pack density be lower than 400 and that the former carrier contact frequency (k) be larger by at least 200 than the latter carrier contact frequency (k).

If the characteristic value ($m \cdot H/f$) defined by the formula (3) is set within a range of 7,000 to 15,000, especially from 9,000 to 13,000, at the development of congregated fine lines, a copied image having a high quality can be obtained at a high density while keeping the width of each line uniform and preventing occurrence of top end lacking or rear end lacking.

Moreover, if the value $m \cdot H/f$ is set within the range specified in the present invention, that is, from 7,000 to 15,000, the dispersion of the line width can be maintained almost at a level of 100% while attaining an image density of at least 1.3. Namely, if the value $m \cdot H/f$ exceeds the above range, the reproducibility of a line image is reduced, and rear end lacking (top end thickening) is caused and the image density is generally degraded. If the value $m \cdot H/f$ is below the above

range, top end lacking (rear end thickening) is caused, and the image density is reduced and troubles such as carrier dragging are brought about.

Of the characteristic value $m \cdot H/f$, the numerator $m \cdot H/f$ is a value having a relation to the centripetal force acting on the carrier, and the denominator f is a value having a relation to the centrifugal force acting on the carrier. Accordingly, the ratio of these two values is a dimensionless number having a relation to the balance between the centripetal force and the centrifugal force. Within the range specified in the present invention, the centripetal force is relatively small and since the carrier contacts strongly a latent image, the influence of dynamic scraping on a toner image is reduced and an image having a high density can be obtained. Furthermore, since the freedom of the carrier is large, neutralization and diffusion of counter charges are enhanced. For these reasons, it is considered that the reproducibility of fine lines is improved by a high electric field owing to an edge effect.

Referring to Fig. 3 illustrating the magnetic brush developing process of the present invention, a magnet roll 11 having many magnetic poles N and S is contained in a developing sleeve 12 composed of a nonmagnetic material such as aluminum. A photosensitive drum 15 comprising a substrate 13 and an electrophotographic photosensitive layer 14 formed thereon is arranged separately by a minute distance $dD-S$ from the developing sleeve 12. The developing sleeve 12 and the photosensitive drum 15 are rotatably supported on a machine frame (not shown) and are driven so that the moving directions (indicated by arrows) at the nip position are the same (the revolution directions are reverse to each other). The developing sleeve 12 is arranged at an opening of a developing device 16. A mixing stirrer 17 for a two-component developer (a mixture of a toner and a magnetic carrier) 18 is arranged in the interior of the developing device 16, and a toner supply mechanism 20 for supplying a toner is disposed above the mixing stirrer 17. The two-component developer 18 is mixed by the stirrer 17 to frictionally charge the toner, and the developer is supplied to the developing sleeve 12 to form a magnetic brush on the surface thereof. The earing length of the magnetic brush 21 is regulated by a brush-cutting mechanism 22, and the magnetic brush 21 is delivered to the nip position to the electrophotosensitive layer 14, that is, to a developing area 23, to develop an electrostatic latent image on the photosensitive layer 14 with the toner 19 and form a visible image.

According to the present invention, in advance to the delivery of the magnetic brush 21 to the developing area 23, portions having a high pack density and portions having a low pack density are formed in the magnetic brush 21. The coarse-dense ratio between portions having a lowest pack density and portions

having a highest pack density is in the range of from 1/1.1 to 1/2.5, preferably from 1/1.2 to 1/2, especially preferably from 1/1.3 to 1/1.8.

Referring to Fig. 4 showing the method of forming such coarse portions and dense portions, a developing sleeve having many grooves 24 extending in the axial direction, which are arranged in the circumferential direction, is used as the developing sleeve 21, and portions 25 having a high pack density of the developer are formed in the grooves 24 and portions 27 having a low pack density of the developer are formed at circumferential parts 26, other than the grooves 24, of the sleeve. The flux density is high at grooves 24 of the developing sleeve 21 and therefore, the earing length of the brush is large and the pack density of the developer is high. On the other hand, at parts 26 other than the grooves 24, the flux density is low, and therefore, the earing length of the developer is small and the pack density of the developer is low.

