

Description

FIELD OF THE INVENTION AND RELATED ART

The present invention relates to a developing method and a developing apparatus embodying the method, wherein a latent image is developed by two component developer containing magnetic particles and toner particles mixed together.

A developing system using one component magnetic toner and a developing system using two component developer, are known. With respect to each of the developing systems, it is also known that the development effect can be enhanced by applying an alternating electric field at the developing station, as disclosed, for example, U.S. Patents Nos. 4,395,476; 4,425,373; 4,292,387; 4,548,489; 4,579,082; and 4,563,978, all of which have been assigned to the assignee of the present application.

In the developing system disclosed in the U.S. Patents Nos. 4,395,476; 4,425,373; and 4,292,387, a thin layer of the developer having such a thickness that the developer does not contact the latent image, is formed on a developer carrying member, which will hereinafter be called "sleeve", and then, the developer in the form of a thin layer is brought close to the latent image, where an electric field is formed between the latent image and the developer layer. Since this system uses the one component magnetic toner, it is preferable to employ a developing magnetic pole and to move the sleeve and the latent image bearing member, which hereinafter will be called "drum", at the same peripheral speed in the same direction. This system is found to be very useful since the image reproducibility is good, since the development efficiency (the ratio of the toner to be consumed for the developing action to the toner present at the developing position) is high, and also since the size of the developing device can be reduced.

However, the developer particle contains a relatively large amount of magnetic material, and therefore, it is not suitable for the image formation in non-black colors, e.g., red, blue or the like because the color is not bright enough due to the presence of the magnetic material which is usually black in color. In addition, the image formed with the one component magnetic developer is not strongly fixed on a recording member such as paper by fixing means. Practically, those problems are not very significant. However, from the standpoint of enhancing the quality of the image, they should be solved.

As a developing system wherein those problems have been solved, the U.S. Patents Nos. 4,548,489; 4,579,082; and 4,563,978 have proposed a system wherein two component developer containing non-magnetic toner particles and magnetic

particles are accommodated in a developer container. A thin layer comprising only the non-magnetic toner particles is formed on a developer carrying sleeve. The thin layer of the non-magnetic toner particles is opposed to a latent image to be developed, where an alternating electric field is formed between the latent image and the sleeve. This system does not involve the above described problems arising from the magnetic material, because at the developing position, one-component developer is used. However, this system has a problem that the image density of the developed image is relatively low and a problem in the development characteristics, in the following called negative property (the image density decreases with increase of the latent image potential) which will be described in detail hereinafter.

On the other hand, a developing system wherein two component developer is brought to the developing position, is known, as disclosed in Japanese Laid-Open Patent Application No. 93841/1978, for example. In this system, a large amount of magnetic brush constituted by magnetic particles is supplied to the developing position, with the result that only the toner particles that exist adjacent the free ends of the magnetic brush can participate in the actual developing action. In order to increase the image density by causing a large amount of the magnetic brush (not less than 5 mm) to contact the drum, the rotational speed of the sleeve is increased to be not less than three times the drum rotational speed. Additionally, since the percentage of the toner particles consumable for the development in the magnetic brush is small, the development efficiency is low. Furthermore, the developed image has a trace of brushing. In order for the sleeve to convey the large amount of the magnetic brush, high driving power is required. This is not advantageous since the uniform rotation can be damaged as well as the wasteful power consumption.

As for a developing system having a high development efficiency in the magnetic brush development using two component developer, a proposal has been made in Japanese Laid-Open Patent Application 32060/1980 filed by the assignee of the present application. In this system, the magnetic brush is formed at the developing position in an alternating electric field, by which the non-magnetic toner particles contained in the magnetic brush as well as those particles adjacent the free ends of the magnetic brush are usable for the developing action, thus increasing the development efficiency. It has been found that good images can be formed by this system.

However, this system which forms a large amount of the magnetic brush at the developing station, involves a problem that when the toner

content controlled in the developer container changes, the change directly influences the image quality developed thereby. Therefore, it is inevitably required that the toner content is strictly controlled in the developer container. It is practically impossible to omit the toner content control means. As will be understood, the development efficiency is even better than in the conventional systems described hereinbefore. However, wasteful magnetic particles and toner particles still have to be conveyed to the developing station.

SUMMARY OF THE INVENTION

Accordingly, it is a principal object of the present invention to provide a developing method and a developing apparatus having high developing efficiency, not having the negative property, which method is capable of forming a developed image with high image density.

It is another object of the present invention to provide a developing method and a developing apparatus, whereby a developed image having enough image density can be provided without use of an automatic toner content control mechanism.

It is a further object of the present invention to provide a developing method and a developing apparatus wherein the developer on the developer carrying member is consumed efficiently for the development.

According to the present invention the method of developing an electrostatic latent image comprises:

forming on a surface of a movable developer carrier a layer of a developer comprising magnetic particles having electrically charged toner particles retained thereon;

moving the layer to a developing position where a surface of a member for bearing an electrostatic latent image is opposed with a clearance to the surface of the developer carrier;

forming a brush of the magnetic and toner particles at the developing position by applying a magnetic field thereat; and

transferring toner particles from the brush to the image bearing member to develop the latent image by applying an alternating electric field across the clearance;

characterised in that:

the layer of developer includes further electrically charged toner particles as a toner particle layer retained on the surface of the developer carrier;

the transfer of the toner particles from the brush to the image bearing member is accompanied by substantial transfer of the further toner particles from the developer carrier to the image bearing member; and

the brush is formed by chains of the magnetic

particles sufficiently sparse to permit the transfer of the further toner particles.

According to the present invention apparatus for developing an electrostatic latent image, comprising:

a movable developer carrier, on which a layer of a developer comprising magnetic particles can be formed the magnetic particles having electrically charged toner particles retained thereon;

an electrostatic latent image bearing member being opposed with a clearance to the surface of the developer carrier;

a first magnetic field generating means disposed across said developer carrier for generating a magnetic field to contact the magnetic particles to the image bearing member at the developing position in order to form a brush of the magnetic and toner particles;

a developer regulating member, disposed upstream of the developing position with respect to the movement of the surface of said developer carrier and spaced apart from the surface of said developer carrier, for regulating the developer carried to the developing position;

a second magnetic field generating means disposed across said developer carrier upstream of said developer regulating member with respect to said movement;

an alternating electric field generating means for forming an alternating electric field at the developing position to transfer at least the toner particles carried on said developer carrier to the latent image bearing member;

characterised in that:

the apparatus is such that in operation the layer of developer includes further electrically charged toner particles as a toner particle layer retained on the surface of the developer carrier;

the transfer of the toner particles from the brush to the image bearing member is accompanied by substantial transfer of the further toner particles from the developer carrier to the image bearing member; and

the brush is formed by chains of the magnetic particles sufficiently sparse to permit the transfer of the further toner particles.

By using the toner particles in the toner particle layer for the development, the image density of the developed image is stabilized, and in addition, the image quality is enhanced. Therefore, the image density is not influenced very much by the image density provided only by the toner particles on the magnetic particle surface, thus stabilizing the development operation. In some applications, the automatic toner content control means can be omitted. Simultaneously, the development efficiency can be increased up to as much as 70%, or even to the extent of almost 100% in preferred

conditions. One of the preferred conditions is that a volumetric ratio of the magnetic particles in the developing position is 1.5% - 30% in order to further stabilize the development.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectional view of a developing apparatus according to an embodiment of the present invention.

Figure 2 is an enlarged sectional view at the developing position of the developing apparatus shown in Figure 1, illustrating the method of development according to an embodiment of the present invention.

Figure 3 is a graph indicating the development property of the developing apparatus according to the embodiment of the present invention.

Figure 4 is a sectional view illustrating a preferable formation of chains of the magnetic particles in the developing apparatus according to the present invention.

Figure 5 is a sectional view illustrating an unpreferable formation of chains of the magnetic particles.

Figure 6 is a sectional view of a part of a preferable example of a developer container.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 1, there is shown a developing apparatus according to an embodiment of the present invention, wherein an electrostatic latent image bearing member for bearing the electrostatic latent image to be developed is indicated by a reference numeral 1. The image bearing member 1 is in this embodiment a photosensitive drum, but may be a photosensitive or dielectric drum or belt movable along an endless path. The process of forming an electrostatic latent image on the image bearing member is known, and any suitable electrostatic latent image formation process is usable. In this embodiment, the image bearing member is a photosensitive drum on which an electrostatic latent image is formed by an electrophotographic process. The photosensitive drum 1 is rotatable in the direction indicated by an arrow a.

The developing apparatus according to this embodiment comprises a developer container 21, a developing sleeve 22 (hereinafter will be called simply "sleeve") as the developer carrying mem-

ber, a magnet 23 as the magnetic field generating means, a regulating blade 24 (hereinafter will also be called simply "blade") for regulating the amount of the developer conveyed to the developing position on the sleeve 22 and an electric power source 34 as the alternating electric field generating means. The structures of the respective elements will be described.

The container 21 contains the developer containing the magnetic particles 27 and the toner particles 28 mixed together. The toner particle in this embodiment is a non-magnetic toner particle having a particle size of 7 - 20 microns, mainly consisting of 10 parts of carbon and 90 parts of polystyrene, for example. The toner particles and the magnetic particles are accommodated in this embodiment such that the magnetic particle content is high in the neighborhood of the sleeve 22 surface but it is low away from the sleeve 22 surface. However, they may be contained under uniform content in the container 21. The container 21 has an opening at a left bottom position, as seen in Figure 1.

The sleeve 22 is made of a non-magnetic material such as aluminum and is disposed in the opening of the container 21 with a part of its surface exposed and the rest of the surface within the container 21. The sleeve 22 is rotatably supported along an axis perpendicular to the sheet of the drawing of Figure 1 and is rotated in operation in the direction of an arrow b. In this embodiment, the sleeve 22 is illustrated as being a cylindrical sleeve, but it may be an endless belt.

The sleeve 22 is opposed to the photosensitive drum 1 with a small clearance to constitute a developing position or zone, to which the toner and magnetic particles are carried on the sleeve 22 so that the volumetric ratio of the magnetic particles therein is 1.5 - 30 %. This will be described in detail hereinafter.

The magnet 23 is disposed in the sleeve 22. The magnet 23 is fixed so that it does not rotate when the sleeve 22 rotates. The magnet 23 has a magnetic pole 23a (N) cooperative with the blade 24 which will be described hereinafter to regulate the amount of the developer to be applied on the sleeve 22 as a developer layer, a developing pole 23b (S), magnetic poles 23c (N) and 23d (S) for collecting the developer after passing through the developing position back into the container 21. The polarities of the magnetic poles may be reversed. The magnet 23 is a permanent magnet in this embodiment, but it may be an electromagnet.

The blade 24 in this embodiment is made of a non-magnetic material such as aluminum at least at its free end portion. The blade 24 extends along the length of the sleeve 22 in the neighborhood of the upper portion of the opening of the container

21. The base portion of the blade 24 is fixed to the container 21. The free end of the blade 24 is opposed to the surface of the sleeve 22 with a clearance, which is 50 - 500 μm , preferably 100 - 350 μm . In this embodiment, the clearance is 250 μm . If the clearance is less than 50 μm , the clearance is easily clogged by the magnetic particles, whereas if it is larger than 500 μm , a too large amount of the magnetic particles and toner particles are passed through the clearance with the result that the suitable thickness of the developer layer can not be formed on the sleeve 22. The thickness of the layer is less than the clearance between the surface of the photosensitive drum 1 and the surface of the sleeve 22 at the developing position on the assumption that the magnetic force does not exist. In order to form the developer layer of this thickness, it is preferable that the clearance between the edge of the blade 24 and the surface of the sleeve 22 is equivalent or smaller than the clearance between the surface of the photosensitive drum 1 and the surface of the sleeve 22. However, it is possible to form such a layer with a larger clearance between the blade 24 and the sleeve 22. At the inside wall of the blade 24, there is provided a member 26 effective to limit the circulating movement of the magnetic particles. The member 26 serves to limit the region of circulation of the magnetic particles within the container 21. The circulation will be described hereinafter.

The positional relationship between the developer carrier 22, the regulating member 24 and the limiting member 26 is such as to form a sectional area 261 which gradually decreases toward the regulating member 24 from an upstream side.

The power source 34 applies a voltage between the photosensitive drum 1 and the sleeve 22 to form an alternating electric field across the clearance therebetween, by which the toner particles transfer onto the photosensitive drum 1 from the developer layer on the sleeve 22. The alternating voltage provided by the power source 34 may be symmetrical, that is, the peak voltages at the positive side and the negative side are equal, or may be an asymmetrical voltage which may be provided by superimposing a DC voltage to the symmetrical voltage. As an example, when the electrostatic latent image having a dark portion potential of -600 V and a light portion potential -200 V is to be developed, the sleeve 22 is supplied with the asymmetrical voltage of 200 - 3000 Hz having a peak-to-peak voltage of 300 - 2000 Vpp provided by a superimposed DC voltage of -300 V, while the photosensitive drum 1 is grounded.

The bottom portion of the container 21 extends toward the photosensitive drum 1 to form an extension to prevent the developer, particularly the toner

particles, from scattering or leaking outside. In order to assure the prevention, a member 29 is fixed to the top surface of the extension in this embodiment so as to receive and confine the developer particles. To the edge of the extension, a member 30 is fixed extending along the length of the sleeve 22 to prevent the particles from scattering, as shown in the Figure. To the member 30, a voltage having the same polarity as the toner particles may be applied, whereby the toner scattered from the developing position is urged toward the photosensitive drum 1 by the electric field formed thereby, so as to prevent the toner scattering.

Adjacent the opposite ends of the sleeve 22, there is provided a developer limiting member, which functions to prevent the application of the developer on the sleeve 22 surface adjacent the longitudinal end portions of the sleeve.

The operation of the developing apparatus according to this embodiment will be described. First, the magnetic particles 27 are supplied into the container 21. Those magnetic particles are attracted and maintained on the sleeve 22 surface by the magnetic force provided by the magnetic poles 23a and 23d to cover the entire surface of the sleeve 22 within the container 21, thus forming a layer of magnetic particles. Those portions of the magnetic particle layer which are close to the magnetic poles 23a and 23d are formed into a magnetic brush. Subsequently, the toner particles 28 are supplied into the container 21, thus forming a toner layer outside the magnetic particle layer. It is preferable that the magnetic powder first supplied into the container 21 contains 2 - 70 % by weight of the toner, but the powder may consist only of magnetic particles. After the magnetic particles 27 are once attracted to the surface of the sleeve 22 as the magnetic particle layer, they do not significantly flow or incline even when the developing apparatus vibrates or fairly inclines, and keep covering the surface of the sleeve 22.

When the sleeve 22 rotates in the direction indicated by an arrow, the magnetic particles move upwardly in the direction along the surface of the sleeve 22 from the bottom portion of the container 21 to reach the neighborhood of the blade 24, where a part of the magnetic particles passes through the clearance between the sleeve 22 and the edge of the blade 24 together with the toner particles. The rest of the magnetic particles impinges on the member 26, and thereafter, is turned downwardly and is lowered by the gravity outside the rising passage to the bottom portion of the container 21. They again rise by the rotation of the sleeve 22 adjacent thereto. This is repeated to form a circulation of the magnetic particles. Among the magnetic particles 27 rising toward the blade 24 from the bottom portion of the container 21, there

are particles which turn downwardly prior to reaching the neighborhood of the blade 24. The magnetic particles relatively away from the surface of the sleeve 22 tend to make this movement.

The magnetic powder turned in the neighborhood of or before the blade 24 takes thereinto the toner particles from the outside toner layer. During the circulation with the rotation of the sleeve 22, the toner particles 28 are triboelectrically charged by the friction with the magnetic particles 27 and the sleeve 22 surface.

Adjacent the position before the blade 24, the magnetic particles 27 near the surface of the sleeve 22 are attracted to the sleeve surface by the magnetic force of the magnetic pole 23a, and therefore, they pass under the blade 24 to go out of the container 21 with the rotation of the sleeve 22. During this movement, the magnetic particles 27 carry the toner particles deposited on their surfaces out of the container 21. Additionally, a part of the charged toner particles 28 are attracted onto the sleeve surface and are carried out of the container 21 on the sleeve 22. The blade 24 is effective to remove surplus developer applied to the sleeve 22 surface.

The layer of the developer (the mixture of the magnetic particles 27 and the toner particles 28) formed on the sleeve surface 22 is carried on the surface of the sleeve 22 to reach the developing position or zone where the sleeve 22, and therefore, the layer is opposed to the surface of the photosensitive drum 1. In the developing position, the toner particles are transferred onto the latent image on the photosensitive drum 1 both from the surfaces of the magnetic particles and from the surface of the sleeve 22 by the alternating electric field formed across the clearance between the photosensitive drum 1 and the sleeve 22, whereby the latent image is developed. The volumetric ratio of the magnetic particles in the developing position is preferably 1.5 - 30 %, which will be described in detail hereinafter.

With the continued rotation of the sleeve 22, the toner particles and magnetic particles not having been consumed for the development are collected back into the container 21. They are mixed with the particles in the container 21 by the above described circulation and are again supplied on the sleeve 22. During this circulation, the magnetic powder takes thereinto the toner particles from the upper toner layer in the container 21, whereby it is resupplied with the toner by the amount which has been consumed.

Figure 2 is an enlarged sectional view of the developing position illustrating the developing action. The photosensitive drum 1 retains the electric charge constituting the latent image. In this embodiment, the electric charge constituting the latent

image is negative, and therefore, the toner particles are charged positive. In Figure 2, the photosensitive drum 1 and the sleeve 22 rotate such that the peripheral movements thereof are co-directional, as indicated by the arrows. Across the clearance formed therebetween, the above described alternating voltage is applied from the power source 34. At a position corresponding to a position where the photosensitive drum 1 and the sleeve 22 are closest, the magnetic pole 23b of the magnet 23 is disposed within the sleeve 22.

In the space between the photosensitive drum 1 and the sleeve 22, there is the developer which is the mixture of the magnetic particles 27 and the toner particles carried on the rotating sleeve 22. It should be noted that the developing system according to this embodiment is essentially different from those disclosed in the above mentioned U.S. Patents Nos. 4,548,489, 4,579,082 and 4,563,978 in the existence of the magnetic particles in the developing position. Because of the volumetric ratio which will be described hereinafter, of the magnetic particles in the developing position, the amount of the magnetic particles present in this position is far less than in usual so-called magnetic brush developing system, and in this point, the developing system according to this embodiment is essentially different from the magnetic brush developing system. The very small amount of the magnetic particles 27 form sparse chains 51 of the magnetic particles by the magnetic pole 23a. Due to the larger movability of the magnetic particles 23 provided by the sparseness, the action of the magnetic particles 27 is peculiar.

More particularly, the sparse chains of the magnetic particles are distributed uniformly in the direction of the magnetic lines of force, and simultaneously, the surface of the sleeve 21 as well as the surfaces of the magnetic particles are opened. Therefore, the toner particles on the magnetic particle surfaces can be supplied to the photosensitive drum without obstruction by the chains, and simultaneously, the uniformly distributed opened portions of the sleeve surface can be established, whereby the toner particles can be transferred from the sleeve surface to the photosensitive surface by the alternating electric field.

Accordingly,

both of the toner particles 101 deposited or retained on the surfaces of the magnetic particles and the toner particles in the toner particle layer 100 (Figure 2) on the developer carrying member surface are usable for the developing operation. Substantially the entire surfaces of the magnetic particles are capable of functioning as extensions of the developer carrying member surface. At the same time, the toner particles deposited or retained on the developer carrying member surface

can be utilized efficiently as the toner particles for developing movement. As a result, the amount of the toner particles in the toner particle layer 100 on the developer carrying member surface decreases to a large extent after it passes by the developing position as compared with that before passing thereby. Under the preferable conditions, the toner particle layer 100 no longer exists after the development. It should be noted that, according to the present invention, the toner particles on the sleeve 100 is usable for the development, as well as the toner particles 101 on the magnetic particle surfaces.

The description will be made as to the behavior of the magnetic particles and the toner particles. As shown in Figure 2, the electrostatic latent image in this example is formed by the negative charge (dark portion of the image), so that the electric field by the electrostatic latent image is directed as indicated by an arrow a in Figure 2. The direction of the electric field provided by the alternating electric field alternates.

In the phase wherein the positive voltage is applied to the sleeve 22, the electric field is co-directional with the electric field of the latent image. At this time, the amount of the electric charge injected into the chains 51 is maximum, and therefore, the chains 51 stand up most, and long chains reach to the surface of the photosensitive drum 1. On the other hand, the toner particles 28 on the sleeve surface and the magnetic particle surfaces are charged in the positive polarity as described hereinbefore, and therefore, they are transferred to the photosensitive drum 1 by the electric field formed in this space. It should be noted here that the erected chains 51 are sparsely distributed, so that the surface of the sleeve 22 is exposed or opened, whereby the toner particles are released both from the surface of the sleeve 22 and the surfaces of the chains 51. Additionally, there is the electric charge having the polarity opposite to that of the toner particles 28 in the chains 51, and therefore, the toner particles 28 on the surfaces of the chains 51 are easy to be released by the electrostatic repelling force.