In the present invention, it is important that the pitch P of the grooves 24 (the pitch of the circumferential parts 26 other than the grooves) should be such that along the above-mentioned developing length L , the unit latent image has at least one contact with the developer 25 having a high pack density on the groove 24 and at least one contact with the developer 27 having a low pack density on the circumferential part 26. It is generally preferred that the pitch P be from 1.5 to 8 mm, especially 2 to 5 mm. The ratio between the width (ℓ_1) of the groove 24 and the width (ℓ_2) of the circumferential part 26 other than the groove is preferably in a range of from 1/3 to 3/1. The depth of the groove 24 is such as giving a substantial difference of the pack density in the developer. It is preferred that the depth of the groove 24 be 0.2 to 1.0 mm, especially 0.2 to 0.5 mm. The shape of the groove 24 is not particularly critical. In general, there can be adopted a V-shaped shape, a U-shaped shape, a semicircular shape, a semi-ellipsoidal shape, a trapezoidal shape, a sine shape, a cycloidal shape and combinations of two or more of these shapes. The circumferential part other than the groove may be a circumferential face or a plane. It is preferred that the groove be smoothly connected to the other part through a face of curvature, and it is preferred that the curvature radius (R) of this connecting part be 0.1 to 1.0 mm.

Practically, concavities and convexities of the magnetic brush, shown in Fig. 4, are formed on larger concavities and convexities formed by the magnets arranged in the magnetic brush, but in the drawings, these larger concavities and convexities are omitted for facilitating the understanding of the function of the groove 24.

In accordance with one embodiment of the present invention, the carrier contact frequency (k) represented by the formula (1) is set within the above-mentioned range. In accordance with another em-

bodiment of the present invention, the flux density H of the magnetic pole located at the developing area, the saturation magnetization m of the magnetic carrier and the revolution frequency f of the developing sleeve are set so that the requirement represented by the formula (3) is satisfied. In accordance with still another embodiment of the present invention, the requirement of the formula (3) is satisfied and the carrier contact frequency (k) of the formula (1) is set within the above-mentioned range. This setting is accomplished, for example, in the following manner, though the following description by no means limits the scope of the present invention.

If the saturation magnetization of the magnetic carrier is small, the ratio $m \cdot H/f$ is reduced and the number of contacts of the carrier per unit area of the photosensitive material is reduced, and accordingly, the contact frequency (k) tends to lower. In the reverse case, a reverse tendency is observed.

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

As the ferrite, there have been used sintered ferrite particles composed of at least one member selected from the group consisting of zinc iron oxide (ZnFe_2O_4), Yttrium iron oxide ($\text{Y}_3\text{Fe}_5\text{O}_{12}$), cadmium iron oxide (CdFe_2O_4), gadolinium iron oxide ($\text{Gd}_3\text{Fe}_5\text{O}_{12}$), copper iron oxide (CuFe_2O_4), lead iron oxide ($\text{PbFe}_{12}\text{O}_{19}$), nickel iron oxide (NiFe_2O_4), neodymium iron oxide (NdFeO_3), barium iron oxide ($\text{BaFe}_{12}\text{O}_{19}$), magnesium iron oxide (MgFe_2O_4), manganese iron oxide (MnFe_2O_4) and lanthanum iron oxide (LaFeO_3). Especially, soft ferrites containing at least one member, preferably at least two members, selected from the group consisting of Cu, Zn, Mg, Mn and Ni, for example, a copper/zinc/magnesium ferrite, can be used. If these ferrites, those satisfying the above requirement are used.

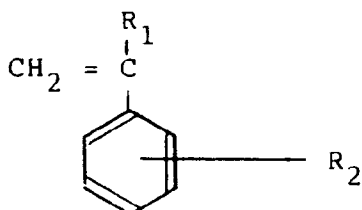
The electric resistance of the ferrite carrier depends not only on the chemical composition thereof, but also on the particulate structure and preparation process thereof and the kind and thickness of the coating. It is preferred that the volume resistivity of the ferrite carrier be 1×10^{10} to $5 \times 10^{11} \Omega\text{-cm}$, especially 4×10^{10} to $1 \times 10^{11} \Omega\text{-cm}$.

The toner used in the present invention is prepared by incorporating a coloring agent, a charge-controlling agent and, optionally, known toner additives into a fixing resin binder. It is preferred that the volume resistivity, determined by the method described below, of the toner used in the present invention be 1×10^8 to $3 \times 10^9 \Omega\text{-cm}$, especially 2×10^8 to $8 \times 10^8 \Omega\text{-cm}$, and that the dielectric constant of the toner be 2.5 to 4.5, especially 3.0 to 4.0.

The fixing binder resin for the toner, the coloring agent, the charge-controlling agent and other toner additives are selected and combined so that the above-mentioned characteristics can be obtained.

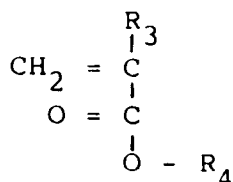
A styrene resin, an acrylic resin and a styreneacrylic-copolymer resin are generally used as the fixing binder resin.

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



wherein R_1 represents a hydrogen atom, a lower alkyl group (having up to 4 carbon atoms) or a halogen atom, and R_2 represents a substituent such as a lower alkyl group or a halogen atom, such as styrene, vinyltoluene, α -methylstyrene, α -chlorostyrene and vinylxylene, and vinylnaphthalene. Of these monomers, styrene is preferably used.

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



wherein R_3 represents a hydrogen atom or a lower alkyl group, and R_4 represents a hydrogen atom or a substituted or unsubstituted alkyl group having up to 18 carbon atoms, such as ethyl acrylate, methyl methacrylate, butyl acrylate, butyl methacrylate, 2-ethylhexyl acrylate 2-ethylhexyl methacrylate, hydroxyethyl (meth)acrylate, hydroxypropyl (meth)acrylate, aminoethyl (meth)acrylate, acrylic acid and methacrylic acid. As the acrylic monomer, there can be used other ethylenically unsaturated carboxylic acids and anhydrides thereof, such as maleic anhydride, fumaric acid, maleic acid, crotonic acid and itaconic acid.

A styrene-acrylic copolymer resin is one of preferred resin binder, and the weight ratio A/B of the styrene type monomer (A) to the acrylic monomer (B) is preferably from 50/50 to 90/10, especially preferably from 60/40 to 85/15. Preferably, the acid value of the resin used is 0 to 25. From the viewpoint of the fixing property, it is preferred that the resin should

have a glass transition temperature (T_g) of 50 to 65°C.

As the coloring agent to be incorporated into the binder resin, there can be used at least one member selected from the group consisting of inorganic and organic pigments and dyes, for example, carbon blacks such as furnace black and channel black, iron blacks such as triiron tetroxide, rutile titanium dioxide, anatase titanium dioxide, Phthalocyanine Blue, Phthalocyanine Green, cadmium yellow, molybdenum orange, Pyrazolone Red and Fast Violet B.

Known charge-controlling agents can be used. For example, there can be mentioned oil-soluble dyes such as Nogrosine Base (CI 50415), Oil Black (CI 20150) and Spilon Black, 1:1 or 2:1 type metal complex dyes, and metal salts of naphthonic acid, fatty acid soaps and resin acid soaps.

The particle size of toner particles is preferably such that the volume-based median diameter measured by a Coulter counter is 8 to 14 μm , especially 10 to 12 μm . The particulate shape may be an indeterminate shape formed by melt kneading and pulverization, or a spherical shape formed by dispersion or suspension polymerization.

The carrier and the toner are used at a mixing weight ratio of from 99/1 to 85/15, especially from 98/2 to 95/5, though the preferred mixing ratio is changed to some extent according to the physical properties of the toner and the magnetic carrier. In order to attain the object of the present invention, it is preferred that the resistivity of the developer as a whole be 5×10^9 to $5 \times 10^{10} \Omega\text{-cm}$, especially 1×10^{10} to $4 \times 10^{10} \Omega\text{-cm}$.

In the developer of the present invention, it is preferred that the carrier contact number per unit area of the photosensitive material be 100 to 300 per mm^2 , especially 100 to 200 per mm^2 .

The developing length L represented by the above formula (2) has relations to both of the contact frequency k and the image density. Preferably, the nip width (Nip), the peripheral speed (VS) of the developing sleeve and the peripheral speed (Vs) of the drum are set so that the developing length L is 4 to 35 mm, especially 4 to 20 mm.

In general, the developing nip width (Nip) is preferably 1 to 15 mm, especially preferably 2 to 8 mm. As pointed out hereinbefore, the distance dD-S between the developing sleeve and the photosensitive layer has an important influence on the value n, and it is preferred that dD-S be 0.5 to 3.0 mm, especially 0.7 to 1.7 mm.

Preferably, magnetic poles having a relatively small flux density are dispersed in the developing sleeve, so far as carrier dragging is not caused. In general, magnetic poles having a flux density of 400 to 1500 Gauss, especially 550 to 900 Gauss, are preferably used. A relatively large revolution speed of the developing sleeve is effective, and a revolution speed

of the developing sleeve is effective, and a revolution number of 1.50 to 5.00 per second is preferably adopted, though the preferred revolution number depends to some extent on the sleeve diameter.