During the phase wherein the negative voltage is applied to the sleeve 22, the electric field by the alternating voltage (arrow b) and the electric field by the electrostatic latent image (arrow a) are counter-directional. Therefore, the electric field in this space is strong in the opposite direction, so that the amount of charge injection is relatively small. Consequently, the chains 51 are collapsed in accordance with the amount of the charge, and they establish collapsed contact state.

Since the toner particles 28 on the photosensitive drum 1 are charged positive as described hereinbefore, the toner particles 28 transfer back to

the sleeve 22 and back to the magnetic particles 27 from the photosensitive drum 1 by the electric field formed across the space. In this manner, the toner particles 28 reciprocate between the photosensitive drum 1 and the sleeve 22 surface and between the photosensitive drum 1 and the magnetic particle surfaces. With the increase of the clearance therebetween caused by the rotation of the photosensitive drum and the sleeve 22, the electric field is weakened, and the developing operation terminates.

At the chains 51, there are triboelectric charge by the friction with the toner particles 28 or image charge and charge injected by the electrostatic latent image charge on the photosensitive drum 1 and the alternating electric field between the photosensitive drum 1 and the sleeve 22. The state of those electric charges depends on the time constant of the charging and the discharging determined by the material of the magnetic particles 27 and other parameters.

In this manner, the chains 51 of the magnetic particles 27 make fine but violent vibrating movement.

Now, the description will be made with respect to the volumetric ratio of the magnetic particles at the developing station. The "developing position" or "developing zone" is defined as the region in which the toner particles are transferred or supplied from the sleeve 22 to the photosensitive drum 1. The "volumetric ratio" is the percentage of the volume occupied by the magnetic particles present in the developing position or zone to the entire volume of the developing position or zone. As a result of the various experiments and considerations, the inventors have found that the volumetric ratio is significantly influential in this developing apparatus, more particularly, it is preferable that the volumetric ratio is 1.5 - 30 %, more preferably 2.6 - 26 %.

If this is smaller than 1.5 %, the problems have been confirmed that the image density of the developed image is too low; that a ghost image appears in the developed image; a remarkable density difference occurs between the position where the chain 51 exists and the position where no chain exists; and or that the thickness of the developer layer formed on the sleeve 22 is not uniform.

If the volumetric ratio is larger than 30 %, the surface of the sleeve is closed, that is, covered by the magnetic particles too much, and a foggy background results.

The inventors have found that the image quality does not monotonously become better or worse with the increase or decrease of the volumetric ratio; that the satisfactory image density can be obtained within the range of 1.5 - 30 % of the

volumetric ratio; the deterioration of the image is recognized both below 1.5 % and beyond 30 % of the volumetric ratio; and that in this satisfactory range, neither the ghost image nor the foggy background results. The image deterioration resulting when the volumetric ratio is low is considered as being caused by the negative property, while the deterioration when the volumetric ratio is too large is considered as being caused by the closed or covered sleeve surface resulting from the large amount of the magnetic particles, thus reducing too much the toner supply from the sleeve surface.

If the volumetric ratio is less than 1.5 %, the image reproducibility of a line image is not satisfactory with a remarkable decrease of the image density. If it is more than 30 %, the magnetic particles can physically damage the surface of the photosensitive drum 1, and the toner particles can be kept deposited on the photosensitive drum as a part of the developed image, which is a problem at the subsequent image transfer or at the image fixing station.

In the region where the volumetric ratio is near 1.5 %, a locally non-uniform development can occur (under particular conditions) when a large area solid black image is developed. For this reason, the volumetric ratio is determined such that this does not occur. For this purpose, it is more preferable that the volumetric ratio is not less than 2.6 %, and therefore, this defines a further preferable range.

If the volumetric ratio is near 30 %, the toner supply from the sleeve surface can be delayed in such a region adjacent the positions where the chains of the magnetic particles are contacted, for example, when the developing speed is high. If this occurs, a non-uniform developed image can result in the form of scales in the case of solid black image reproduction. In order to assure the prevention of this, the volumetric ratio is preferably not more than 26 %.

Where the volumetric ratio is in the range of 1.5 - 30 %, the chains 51 of the magnetic particles are formed on the sleeve surface and are distributed sparsely to a satisfactory extent, so that the toner particles on the chain surfaces and those on the sleeve surfaces are sufficiently opened toward the photosensitive drum 1, and the toner particles on the sleeve 22 are transferred by the alternating electric field. Thus, almost all of the toner particles are consumable for the purpose of development. Accordingly, the development efficiency (the ratio of the toner consumable for the development to the overall toner present in the developing position), and also a high image density can be provided. Preferably, the fine but violent vibration of the chains is produced, by which the toner powder deposited on the magnetic particles and the sleeve surface are sufficiently loosened. In any case, the

trace of brushing or occurrence of the ghost image as in the magnetic brush development can be prevented. Additionally, the vibration of the chains enhances the frictional contact between the magnetic particles 27 and the toner particles 28, with the result of increased triboelectric charging to the toner particles 28, by which the occurrence of the foggy background can be prevented. Also, the high development efficiency is suitable to the reduction of the size of the developing apparatus.

The volumetric ratio of the magnetic particles in the developing position is determined;

$$(M/h) \times (1/\rho) \times [C/(T+C)]$$

where M is the weight of the developer (the mixture) per unit area of the sleeve surface when the erected chains are not formed (g/cm^2);

h is the height of the space of the developing position (cm);

ρ is the true density (g/cm^3);

$C/(T+C)$ is the percentage of the magnetic (carrier) particles in the developer on the sleeve.

The percentage of the toner particles to the magnetic particles at the developing position as defined above is preferably 4 - 40 % by weight.

In this embodiment, the alternating electric field is strong enough (large rate of change or large V_{pp}), the chains 51 are released from the sleeve 22 surface or from their base portions, and the released magnetic particles 27 also reciprocate between the sleeve 22 and the photosensitive drum 1. Since the energy of the reciprocal movement of the magnetic particles is large, the above described effects of vibration are further enhanced.

The above described behavior has been confirmed by a high speed camera available from Hitachi Seisakusho, Japan operable at the speed of 8000 frames/sec.

Even in the case where the clearance is reduced between the photosensitive drum 1 surface and the sleeve 22 surface so as to increase the contact pressure between the photosensitive drum 1 and the magnetic particle chains 51 and to decrease the vibration, the clearance is still large enough at the inlet and outlet sides of the developing position, and therefore, the vibration is sufficient with the above described advantages.

On the contrary, if the clearance is increased it is preferable that the magnetic particle chains 51 are contacted to the drum 1 surface when the electric field is applied, even if they do not contact the drum surface without the electric field.

When magnetic particles having a relatively low resistance are used, the alternating voltage applied between the photosensitive drum 1 and the sleeve 22 is selected such that at the peaks thereof, the electric discharge does not occur therebetween at

the dark portions or light portions of the latent image. When chains of the magnetic particles having a relatively high resistance are used, the voltage is preferably selected such that the voltage across the clearance reaches a discharge on-set voltage by suitably selecting the frequency of the alternating voltage and selecting the charge and discharge time constant of the chains of the magnetic particles.

The resistance of the entire chain in the direction of the height thereof measured with the chain being contacted to the photosensitive drum 1, is preferably $10^{15} - 10^6$ ohm-cm. When the developing electrode effect of the chain 51 is expected, it is preferably $10^{12} - 10^6$ ohm-cm, and more preferably $10^{10} - 10^6$ ohm-cm.

The average particle size of the magnetic particles 27 is 30 - 100 μm preferably 40 - 80 microns. In general, with decrease of the average particle size, the triboelectric charging property with the sleeve is improved, so that a so-called sleeve ghost (the image density decreases in the image which is developed immediately after a solid black image is developed, or the image density decreases gradually with the integrated number of rotations of the sleeve) does not result. However, when the particle size is small, there is a tendency that the magnetic particles are deposited onto the latent image bearing member. The positions where the magnetic particles are deposited, are different depending on the resistance of the magnetic particles. For example, relatively low resistance magnetic particles are deposited on the image area of the latent image, while high resistance particles are deposited in the non-image area. This is a general tendency, and actually the influence is recognized more or less by the magnetic properties of the magnetic particles, the surface configuration and the surface treating material (including resin coating).

In the developing apparatus used with commercial electrophotographic machines, wherein the magnetic field on the sleeve in the developing position is approximately 600 - 900 Gausses, it has been found that the magnetic particles are increasingly deposited when the size thereof is not more than 30 μm . On the contrary, if it is not less than 100 μm , the sleeve ghost is remarkable. Therefore, the range of 30 - 100 μm is preferable. In the developing apparatus according to this embodiment, a relatively high resistance carrier particles having the particle size of 50 - 100 μm for a two component developer, are usable.

The magnetic particle contains only magnetic material or may contain magnetic material and non-magnetic material. In addition, the magnetic particles may contain two or more magnetic materials mixed.

Next, the description will be made with respect to a so-called V-D curve, that is, the relation of the developed image density with respect to the surface potential of the latent image in the developing apparatus according to this embodiment.

Figure 3 is a V-D curve graph, wherein the V-D curve in this apparatus is indicated by a reference X, and wherein the reflection density of the developed image measured by a Macbeth density meter is plotted against the potential difference between the photosensitive drum potential and the sleeve surface potential when the sleeve surface potential is assumed to be zero. It is understood that the V-D curve is excellent since it indicates that the background fog does not result at the low potential region, and the appropriate inclination is provided in the intermediate potential region, and still the sufficient image density can be provided at the high potential region. As an example of a V-D curve of a developing apparatus not using the present invention, that of the developing apparatus disclosed in U.S. Patents Nos. 4548489, 4579082 and 4563978 wherein one component non-magnetic developer layer is opposed to a latent image under the existence of an alternating electric field, the developer layer being thin on the sleeve surface, is given in Figure 3 and is indicated by a reference Y. As will be understood, the negative developing property appears, that is, in a range beyond a certain potential, the image density decreases with increase of the potential. This provides a tendency that the image density is not sufficient in a high potential region. As contrasted to this V-D curve, the property of the present invention is much better, since the foggy background is not produced in the low potential region; since the inclination is relatively less steep in the intermediate region, and therefore, the edge effect is not extreme; since the negative property does not appear in the intermediate potential region; and since the sufficient image density can be obtained in the high potential region.