As the photosensitive material, all of photosensitive materials used heretofore for the electrophotography, such as 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.

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

The resistivity and dielectric constant of the toner used in the present invention are measured by using a parallel plate electrode type measuring device having an electrode area of 2.27 cm² and an electrode spacing of 0.5 mm, packing a sample toner at a space ratio 25% and applying an alternating current voltage having peaks of +1 V and -1 V.

The resistivity of the carrier used in the present invention is measured by using a measuring device shown in Fig. 5 according to a method described below.

Namely, a carrier 33 is introduced into a developing device 32 equipped with a stirrer roller 31 to support the carrier 33 on a sleeve 34, and the thickness of the carrier layer 33 is adjusted to a predetermined value by an earing-regulating member 35 and is delivered in this state. A detecting part 38 having a predetermined surface area is attached to a micrometer 37 arranged as the electrode spacing-adjusting means along an imaginary line 36 on the surface of a photosensitive material confronting the sleeve 34 separately therefrom by a predetermined distance. While the carrier 33 is being delivered together with the sleeve 34, an alternating current voltage having a predetermined frequency is applied to the sleeve 34 and a detection signal y from the detection part 38 is supplied to a parallel circuit comprising a dummy and an oscillogram 39, and wave pattern data on the oscillogram 39 are read by reading means 40 and the resistivity is computed at a computing unit 41.

In Fig. 5, reference numeral 42 represents a cleaning blade as the cleaning means for removing the carrier 33 left on the sleeve 34.

In the measurement of the dielectric constant by the above-mentioned measuring device, the distance between the sleeve 34 and the detecting part 38, that is, the electrode spacing d, is adjusted to 1.2 mm, the surface area of the detecting part 38, that is the electrode area S, is set at 0.785 cm², and an alternating current voltage having a frequency of 50 Hz is ap-

plied.

The thickness of the layer of the carrier 33 supported on the sleeve 34 can be adjusted by the earing-regulating member 35 so that the pack ration of the carrier is about 15 to about 50%.

According to the present invention, by forming a magnetic brush of a two-component developer comprising a magnetic carrier and a toner on a developing sleeve and forming on the developing sleeve, alternately in the circumferential direction, and in advance of the supply of the magnetic brush to a developing area of a photosensitive material, portions having a high pack density of the developer and portions having a low pack density of the developer a proper frequency of contacts between the carrier and drum can be obtained without drastic limitation of the earing length of the magnetic brush or the distance D-S, and an image having a high quality and a high density can be obtained.

The reproducibility of Chinese characters is excellent and a high reproducibility is attained when a copy is reproduced from a copy.

The occurrence of front end lacking or rear end lacking can be prevented in the reproduction of multiple fine lines while keeping the width of each line uniform, and an image having a high density and a high quality can be obtained.

Claims

1. A developing process having an excellent reproducibility, which comprises forming a magnetic brush (21) of a two-component developer (18) comprising a magnetic carrier and a toner on a developing sleeve (12) containing a magnetic pole and bringing the magnetic brush into sliding contact with a photosensitive material (14) having a charged image to form a toner image on the photosensitive material; wherein the developing sleeve has a plurality of axially extending grooves (24) formed in the circumferential direction; wherein in advance of the sliding contact with the photosensitive material, developer sleeve portions (25) having a high pack density of the developer are formed in the grooves and developer sleeve portions (27) having a low pack density of the developer are formed at parts (26) of the sleeve other than the grooves; characterized in that the depth of the grooves is 0.2 to 1.0 mm; in that the pitch of the grooves is 1.5 to 8 mm; in that the ratio of the width of the grooves to the width of the circumferential parts other than the grooves is in the range of from 1/3 to 3/1; in that the sliding contact between the magnetic brush and the photosensitive material is controlled so that the average frequency (k), defined by the formula given below, is 100 to 700:

$$K = L \cdot n \quad (1)$$

wherein n represents the contact number (per mm²) of the carrier per unit area of the photosensitive material, determined from a scanning electron microscope photo with respect to a collo-
dion-fixed magnetic brush, and L represents the developing length defined by the following formula:

$$L = \frac{Nip}{Vd} (VS - Vd) \quad (2)$$

in which Nip represents the nip width (mm) of the developer on the surface of the photosensitive material, VS represents the moving speed (mm/sec) of the developing sleeve, and Vd represents the moving speed (mm/sec) of the surface of the photosensitive material; and in that the developing conditions are set so that the requirement represented by the following formula is satisfied:

$$15,000 \geq \frac{m \cdot H}{f} \geq 7,000 \quad (3)$$

wherein f represents the revolution rate (per second) of the developing sleeve, m represents the saturation magnetization (emu/g) of the magnetic carrier, and H represents the flux density (Gauss) of the magnetic pole in the developing sleeve.