Then, the conditions will be discussed to form preferable chains of the magnetic particles.

Figure 4 illustrates the chains which are preferable in the developing position, wherein the chains are formed independently from each other and wherein the chains are distributed uniformly over the sleeve 22 surface.

Figure 5 illustrates chains which are not preferable, wherein the magnetic particles 27 are in the form of agglomerations. It has been found that if the development is effected with those agglomerations of the magnetic particles, non-uniform pattern in the form of scales have appeared in an image, and therefore, this is not preferable.

Further, the inventors have found that the production of the agglomerations of the magnetic par-

ticles is influenced by the material of the blade 24 and by an angle between the edge of the blade and the magnetic pole 23a seen from the center of the sleeve 22.

As for the material of the blade 24, non-magnetic material is preferable. When magnetic material is used, the magnetic lines of force are concentrated on the blade 24, with the result that the magnetic force for confining the magnetic particles is strong. In order for the magnetic particles to overcome the confining force and to go out of the container 21, an agglomeration over a certain degree is required. Until such an agglomeration is reached, they stay in the neighborhood of the blade 24 due to the strong magnetic confining force. Only when the agglomeration reaches a sufficient level, the agglomeration of the magnetic particles becomes able to advance out of the container 21. This is considered as being the reason why the magnetic particles are in the form shown in Figure 5 when they reach the developing position on the sleeve 22.

Where the blade 24 is of non-magnetic material, the magnetic lines of force do not concentrate adjacent the edge of the blade 24, and therefore, the above-described agglomeration is not produced, but the developer is applied uniformly over the sleeve. Consequently, the uniform and sparse chains are formed in the developing position. For this reason, the blade 24 is preferably of a non-magnetic material. However, if the magnetic property is weak as when provided by bending a stainless steel (SUS304-JIS), such a magnetic material is usable.

As to the angle θ , if it is less than 2 degrees, the agglomeration of the magnetic particles is produced, or the developer is not formed as a uniform layer on the sleeve 21. The reason for this is considered as follows. Since then, the magnetic particles are sparsely distributed along the magnetic lines of force adjacent the blade 24, and therefore, the magnetic particles are advanced only after a predetermined amount of the magnetic particles are stagnated here. On the other hand, if the angle θ is larger than 40 degrees, the effect of regulating the amount of the magnetic particles is extremely decreased. From this, it has been found that the angle θ is preferably not less than 2 degrees but not more than 40 degrees, further preferably, not less than 5 degrees but not more than 20 degrees.

The relationship between the angle θ and the amount of the developer passed under the blade edge is like this. With the decrease of the angle θ , the amount decreases, and therefore, the volumetric ratio at the developing station decreases. If the angle θ is increased, the opposite results. The amount of the toner particles applied on the sur-

face of the sleeve 22 is substantially independent from the angle θ , that is, it is substantially constant.

A developing apparatus was constructed according to this embodiment, as shown in Figure 1. As for the sleeve 22, an aluminum sleeve having the diameter of 20 mm was used after the surface thereof is treated by irregular sand-blasting with ALUNDUM abrasive. Within the sleeve 22, the magnet 23 magnetized with four poles was used, the N and S poles being arranged alternately along the circumference as shown in Figure 1. The maximum surface magnetic flux density by the magnet 23 was approximately 900 Gauss.

The blade 24 used had the thickness of 1.2 mm made of non-magnetic stainless steel. The angle θ was set 15 degrees.

As for the magnetic particles, ferrite particles (maximum magnetization of 60 emu/g) had the particle size of 70 - 50 μm (250/300 mesh), whose surface was treated by silicon resin.

As for the non-magnetic toner, blue powder provided by a mixture of 100 parts of styrene/butadiene copolymer resin and 5 parts of copper phthalocyanine pigments, and added by 0.6 % of the colloidal silica, was used. The average particle size of the toner particles was 10 μm . Upon operation, approximately 20 - 30 μm thickness of the toner layer was obtained on the sleeve 22 surface, and above the toner layer, the magnetic particle layer of 100 - 200 μm thickness was formed. On the surfaces of the magnetic particles, there were toner particles.

At that time, the total weight of the magnetic particles and the toner particles on the sleeve 22 was approximately 2.43×10^{-2} g/cm².

The magnetic particles were formed into erected chains at and adjacent the developing position by the magnetic pole 23b within the sleeve 22. The maximum height of the chains was approximately 0.9 mm.

The amount of electric charge was measured by a blow-off method, and the triboelectric charge of the toner particles on the sleeve 22 and the magnetic particles was +10 mC/g.

In the "blow-off method", the electrically charged toner particles are placed on a conductive member and are then blown off that member. During this operation the current through the conductive member is measured by an electrometer and from this measurement the amount of electric charge can be obtained.

The developing apparatus was assembled into a commercial copying machine, PC-10 sold by Canon Kabushiki Kaisha, Japan. The clearance between the surface of the photosensitive drum 3 made of organic photoconductor material and the surface of the sleeve 22 was set 350 μm . They were moved at the same peripheral speed, more

particularly 66 mm/sec. The volumetric ratio under those conditions was approximately 10 % ($h = 350 \mu\text{m}$, $M = 2.43 \times 10^{-2} \text{ g/cm}^2$, $\rho = 5.5 \text{ g/cm}^3$, $C/(T+C) = 20.4 \%$). The bias voltage source 34 provided an alternating voltage having the frequency of 1600 Hz, wherein an alternating voltage having the peak-to-peak value of 1300 V was superimposed with a DC voltage of -300 V. When this was operated, good blue images were obtained.

The developing operation was performed to obtain a solid image, and then the surface of the sleeve 22 was carefully observed after the developing operation. It was confirmed that almost all of the toner particles on the sleeve and on the magnetic particles were consumed up, and therefore, the developing operation was effected with almost 100 % development efficiency.

It was confirmed that the development properties were good enough without foggy background, and the V-D curve was as indicated by the reference X in Figure 3.

As described in the foregoing, the present embodiment is advantageous in the high image density, high development efficiency, no foggy background, no ghost image, no trace of brushing and no negative property.

As will be understood from Figure 1, the developer circulation limiting member 26 is disposed upstream of the developer regulating member 24 with respect to the movement of the sleeve surface. The limiting member has a (bottom) surface which defines a clearance with the surface of the sleeve 22, the clearance decreasing toward the regulating member 24. This is preferable to turn the developer downwardly. In this embodiment the angle θ is 15 degrees so that the magnetic brush is formed in the region between the limiting member 26 and the sleeve 22 opposed to each other.

Further, the inventors have found that the state of the magnetic particles immediately before the blade 24 is important in order to assure the formation of the developer layer on the sleeve surface and to further stabilize the developing operation.

In order to perform the developing operation in good order, it is required that the toner particles in the developer layer are uniformly triboelectrically charged to a proper extent. If the charge of the toner is low or uneven, the background fog tends to occur. If, on the contrary, the charge is too large, the toner particles stick to the surface of the sleeve 22 or the surfaces of the magnetic particles 27 with the result of incapability of being consumed for the development, so that the image density is low, or the image is partly void. For this reason, the mechanism is important in which the toner particles are taken into the magnetic powder, and wherein the triboelectric charge is applied to the toner particles. The application of the triboelectric charge to

the toner depends on the state of the developer immediately before the blade 24.

Figure 6 is a sectional view of a part of the developing apparatus according to another embodiment of the present invention, wherein like reference numerals have been used to describe corresponding elements.

As described hereinbefore, the magnetic particles circulate with the rotation of the developing sleeve 22. The circulating movement can be divided into three parts. The first part is indicated by a reference A in Figure 6, which is immediately before the blade 24 (hereinafter will be called "circulation layer A"). Here, the developing particles circulate at a very low speed.

The second part extend from a magnetic seal 31 to the circulation layer A (hereinafter will be called "conveying layer B"), in which the magnetic particles are conveyed by the rotation of the sleeve 22. In this conveying layer B, the toner particles are mainly taken into the magnetic powder.

The third part is indicated by a reference C, which hereinafter will be called "falling layer", wherein the magnetic particles fall by the gravity. The falling layer C is remarkably formed particularly when the amount of the magnetic particles is large or when the T/C ratio in the magnetic particle layer is increased so that the volume of the magnetic particle layer is large.

The movement in the falling layer C is moderate, and therefore, the power of taking the toner particles is weaker than in the conveying layer B. Thus, with respect to taking the toner particles into the magnetic powder, there are two processes. One of them occurs when the ratio T/C is low in the magnetic particle layer. In this case, the above described falling movement in the falling layer C is not strong, and the toner is taken into the magnetic powder by the movement in the conveying layer B, thus increasing the toner content T/C in the magnetic particle layer.

The opposite occurs when the toner content T/C is high in the magnetic particle layer. In this case, the movement has been stabilized in the magnetic particle layer, and the movement in the falling layer C is strong, with the result that the conveying layer B hardly contacts the toner layer. At this time, the toner taking action occurs only during the downward movement of the magnetic particles in the falling layer C, and the amount is slight. Therefore, the toner content T/C does not increase. In this manner, the toner content in the magnetic particle layer is kept substantially constant.

The application of the triboelectric charge to the toner particles can be provided also by the movement in the conveying layer B, but the application in the circulation layer A, particularly adja-

cent the blade 24, is predominant. Here, the force of conveying the magnetic particles by the sleeve 22 and the force of limiting this movement and assisting the turn of the magnetic particles by the circulation limiting member 26, cooperate to increase the pressure among the magnetic particles, and the density of the particles is increased immediately before the blade 24, by which the toner particles are sufficiently frictioned with the surface of the sleeve 22 and the magnetic particles 27 so that the toner particles are electrically charged.

If the pressure (density) is low, the frictional force to the toner particles is weak, which results in low and non-uniform electric charge of the toner. This can be a cause of the foggy background. If, on the contrary, the pressure, and therefore, the density is too high, the frictional force is too strong with the result of extremely charged toner particles. If this occurs, the toner particles are overcharged and/or fused and fixed onto the sleeve surface or the surfaces of the magnetic particles, which are not desirable.

It has been found that the triboelectric charge application power is not represented only by the absolute value of the density of the magnetic powder.