2. A developing process according to claim 1, wherein the carrier contact frequency of the portions (25) having a high pack density of the developer is at least 500; wherein the carrier contact frequency (k) of the portions (27) having a low pack density of the developer is lower than 400; and wherein the former carrier contact frequency (k) is larger by at least 200 than the latter carrier contact frequency (k).

Patentansprüche

1. Ein Entwicklungsprozeß mit hervorragender Reproduzierbarkeit, der umfaßt Bildung einer Magnetbürste (21) aus einem einen magnetischen Träger und einen Toner umfassenden Zwei-Komponenten-Entwickler (18) auf einer einen magnetischen Pol enthaltenden Entwicklungshülse (12) und In-Gleitkontakt-Bringen der Magnetbürste mit einem lichtempfindlichen Material (14), das ein Ladungsbild aufweist, zur Bildung eines Tonerbilds auf dem lichtempfindlichen Material; wobei die Entwicklungshülse eine Vielzahl in Umfangsrichtung gebildeter sich axial erstreckender Furchen (24) aufweist; wobei vor dem Gleitkontakt mit dem lichtempfindlichen Material Entwicklungshülsenbereiche (27) mit hoher Packungsdichte des Entwicklers in den Furchen gebildet werden und Entwicklungshülsenberei-

che (27) mit niedriger Packungsdichte des Entwicklers auf den von den Furchen verschiedenen Bereichen (26) der Hülse gebildet werden; dadurch charakterisiert, daß die Tiefe der Furchen 0.2 bis 1.0 mm beträgt; daß der Abstand der Furchen 1.5 bis 8 mm beträgt; daß das Verhältnis der Furchenbreite zu der Breite der von den Furchen verschiedenen Umfangsbereiche im Bereich von 1/3 bis 3/1 liegt; daß der Gleitkontakt zwischen der Magnetbürste und dem lichtempfindlichen Material so kontrolliert wird, daß die mittlere Frequenz (k), definiert durch die unten angegebene Formel, 100 bis 700 beträgt:

$$K = L \cdot n \quad (1)$$

worin n die Kontakthzahl (pro mm²) des Trägers pro Flächeneinheit des lichtempfindlichen Materials darstellt, bestimmt aus einem Raster-Elektronenmikroskop-Photo einer Kollodium-fixierten Magnetbürste, und L die durch die folgende Formel definierte Entwicklungslänge darstellt:

$$L = \frac{Nip}{Vd} (VS - Vd) \quad (2)$$

worin Nip die Berührungslinienbreite (mm) des Entwicklers auf der Oberfläche des lichtempfindlichen Materials darstellt, VS die Bewegungsgeschwindigkeit (mm/sec) der Entwicklungshülse darstellt, und Vd die Bewegungsgeschwindigkeit (mm/sec) der Oberfläche des lichtempfindlichen Materials darstellt; und dadurch, daß die Entwicklungsbedingungen so festgesetzt sind, daß die durch die folgende Formel dargestellte Bedingung erfüllt wird:

$$15,000 \geq \frac{m \cdot H}{f} \geq 7,000 \quad (3)$$

worin f die Umdrehungszahl (pro Sekunde) der Entwicklungshülse darstellt, m die Sättigungsmagnetisierung (emu/g) des magnetischen Trägers darstellt, und H die Flußdichte (Gauss) des Magnetpols in der Entwicklungshülse darstellt.

2. Ein Entwicklungsprozeß entsprechend Anspruch 1, worin die Trägerkontaktfrequenz der Bereiche (25) mit hoher Packungsdichte des Entwicklers mindestens 500 beträgt; worin die Trägerkontaktfrequenz (k) der Bereiche (27) mit niedriger Packungsdichte des Entwicklers niedriger ist als 400; und worin die erste Kontaktfrequenz (k) um mindestens 200 größer ist als die letztere Trägerkontaktfrequenz (k).

Revendications

1. Un procédé de développement ayant une excellente reproductibilité, qui consiste à former une brosse magnétique (21) d'un révélateur à deux composants (18) comprenant un support magnétique et un toner sur un manchon de développe-

ment (12) contenant un pôle magnétique et à amener la brosse magnétique en contact glissant avec une matière photosensible (14) ayant une image chargée pour former une image de toner sur la matière photosensible ; dans lequel le manchon de développement a une pluralité de rainures axiales (24) formées dans le sens circonférentiel ; dans lequel, avant le contact glissant avec la matière photosensible, des portions (25) du manchon de développement ayant une forte densité de remplissage du révélateur sont formées dans les rainures et des portions (27) du manchon de développement ayant une faible densité de remplissage du révélateur sont formées sur les parties (26) du manchon autres que les rainures ; caractérisé en ce que la profondeur des rainures est de 0,2 à 1,0 mm ; en ce que le pas des rainures est de 1,5 à 8 mm ; en ce que le rapport entre la largeur des rainures et la largeur des parties circonférentielles autres que les rainures se situe dans la gamme de 1/3 à 3/1 ; en ce que le contact glissant entre la brosse magnétique et la matière photosensible est contrôlé de telle sorte que la fréquence moyenne (k), définie par la formule donnée ci-après, soit de 100 à 700 :

$$K = L \cdot n \quad (1)$$

dans laquelle n représente le nombre de contacts (par mm²) du support par unité de surface de la matière photosensible, déterminé à partir d'une photographie de microscope électronique à balayage par rapport à une brosse magnétique fixée au collodion, et L représente la longueur de développement définie par la formule suivante:

$$L = \frac{Nip}{Vd} (VS - Vd) \quad (2)$$

dans laquelle Nip représente la largeur de pincement (mm) du révélateur sur la surface de la matière photosensible, VS représente la vitesse de déplacement (mm/s) du manchon de développement, et Vd représente la vitesse de déplacement (mm/s) de la surface de la matière photosensible ; et en ce que les conditions de développement sont réglées de telle sorte que l'exigence représentée par la formule suivante soit satisfaite :

$$15,000 \geq \frac{m \cdot H}{f} \geq 7,000 \quad (3)$$

dans laquelle f représente la vitesse de rotation (par seconde) du manchon de développement, m représente l'aimantation à saturation (emu/g) du support magnétique, et H représente la densité de flux (Gauss) du pôle magnétique situé dans le manchon de développement.

moins égale à 500 ; dans lequel la fréquence de contact du support (k) avec les portions (27) ayant une faible densité de remplissage du révélateur est inférieure à 400 ; et dans lequel la première fréquence de contact du support (k) est supérieure d'au moins 200 à la seconde fréquence de contact du support (k).

2. Un procédé de développement selon la revendication 1, dans lequel la fréquence de contact du support avec les portions (25) ayant une forte densité de remplissage du révélateur est au

Fig. 1

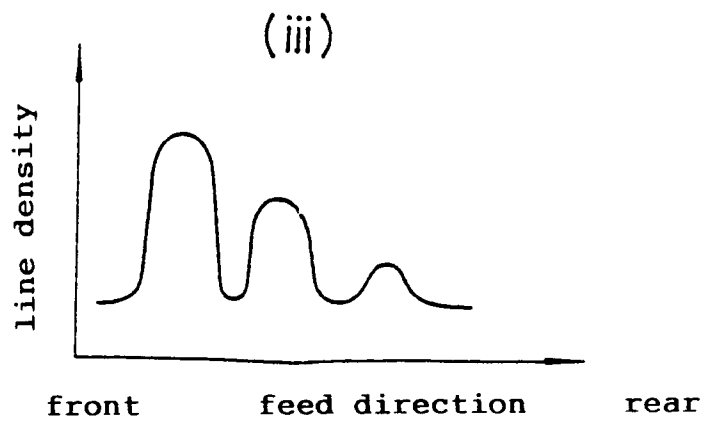
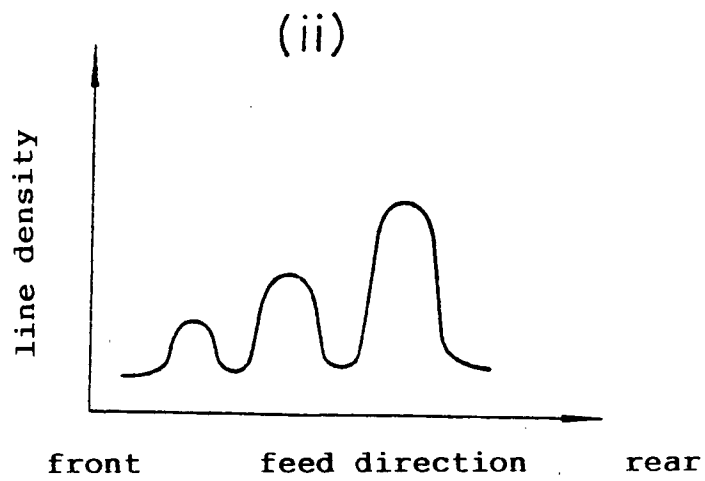
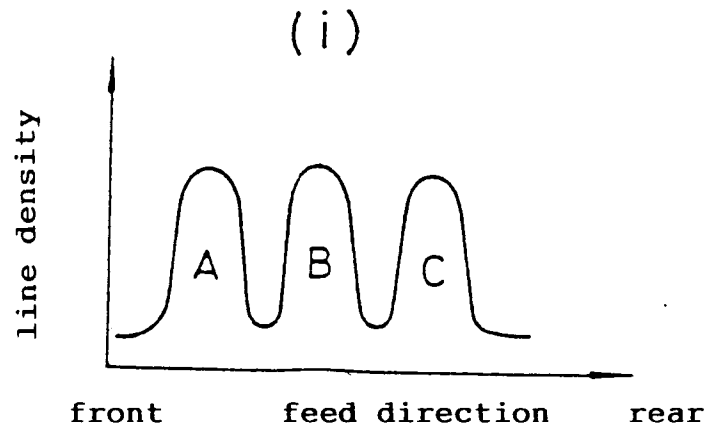