This is because the toner content T/C can widely range from 0.10 - 0.3 in the developing apparatus according to this embodiment, and therefore, the absolute value of the density of the magnetic powder changes depending on the amount of the toner. When only the magnetic particles are contained in space at most condensed state, the total volume of the magnetic particles to the volume of the space is $(1/6\pi\sqrt{2} = 74\%)$ if a face-centered cube is considered (Introduction to Solid State Physics by Charles Kittel). However, if the toner particles are contained therein by the amount of 20 % by weight of the magnetic particles, the amount of the magnetic particles in the space is as low as 30 % even under the most condensed condition. If the 20 % toner is contained and if the volume of the magnetic particles is 30 % in the region immediately before the blade 24, the toner particles are easily charged too much. If several % by weight toner is contained, and if the volume of the magnetic particles is 30 % immediately before the blade 24, a cavity or cavities are produced in the developer powder, into which the toner particles floating in the developing apparatus come, and they are deposited before being triboelectrically charged. This may be a cause of the foggy background. The inventors have found a particular relationship existing between the amount of the magnetic particles at the developing position and the amount of the magnetic particles immediately before the blade 24.

The amount of the magnetic particles at the

developing station changes depending on the toner content T/C. And the proper amount of the magnetic particles immediately before the blade 24 is also dependent on the toner content T/C. If they satisfy particular relation, sufficient triboelectric charge can be applied, and satisfactory developer layer can be provided independently of the ratio T/C. The relation is:

$$0.1 \leq V_d/V \leq 1.0$$

where V is a volumetric ratio of the magnetic particles in the region immediately before the blade;

V_d is a volumetric ratio of the magnetic particles at the developing station.

Those conditions are satisfied under the conditions that the above described development are accomplished.

More preferably, the relation is:

$$0.2 \leq V_d/V \leq 0.8$$

Further preferably, the volumetric ratio V_d satisfies $1.5\% \leq V_d \leq 30\%$ as described hereinbefore.

If $V_d/V < 0.1$, the magnetic particle layer tends to be clogged immediately before the blade 24, so that it is difficult to uniformly form the developer layer. In this state, the frictional force to the toner particles is too strong with the result of extremely charged toner particles.

If $V_d/V > 0.1$, the magnetic particle layer is fairly sparse, and the above described entering of the floating toner can not be prevented to the satisfactory extent, so that foggy background is produced.

The above analysis is based on the volumetric ratio V_d ($1.5\% \leq V_d \leq 30\%$). Based on the volumetric ratio V, the ratio V_d/V is preferably 0.8 or less when the volumetric ratio V is approximately 40 %. Also, it is preferable that $V_d < V$ is satisfied within the range where the volumetric ratio V_d satisfies the above requirement.

In the first embodiment described in conjunction with Figure 1, the volumetric ratio V was set 40 %, and the volumetric ratio V_d was set 10 %. In that case the value $V_d/V = 0.25$. The bias voltage applied by the voltage source 34 had the frequency of 1600 Hz and was obtained by superimposing the DC voltage of -300 V to the AC voltage of the peak-to-peak voltage of 1300 V. The resultant blue image was satisfactory.

A solid image was developed, and the sleeve surface after the development was observed. It was confirmed that almost all of the toner particles on the magnetic particles and on the sleeve 22 was

consumed up. Namely, the development efficiency was almost 100 %.

The region immediately before the blade 24 is represented by the space or region A defined by the blade 24, the limiting member 26 and the sleeve 22. Where the volume of the region A thus defined is very large, the representative volume of the region is determined as a volume of the space defined by the blade 24, the surface of the sleeve 22 and an extension of a line connecting the center of the magnetic pole 23a adjacent the blade 24 and the rotational center of the sleeve 22. In any case, the volumetric ratio of the magnetic particles in the region immediately before the blade 24 is the maximum within the container 21, and therefore, this is used.

It is preferable that the volumetric ratio in the region immediately before the blade 24 is not less than 20 % from the standpoint of the stabilized charge application to the toner particles.

In this embodiment, the toner particles are retained on the magnetic particle 27 surfaces and the sleeve 22 surface. The inventors have determined as a consequence of various experiments and considerations that the ratio of those toner particles, more particularly, the ratio between the toner particles retained on the magnetic particles and the toner particles retained on the sleeve, is 1:2 - 10:1 by weight, more preferably, 1:1 - 5:1.

This ratio can be controlled by changing the surface property of the sleeve 22, the triboelectric charging property of the toner particles and/or the property and the supply of the magnetic particles. Among those factors, the particle size of the magnetic particles and the amount of the magnetic particles supplied to the developing position are particularly influential.

With the increase of the particle size of the magnetic particles, the area of the surfaces capable of retaining the toner particles decrease (for the purpose of comparison, the total volume of the magnetic particles is supposed to be constant). Therefore, the amount of the toner retained on the magnetic particles, which is conveyed to the developing position, decreases. On the contrary, the amount of the toner particles retained on the sleeve 22 increases as if it compensates the reduction of the toner particles retained on the magnetic particles. If the particle size of the magnetic particles is reduced, the opposite tendencies result.

As for the amount of supply of the magnetic particles to the developing position, the amount of toner particles retained on the magnetic particles increases with the increase of the supply of the magnetic particles. With this increase, the amount of the toner retained on the sleeve 22 decreases slightly. If the supply of the magnetic particles is reduced, the tendencies are opposite.

Therefore, by suitably selecting those factors, the above region of the ratio can be provided.

If the above ratio is less than 1:2, the V-D curve approaches the curve Y shown in Figure 3, and therefore, not preferable. If it is more than 10:1, on the contrary, the magnetic particles 27 are contacted to the surface of the photosensitive drum 1 too much with the result that the magnetic particles 27 are deposited on the photosensitive drum 1. This is not preferable, either. It has been confirmed that the good image results when the above ratio is within the range of 1:2 - 10:1. As described, by properly selecting the particle size of the magnetic particles and the supply of the magnetic particles, the ratio is set within the range of 1:1 - 5:1, which is more preferable for the satisfactory development.

The ratio is measured in the following manner. First, all of the magnetic particles on the sleeve 22 is attracted from the sleeve 22 by a magnet. By doing so, the magnetic particles and the toner particles retained thereon are all collected to a magnet. The same is rinsed, and the amount of the toner which has been retained on the magnetic particles is measured in weight. Then, the toner particles remaining on the sleeve 22 is all sucked and collected by a filter. Again, it is rinsed, and the weight of the toner particles which have been retained on the sleeve is measured. As an alternative, the magnetic particles on the sleeve 22 is externally attracted by a magnet and rinsed, and thereafter, another developer layer is formed. Then, the developer layer (the magnetic particles, the toner particles retained on the magnetic particles and the toner particles retained on the sleeve) are all removed and rinsed to determine the total amount of the toner. Then, the amount of the toner particles on the sleeve 22 is obtained as a difference between the total amount of the toner and the amount of the toner retained on the magnetic particles. This alternative method is usable when the developing operation is sufficiently stabilized.

The description will be made with respect to the amount of the developer carried on the sleeve 22, more particularly the amount of the developer (the total of the magnetic particles and toner particles) on the sleeve 22 downstream of the blade 24. Various experiments and considerations by the inventors have revealed that in the developing apparatus according to this embodiment, when the magnetic particles are each substantially spherical, the amount of the developer is preferably $0.5 - 5.0 \times 10^{-2}$ g/cm². If it is larger than 5.0×10^{-2} g/cm², the foggy background is produced. Particularly, if it is larger than 6.0×10^{-2} g/cm², the background is extremely foggy. If it is smaller than 0.5×10^{-2} g/cm², on the contrary, the trace of the brushing is visible with naked eyes. Therefore, the above range

is preferable.

With respect to the ratio of mixture between the toner and magnetic particles, the inventors experiments and considerations have revealed that the ratio of the toner weight to the magnetic particle weight is preferably 4 - 40 %. With the ratio larger than 40 %, the foggy background is produced independently of the amount of the developer applied on the sleeve 22. If it is smaller than 4 %, no satisfactory image density is provided independently of the amount of the developer applied on the sleeve 22. Therefore, the above range is preferable.

Referring back to the ratio of the toner particles retained on the magnetic particles and the toner particles retained on the sleeve, the ratio was approximately 2:1 by weight in the above described actual example of the developing apparatus according to this embodiment. It should be noted that if the ratio is within this range, the change in the amount of the toner particles retained on the magnetic particles is substantially compensated by the toner particles retained on the sleeve, so that the stabilized developing operation can be maintained even if the amount of the toner on the magnetic particles varies more or less.

A further preferable condition will be described. This condition is that the amount of the toner particle layer on the sleeve 22 surface carried to the developing position is not less than $0.05 \times 10^{-3} \text{ g/cm}^2$ and not more than $1.0 \times 10^{-3} \text{ g/cm}^2$.

As described hereinbefore, the above described developing action is based on the toner particle layer on the surface of the sleeve 22 as well as the toner particles on the toner particles retained on the surfaces of the magnetic particles and on the action of the magnetic particles. The developing action is governed or supplemented by the toner particle layer on the sleeve 22. This is particularly so, when the chains of the magnetic particles formed in the developing position by the action of the magnetic field is so sparsely distributed on the surface of the sleeve 22 that the toner particle layer on the surface of the sleeve is opened to the latent image bearing member (drum). To accomplish this, the volumetric ratio defined hereinbefore of the magnetic particles in the developing position is not more than 50 %, for example.

In any event, in the developing apparatus according to this embodiment of the present invention the toner particles in the toner particle layer on the surface of the sleeve 22 between the chains of the magnetic particles are transferable to the latent image bearing member without restraint by the magnetic particles. Therefore, the toner particle layer is influential to the result of the development.

From this aspect, the amount of the toner par-

ticles in the toner particle layer carried on the sleeve 22 to the developing position is preferably not less than $0.05 \times 10^{-3} \text{ g/cm}^2$ and not more than $1.0 \times 10^{-3} \text{ g/cm}^2$. If it is less than $0.05 \times 10^{-3} \text{ g/cm}^2$, the amount of the toner usable for development is not sufficient with the result that low image density portion is produced and that a line image is thinned. This is so, even if a quite large amount of toner particles are made to be retained on the magnetic particles. If, on the other hand, it is larger than $1.0 \times 10^{-3} \text{ g/cm}^2$, the amount of the toner particles is too large with the result that the developed image is thickened and/or defaced and that the foggy background is produced. This is so, even if the amount of the toner particles retained on the magnetic particles is made significantly reduced. If it is $0.05 \times 10^{-3} \text{ g/cm}^2 - 1.0 \times 10^{-3} \text{ g/cm}^2$, the developing action is stabilized since, if the amount of the toner particles retained on the magnetic particles varies, the toner particles on the sleeve surface can supplement or compensate the variation.

Under the condition of the above described toner particle layer formed, the ratio described hereinbefore between the toner particles retained on the magnetic particles and the toner particles retained on the sleeve, is 1:2 - 10:1 by weight further stabilize the developing operation.

In addition, the volumetric ratio of the magnetic particles at the developing position (1.5 - 30 %) further ensures the function of the toner particle layer described above.

It has been confirmed that if the toner particle layer is not less than $0.1 \times 10^{-3} \text{ g/cm}^2$ and not more than $0.6 \times 10^{-3} \text{ g/cm}^2$, the stabilized developing operation can be maintained satisfactorily, even if the above described other conditions are varied or if there is some variation in the ambient conditions. This is because the development according to this embodiment effectively uses the toner retained on the magnetic particles and also the toner retained on the sleeve surface.

It is preferable that the toner particle layer is spaced from the latent image bearing member at the developing position. The thickness of the toner layer is preferably not less than 1/50 and not more than 1/5 of the clearance between the electrostatic latent image bearing member 1 and the sleeve 22 at the developing position in view of the transfer of the toner particles.

The above described amount and ratio can be measured in the same manner as described hereinbefore.

In the above described example, the amount of the toner applied on the sleeve surface was measured and found to be $0.1 \times 10^{-3} \text{ g/cm}^2 - 0.6 \times 10^{-3} \text{ g/cm}^2$.

Next, the description will be made with respect to the peripheral speeds of the photosensitive drum

1 and the sleeve 22. As described hereinbefore, the image quality is significantly influenced by the presence of the toner particles and the magnetic particles in the clearance between the photosensitive drum 1 and the sleeve 22. It is therefore preferable to pay consideration to the peripheral speed difference between the photosensitive drum 1 and the sleeve 22, more particularly, they are substantially equal. Further, the peripheral speed of the sleeve 22 is preferably 1.5 - 0.8 times the peripheral speed of the photosensitive drum 1.

If the peripheral speed of the sleeve 22 is less than 0.8 time of that of the photosensitive drum 1, the amount of the developer (the toner particles on the sleeve 22 and the toner particles on the surfaces of the magnetic particles) which is capable of being supplied to the electrostatic latent image while the latent image passes by the developing position, is very small, with the result that the density of the developed image is low, and that the distribution of the portion where the chains 51 exist and the portions where they do not exist is not stabilized so that a local density difference appears. Those inconveniences occur depending on the particle size of the magnetic particles or toner particles. Thus, the developer usable are more limited.

If the peripheral speed of the sleeve 22 is higher than 1.5 times of the photosensitive drum peripheral speed, the amount of the magnetic particles present at the developing position per unit time is so large that the sufficient vibration of the chains are not provided. It is recognized that the toner supply from the sleeve surface is delayed adjacent the area where the chains of the magnetic particles are contacted to the photosensitive member 1. In an extreme case, a non-uniform pattern in the form of scales are observed in the very high density portion as in the case of a solid black image. Additionally, the insufficient vibration per unit time at the developing position sometimes prevents the active frictional contact between the magnetic particles and toner particles, and therefore, the triboelectric charge to the toner particles is insufficient. This results in foggy background of the developed image.

Accordingly, the peripheral speed of the sleeve 22 and that of the drum 1 are kept substantially equal, more particularly, the peripheral speed of the sleeve 22 is 1.5 - 0.8 times that of the drum peripheral speed. By doing so, the action and behavior of the relatively slight amount of the magnetic particles existing at the developing position are most effectively utilized.

It should be noted that this does not apply to the conventional magnetic brush development using two component developer (the peripheral speed of the sleeve is more than twice the peripheral

speed of the drum, practically it is 4 - 8 times). This stems from the fact that the developing apparatus according to this invention effectively uses the transfer of the toner particles from the surface of the sleeve, and uses the balance with the toner supply from the surfaces of the magnetic particles under the action of the magnetic particles.

Referring back to Figure 6, the line L1 is the line connecting the center of the magnetic pole 23a disposed upstream of the blade 24 with respect to the movement of the surface of the sleeve 22 and the rotational center of the sleeve 22. The line L1 defines the angle θ . In the example of Figure 6, on an extension of the line L1, there is a surface of the limiting member 26 opposed to the sleeve 22, and the magnetic pole forms a most condensed portion of the magnetic particles. The length of the surface measured along the peripheral movement of the sleeve 22 is 10 mm. As will be understood from Figure 6, the volumetric ratio of the magnetic particles at the developing position is smaller than the volumetric ratio of the magnetic particles in this most condensed portion.

As regards the magnetic pole 23b at the developing position, it is disposed at the center of the developing station in the direction of the movement of the surfaces of the photosensitive member and the sleeve. However, it may be deviated from the center, or the developing position may be disposed between magnetic poles.

To the toner powder, silica particles may be added to enhance the flowability or abrasive particles, or the like may be added to abrade the surface of the photosensitive drum 1 (latent image bearing member) in an image transfer type image forming apparatus. To the toner powder a small amount of magnetic particles may be added. Magnetic toner particles may be used if the magnetic property thereof is very weak as compared with that of the magnetic particles and is triboelectrically chargeable.

In order to prevent the occurrence of the ghost image, the developer layer remaining on the sleeve 22 after the developing action may be once scraped off by scraper means (not shown), and then the scraped sleeve surface is brought into contact to the magnetic particle layer in the container, and then the developer is applied thereon. This is effective to prevent the ghost image.

A mechanism may be added to the developing apparatus, which detect the content of the magnetic particles and the toner particles, and in response to the detection, the toner is automatically supplied.

The developing apparatus according to the present invention is usable with a disposable developing device which contains as a unit the container 21, the sleeve 22 and the blade 24, although it is

applicable to the usual developing device which is fixed in an image forming apparatus.

Claims

1. A method of developing an electrostatic latent image, comprising:

forming on a surface of a movable developer carrier (22) a layer of a developer comprising magnetic particles (27) having electrically charged toner particles (28) retained thereon;

moving the layer to a developing position where a surface of a member (1) for bearing an electrostatic latent image is opposed with a clearance to the surface of the developer carrier (22);

forming a brush of the magnetic and toner particles (27,28) at the developing position by applying a magnetic field (23) thereat; and

transferring toner particles (28) from the brush (51) to the image bearing member (1) to develop the latent image by applying an alternating electric field across the clearance; characterised in that:

the layer of developer includes further electrically charged toner particles (100) as a toner particle layer retained on the surface of the developer carrier (22);

the transfer of the toner particles (28) from the brush to the image bearing member is accompanied by substantial transfer of the further toner particles from the developer carrier (22) to the image bearing member (1); and

the brush is formed by chains (51) of the magnetic particles sufficiently sparse to permit the transfer of the further toner particles (100).

2. A method according to Claim 1, wherein the chains of the magnetic particles are contacted to the image bearing member at the developing position, and wherein the volumetric ratio V_d of the total volume of the magnetic particles existing at the developing position to the volume of the space, defined by the surface of the image bearing member and the developer carrier at the developing position, is 1.5 - 30%.

3. A method according to Claim 2, wherein the volumetric ratio V_d is 2.6 - 26%.

4. A method according to Claim 2, wherein the total weight of the toner particles (100) in the toner particle layer on the surface of the developer carrier and the toner particles (101) on the surfaces of the magnetic particles at the developing position is 4 - 40% of the weight of the magnetic particles existing at the develop-

ing position.

5. A method according to Claim 2 or 4, wherein the amount of the developer carried on the developer carrier including the toner particle layer, the toner particles (101) on the surfaces of the magnetic particles and the magnetic particles is 0.5×10^{-2} - 5×10^{-2} g/cm².

6. A method according to Claim 2, wherein the toner particle layer, the toner particles on the surfaces of the magnetic particles and the magnetic particles moved to the developing position are applied onto the surface of the developer carrier from a developer container (21) containing mixed toner particles (28) and magnetic particles (27), with a regulation by a developer regulating member (24) disposed opposed to the surface of the developer carrier (22), and wherein said volumetric ratio V_d and the volumetric ratio V of the magnetic particles in a region immediately before the developer goes out of the container, satisfy:

$$0.1 \leq V_d/V \leq 1.0.$$

7. A method according to Claim 6, wherein V_d/V satisfies $0.2 \leq V_d/V \leq 0.8$.

8. A method according to Claim 6, wherein the volumetric ratio V is not less than 20%.

9. A method according to Claim 1, wherein the amount of the toner particles (100) in the toner particle layer is not less than 0.05×10^{-3} g/cm² and not more than 1.0×10^{-3} g/cm².

10. A method according to Claim 9, wherein the amount of the toner particles (100) in the toner particle layer is not less than 0.1×10^{-3} g/cm² and not more than 0.6×10^{-3} g/cm².

11. A method according to Claim 9, wherein the thickness of the toner particle layer is 1/50 - 1/5 of the clearance between the surface of the image bearing member and the surface of the developer carrier at the developing position.

12. A method according to Claim 1 or 9, wherein the weight ratio between the toner particles (100) in the toner particle layer and the toner particles (101) on the surfaces of the magnetic particles is 2:1 - 1:10.

13. A method according to Claim 12, wherein the weight ratio is 1:1 - 1:5.

14. A method according to Claim 1, wherein the



applicable to the usual developing device which is fixed in an image forming apparatus.

Claims

1. A method of developing an electrostatic latent image, comprising:

forming on a surface of a movable developer carrier (22) a layer of a developer comprising magnetic particles (27) having electrically charged toner particles (28) retained thereon;

moving the layer to a developing position where a surface of a member (1) for bearing an electrostatic latent image is opposed with a clearance to the surface of the developer carrier (22);

forming a brush of the magnetic and toner particles (27,28) at the developing position by applying a magnetic field (23) thereat; and

transferring toner particles (28) from the brush (51) to the image bearing member (1) to develop the latent image by applying an alternating electric field across the clearance; characterised in that:

the layer of developer includes further electrically charged toner particles (100) as a toner particle layer retained on the surface of the developer carrier (22);

the transfer of the toner particles (28) from the brush to the image bearing member is accompanied by substantial transfer of the further toner particles from the developer carrier (22) to the image bearing member (1); and

the brush is formed by chains (51) of the magnetic particles sufficiently sparse to permit the transfer of the further toner particles (100).

- A method according to Claim 1, wherein the chains of the magnetic particles are contacted to the image bearing member at the developing position, and wherein the volumetric ratio V_d of the total volume of the magnetic particles existing at the developing position to the volume of the space, defined by the surface of the image bearing member and the developer carrier at the developing position, is 1.5 - 30%.