Fig. 2

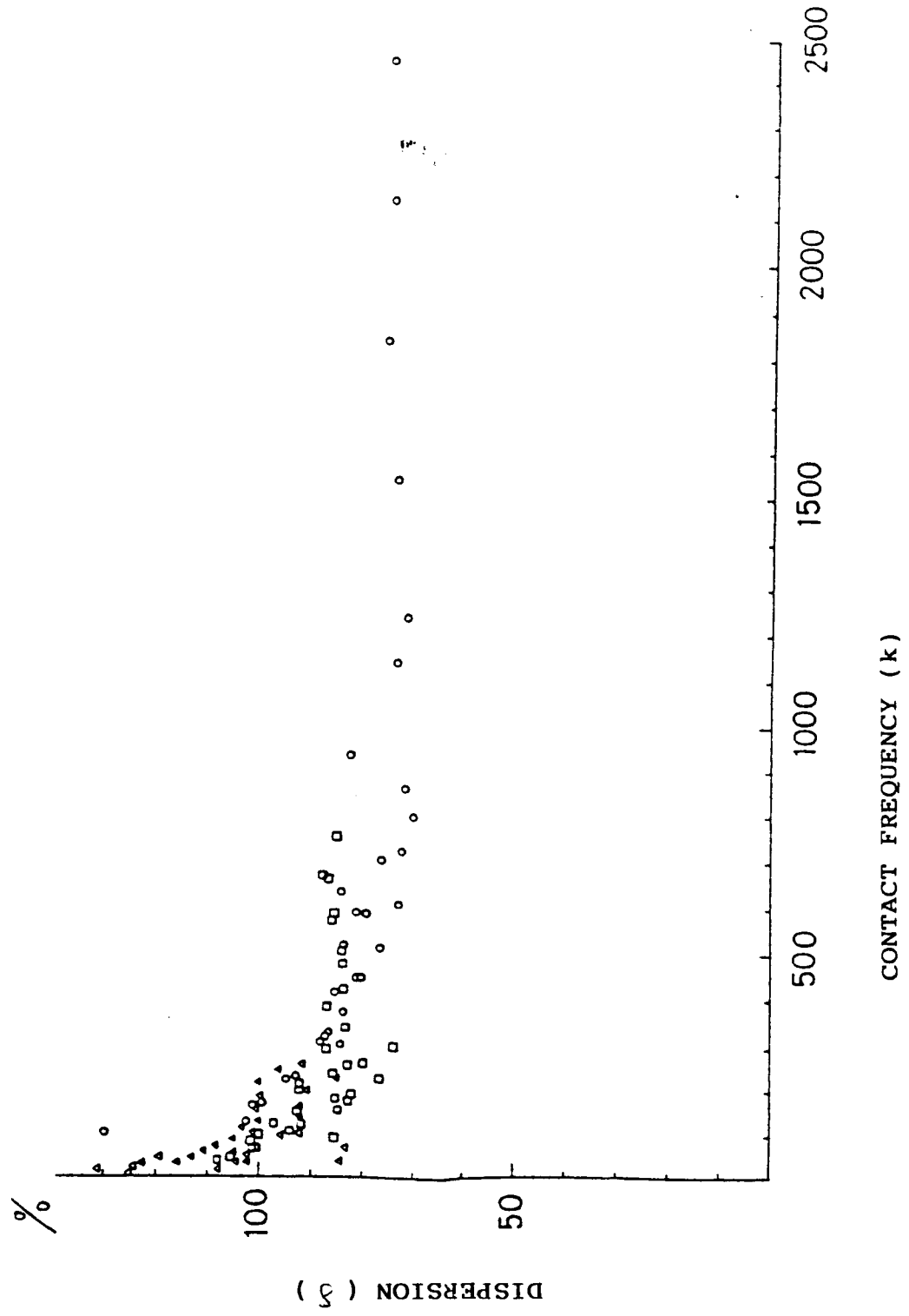


Fig. 3

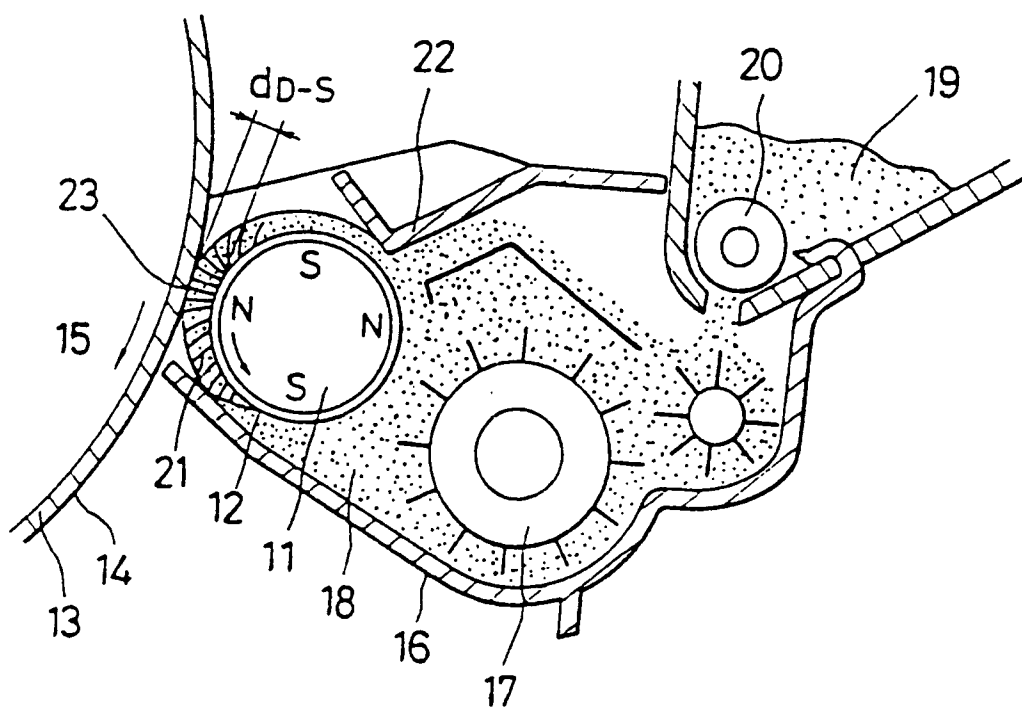


Fig. 4

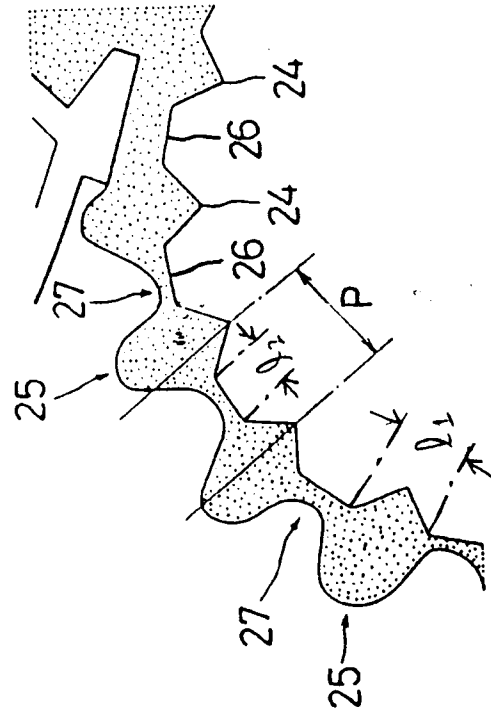


Fig. 5