3. A method according to Claim 2, wherein the volumetric ratio V_d is 2.6 - 26%.

4. A method according to Claim 2, wherein the total weight of the toner particles (100) in the toner particle layer on the surface of the developer carrier and the toner particles (101) on the surfaces of the magnetic particles at the developing position is 4 - 40% of the weight of the magnetic particles existing at the develop-

ing position.

5. A method according to Claim 2 or 4, wherein the amount of the developer carried on the developer carrier including the toner particle layer, the toner particles (101) on the surfaces of the magnetic particles and the magnetic particles is 0.5×10^{-2} - 5×10^{-2} g/cm².

6. A method according to Claim 2, wherein the toner particle layer, the toner particles on the surfaces of the magnetic particles and the magnetic particles moved to the developing position are applied onto the surface of the developer carrier from a developer container (21) containing mixed toner particles (28) and magnetic particles (27), with a regulation by a developer regulating member (24) disposed opposed to the surface of the developer carrier (22), and wherein said volumetric ratio V_d and the volumetric ratio V of the magnetic particles in a region immediately before the developer goes out of the container, satisfy:

$$0.1 \leq V_d/V \leq 1.0.$$

7. A method according to Claim 6, wherein V_d/V satisfies $0.2 \leq V_d/V \leq 0.8$.

8. A method according to Claim 6, wherein the volumetric ratio V is not less than 20%.

9. A method according to Claim 1, wherein the amount of the toner particles (100) in the toner particle layer is not less than 0.05×10^{-3} g/cm² and not more than 1.0×10^{-3} g/cm².

10. A method according to Claim 9, wherein the amount of the toner particles (100) in the toner particle layer is not less than 0.1×10^{-3} g/cm² and not more than 0.6×10^{-3} g/cm².

11. A method according to Claim 9, wherein the thickness of the toner particle layer is 1/50 - 1/5 of the clearance between the surface of the image bearing member and the surface of the developer carrier at the developing position.

12. A method according to Claim 1 or 9, wherein the weight ratio between the toner particles (100) in the toner particle layer and the toner particles (101) on the surfaces of the magnetic particles is 2:1 - 1:10.

13. A method according to Claim 12, wherein the weight ratio is 1:1 - 1:5.

14. A method according to Claim 1, wherein the



peripheral speed of movement of the developer carrier is 0.8 - 1.5 times the peripheral speed of movement of the image bearing member.

15. A method according to any of Claims 4, 8, 9, 12 or 14, wherein the chains of the magnetic particles are contacted to the image bearing member at the developing position, and wherein the volumetric ratio V_d of the total volume of the magnetic particles existing at the developing position to the volume of the space, defined by the surface of the image bearing member and the developer carrier at the developing position, is 1.5 - 30%.

16. A method as claimed in Claim 2 in which the chains of the magnetic particles have a resistivity of 10^6 to 10^{15} ohm - cm.

17. A method as claimed in Claim 16 in which the magnetic particles have an average particle size of 30-100 μm .

18. A method as claimed in any previous claim in which the magnetic particles are ferrite particles coated with resin.

19. A developing apparatus for developing an electrostatic latent image, comprising:

a movable developer carrier (22), on which in operation a layer of a developer comprising magnetic particles (27) is formed the magnetic particles having electrically charged toner particles (28) retained thereon;

an electrostatic latent image bearing member (1) being opposed with a clearance to the surface of the developer carrier (22);

a first magnetic field generating means (23b) disposed across said developer carrier for generating a magnetic field to contact the magnetic particles to the image bearing member at the developing position in order to form a brush of the magnetic and toner particles (27,28);

a developer regulating member (24), disposed upstream of the developing position with respect to the movement of the surface of said developer carrier and spaced apart from the surface of said developer carrier (22), for regulating the developer carried to the developing position;

a second magnetic field generating means (23a) disposed across said developer carrier upstream of said developer regulating member (24) with respect to the movement;

an alternating electric field generating means (34) for forming an alternating electric

field at the developing position to transfer the toner particles (100) from the brush carried on said developer carrier (22) to the latent image bearing member (1);

characterised in that:

the apparatus is such that in operation the layer of developer includes further electrically charged toner particles (100) as a toner particle layer retained on the surface of the developer carrier (22);

the transfer of the toner particles (28) from the brush to the image bearing member is accompanied by substantial transfer of the further toner particles from the developer carrier (22) to the image bearing member (1); and

the brush is formed by chains (51) of the magnetic particles sufficiently sparse to permit the transfer of the further toner particles (100).

20. Apparatus as claimed in Claim 19 in which the volumetric ratio V_d of the total volume of the magnetic particles existing at a developing position to the volume of the space, defined by the surface of the image bearing member and the developer carrier at the developing position, is 1.5 - 30%.

21. An apparatus according to Claim 20, further comprising a developer circulation limiting member (26) disposed upstream of said regulating member (24) with respect to the movement and cooperable with said developer carrier (22) to form a clearance therewith said limiting member (26) having a sectional area (261) gradually decreasing toward said regulating member (24) from an upstream side, wherein said second magnetic field generating means (23a) is opposed to said limiting member (26).

22. An apparatus according to Claim 21, wherein said developer carrier (22) is rotatable and an angle θ formed between a regulating portion of said developer regulating member (24) and said second magnetic field generating means (23a) as seen from the center of rotation of said developer carrier is not less than 2 degrees and not more than 40 degrees.

23. An apparatus according to Claim 21, wherein in a region defined by said limiting member (26) and said developer carrier (22), the amount of the magnetic particles is larger than that in the other region of a developer container (21) containing mixed toner particles (28) and magnetic particles (27), and wherein the volumetric ratio V of the magnetic particles in the defined region satisfies:



$$0.1 \leq V_d/V \leq 1.0.$$

24. An apparatus according to Claim 20 or 21, wherein the amount of the toner particle layer applied on said developer carrier is not less than 0.05×10^{-3} g/cm² and not more than 1.0×10^{-3} g/cm².

25. Apparatus according to Claim 19 or 22, wherein the weight ratio between the toner particles (100) in the toner particle layer and the toner particles (101) on the surfaces of the magnetic particles is 2:1 - 1:10.

Revendications

1. Procédé de développement d'une image latente électrostatique, consistant :

à former sur une surface d'un support mobile (22) de développeur, une couche d'un développeur comprenant des particules magnétiques (27) sur lesquelles sont retenues des particules (28) de toner chargées électriquement ;

à amener la couche dans une position de développement dans laquelle une surface d'un élément (1) destiné à porter une image latente électrostatique est opposée avec un intervalle à la surface du support (22) de développeur ;

à former une brosse des particules magnétiques et de toner (27,28) dans la position de développement en leur appliquant un champ magnétique (23) ; et

à transférer des particules (28) de toner de la brosse (51) à l'élément (1) de support d'image pour développer l'image latente en appliquant un champ électrique alternatif à travers l'intervalle ;

caractérisé en ce que :

la couche de développeur comprend en outre des particules (100) de toner chargées électriquement, en tant que couche de particules de toner retenue sur la surface du support (22) de développeur ;

le transfert des particules (28) de toner de la brosse à l'élément de support d'image est accompagné d'un transfert substantiel des autres particules de toner du support (22) de développeur à l'élément (1) de support d'image ; et

la brosse est formée par des chaînes (51) des particules magnétiques suffisamment éparpillées pour permettre le transfert des autres particules (100) de toner.

2. Procédé selon la revendication 1, dans lequel les chaînes des particules magnétiques sont

mises en contact avec l'élément de support d'image dans la position de développement, dans lequel le rapport volumétrique V_d du volume total des particules magnétiques présentes dans la position de développement au volume de l'espace, défini par la surface de l'élément de support d'image et le support de développeur dans la position de développement, est de 1,5 - 30 %.

3. Procédé selon la revendication 2, dans lequel le rapport volumétrique V_d est de 2,6 - 26 %.

4. Procédé selon la revendication 2, dans lequel le poids total des particules (100) de toner dans la couche de particules de toner sur la surface du support de développeur et des particules (101) de toner sur les surfaces des particules magnétiques dans la position de développement est de 4 - 40 % du poids des particules magnétiques présentes dans la position de développement.

5. Procédé selon la revendication 2 ou 4, dans lequel la quantité de développeur portée sur le support de développeur, comprenant la couche de particules de toner, les particules (101) de toner sur les surfaces des particules magnétiques et les particules magnétiques, est de $0,5 \times 10^{-2}$ - 5×10^{-2} g/cm².

6. Procédé selon la revendication 2, dans lequel la couche de particules de toner, les particules de toner sur les surfaces des particules magnétiques et les particules magnétiques amenées dans la position de développement sont appliquées sur la surface du support de développeur à partir d'un conteneur (21) de développeur contenant en mélange des particules (28) de toner et des particules magnétiques (27), avec une régulation par un élément (24) de régulation de développeur disposé de façon à être opposé à la surface du support (22) de développeur, et dans lequel ledit rapport volumétrique V_d et le rapport volumétrique V des particules magnétiques dans une zone située immédiatement avant que le développeur sorte du conteneur, satisfont :

$$0,1 \leq V_d/V \leq 1,0.$$

7. Procédé selon la revendication 6, dans lequel V_d/V satisfait $0,2 \leq V_d/V \leq 0,8$.

8. Procédé selon la revendication 6, dans lequel le rapport volumétrique V n'est pas inférieur à 20 %.



9. Procédé selon la revendication 1, dans lequel la quantité des particules (100) de toner dans la couche de particules de toner n'est pas inférieure à $0,05 \times 10^{-3} \text{ g/cm}^2$ et n'est pas supérieure à $1,0 \times 10^{-3} \text{ g/cm}^2$.

10. Procédé selon la revendication 9, dans lequel la quantité des particules (100) de toner dans la couche de particules de toner n'est pas inférieure à $0,1 \times 10^{-3} \text{ g/cm}^2$ et n'est pas supérieure à $0,6 \times 10^{-3} \text{ g/cm}^2$.

11. Procédé selon la revendication 9, dans lequel l'épaisseur de la couche de particules de toner est de $1/50 - 1/5$ de l'intervalle entre la surface de l'élément de support d'image et la surface du support de développeur dans la position de développement.

12. Procédé selon la revendication 1 ou 9, dans lequel le rapport en poids entre les particules (100) de toner dans la couche de particules de toner et les particules (101) de toner sur les surfaces des particules magnétiques est de 2:1 - 1:10.

13. Procédé selon la revendication 12, dans lequel le rapport en poids est de 1:1 - 1:5.

14. Procédé selon la revendication 1, dans lequel la vitesse périphérique du mouvement du support de développeur est de 0,8 à 1,5 fois la vitesse périphérique du mouvement de l'élément de support d'image.

15. Procédé selon l'une quelconque des revendications 4, 8, 9, 12 ou 14, dans lequel les chaînes des particules magnétiques sont mises en contact avec l'élément de support d'image dans la position de développement, et dans lequel le rapport volumétrique V_d du volume total des particules magnétiques présentes dans la position de développement au volume de l'espace, défini par la surface de l'élément de support d'image et le support de développeur dans la position de développement, est de 1,5 - 30 %.

16. Procédé selon la revendication 2, dans lequel les chaînes des particules magnétiques ont une résistivité de 10^6 à 10^{15} ohms.cm .

17. Procédé selon la revendication 16, dans lequel les particules magnétiques ont une dimension moyenne de 30 à 100 μm .

18. Procédé selon l'une quelconque des revendications précédentes, dans lequel les particules

magnétiques sont des particules de ferrite revêtues d'une résine.

19. Appareil de développement destiné à développer une image latente électrostatique, comportant :

un support mobile (22) de développeur, sur lequel, en fonctionnement, une couche d'un développeur comprenant des particules magnétiques (27) est formée, les particules magnétiques retenant sur elles des particules (28) de toner chargées électriquement ;

un élément (1) de support d'une image latente électrostatique étant opposé avec un intervalle à la surface du support (22) de développeur ;

un premier moyen (23b) de génération d'un champ magnétique disposé dans ledit support de développeur pour générer un champ magnétique afin de mettre en contact les particules magnétiques avec l'élément de support d'image dans la position de développement pour former une brosse des particules magnétiques et de toner (27,28) ;

un élément (24) de régulation de développeur, disposé en amont de la position de développement par rapport au mouvement de la surface dudit support de développeur et espacé de la surface dudit support (22) de développeur, afin de réguler le développeur amené dans la position de développement ;

un second moyen (23a) de génération de champ magnétique disposé dans ledit support de développeur en amont dudit élément (24) de régulation de développeur par rapport au mouvement ;

un moyen (34) de génération d'un champ électrique alternatif destiné à former un champ électrique alternatif dans la position de développement pour transférer au moins les particules (100) de toner portées sur ledit support (22) de développeur vers l'élément (1) de support d'image latente ;

caractérisé en ce que :

l'appareil est tel qu'en fonctionnement, la couche de développeur comprend d'autres particules (100) de toner chargées électriquement, en tant que couche de particules de toner, retenues sur la surface du support (22) de développeur ;

le transfert des particules (28) de toner depuis la brosse vers l'élément de support d'image est accompagné d'un transfert substantiel des autres particules de toner depuis le support (22) de développeur vers l'élément (1) de support d'image ; et

la brosse est formée par des chaînes (51) des particules magnétiques suffisamment



éparses pour permettre le transfert des autres particules (100) de toner.

20. Appareil selon la revendication 19, dans lequel le rapport volumétrique V_d du volume total des particules magnétiques présentes dans une position de développement au volume de l'espace, défini par la surface de l'élément de support d'image et le support de développeur dans la position de développement, est de 1,5-30 %.
21. Appareil selon la revendication 20, comportant en outre un élément (26) de limitation de la circulation du développeur disposé en amont dudit élément de régulation (24) par rapport au mouvement et pouvant coopérer avec ledit support (22) de développeur pour former avec lui un intervalle, ledit élément (26) de limitation ayant une aire (261) en section diminuant progressivement vers ledit élément (24) de régulation depuis un côté amont, ledit second moyen (23a) de génération d'un champ magnétique étant opposé audit élément (26) de limitation.
22. Appareil selon la revendication 21, dans lequel ledit support (22) de développeur peut tourner et un angle θ , formé entre une partie de régulation dudit élément (24) de régulation de développeur et ledit second moyen (23a) de génération de champ magnétique, tel que vu depuis le centre de rotation dudit support de développeur, n'est pas inférieur à 2 degrés et n'est pas supérieur à 40 degrés.
23. Appareil selon la revendication 21, dans lequel, dans une zone définie par ledit élément (26) de limitation et ledit support (22) de développeur, la quantité des particules magnétiques est plus grande que celle présente dans l'autre zone d'un conteneur (21) de développeur contenant en mélange des particules (28) de toner et des particules magnétiques (27), et dans lequel le rapport volumétrique V des particules magnétiques dans la zone définie satisfait :
- $$0,1 \leq V_d/V \leq 1,0.$$
24. Appareil selon la revendication 20 ou 21, dans lequel la quantité de la couche de particules de toner appliquée sur ledit support de développeur n'est pas inférieure à $0,05 \times 10^{-3} \text{ g/cm}^2$ et n'est pas supérieure à $1,0 \times 10^{-3} \text{ g/cm}^2$.
25. Appareil selon la revendication 19 ou 22, dans

lequel le rapport en poids entre les particules (100) de toner dans la couche de particules de toner et les particules (101) de toner sur les surfaces des particules magnétiques est de 2:1 à 1:10.

Patentansprüche

1. Verfahren zum Entwickeln eines elektrostatischen Ladungsbildes, bei dem

auf einer Oberfläche eines beweglichen Entwicklerträgers (22) eine Schicht aus einem Entwickler, der aus magnetischen Teilchen (27) mit darauf festgehaltenen elektrisch geladenen Tonerteilchen (28) besteht, gebildet wird,

die Schicht zu einer Entwicklungsstelle bewegt wird, wo eine Oberfläche eines zum Tragen eines elektrostatischen Ladungsbildes dienenden Elements (1) der Oberfläche des Entwicklerträgers (22) mit einem Zwischenraum gegenüberliegt,

aus den magnetischen Teilchen (27) und den Tonerteilchen (28) an der Entwicklungsstelle eine Bürste (27, 28) gebildet wird, indem dort ein Magnetfeld (23) erzeugt wird, und

Tonerteilchen (28) durch Erzeugen eines elektrischen Wechselfeldes quer zu dem Zwischenraum von der Bürste (51) auf das Bildträgererelement (1) übertragen werden, um das Ladungsbild zu entwickeln,

dadurch gekennzeichnet, daß

die Entwicklerschicht weitere elektrisch geladene Tonerteilchen (100) in Form einer Tonerteilchenschicht enthält, die auf der Oberfläche des Entwicklerträgers (22) festgehalten wird,

die Übertragung der Tonerteilchen (28) von der Bürste auf das Bildträgererelement von einer beträchtlichen Übertragung der weiteren Tonerteilchen von dem Entwicklerträger (22) auf das Bildträgererelement (1) begleitet ist und

die Bürste durch Ketten (51) aus den magnetischen Teilchen gebildet wird, die ausreichend spärlich sind, um die Übertragung der weiteren Tonerteilchen (100) zu erlauben.

2. Verfahren nach Anspruch 1, bei dem die Ketten aus den magnetischen Teilchen an der Entwicklungsstelle mit dem Bildträgererelement in Berührung gebracht werden und bei dem



das Volumenverhältnis V_d des Gesamtvolumens der an der Entwicklungsstelle vorhandenen magnetischen Teilchen zu dem Volumen des Raums, der an der Entwicklungsstelle durch die Oberfläche des Bildträgerelements und des Entwicklerträgers abgegrenzt wird, 1,5 bis 30 % beträgt.

3. Verfahren nach Anspruch 2, bei dem das Volumenverhältnis V_d 2,6 bis 26 % beträgt.

4. Verfahren nach Anspruch 2, bei dem die Gesamtmasse der Tonerteilchen (100) in der Tonerteilchenschicht auf der Oberfläche des Entwicklerträgers und der Tonerteilchen (101) auf den Oberflächen der magnetischen Teilchen an der Entwicklungsstelle 4 bis 40 % der Masse der an der Entwicklungsstelle vorhandenen magnetischen Teilchen beträgt.

5. Verfahren nach Anspruch 2 oder 4, bei dem die Menge des Entwicklers, der auf dem Entwicklerträger getragen wird, einschließlich der Tonerteilchenschicht, der Tonerteilchen (101) auf der Oberfläche der magnetischen Teilchen und der magnetischen Teilchen $0,5 \times 10^{-2}$ bis 5×10^{-2} g/cm² beträgt.

6. Verfahren nach Anspruch 2, bei dem die Tonerteilchenschicht, die Tonerteilchen auf der Oberfläche der magnetischen Teilchen und die magnetischen Teilchen, die zu der Entwicklungsstelle bewegt werden, aus einem Entwicklerbehälter (21), der gemischte Tonerteilchen (28) und magnetische Teilchen (27) enthält, unter Einstellung durch ein Entwicklereinstell-element (24), das der Oberfläche des Entwicklerträgers (22) gegenüberliegend angeordnet ist, auf die Oberfläche des Entwicklerträgers aufgebracht werden und bei dem das erwähnte Volumenverhältnis V_d und das Volumenverhältnis V der magnetischen Teilchen in einem Bereich unmittelbar vor der Stelle, an der der Entwickler aus dem Behälter austritt, der folgenden Beziehung genügen;

$$0,1 \leq V_d/V \leq 1,0$$

7. Verfahren nach Anspruch 6, bei dem V_d/V der Beziehung $0,2 \leq V_d/V \leq 0,8$ genügt.

8. Verfahren nach Anspruch 6, bei dem das Volumenverhältnis V nicht weniger als 20 % beträgt.

9. Verfahren nach Anspruch 1, bei dem die Menge der Tonerteilchen (100) in der Tonerteilchenschicht nicht weniger als $0,05 \times 10^{-3}$

g/cm² und nicht mehr als $1,0 \times 10^{-3}$ g/cm² beträgt.

10. Verfahren nach Anspruch 9, bei dem die Menge der Tonerteilchen (100) in der Tonerteilchenschicht nicht weniger als $0,1 \times 10^{-3}$ g/cm² und nicht mehr als $0,6 \times 10^{-3}$ g/cm² beträgt.

11. Verfahren nach Anspruch 9, bei dem die Dicke der Tonerteilchenschicht 1/50 bis 1/5 des Zwischenraumes zwischen der Oberfläche des Bildträgerelements und der Oberfläche des Entwicklerträgers an der Entwicklungsstelle beträgt.

12. Verfahren nach Anspruch 1 oder 9, bei dem das Masseverhältnis zwischen den Tonerteilchen (100) in der Tonerteilchenschicht und den Tonerteilchen (101) auf den Oberflächen der magnetischen Teilchen 2:1 bis 1:10 beträgt.

13. Verfahren nach Anspruch 12, bei dem das Masseverhältnis 1:1 bis 1:5 beträgt.

14. Verfahren nach Anspruch 1, bei dem die Umfangsgeschwindigkeit der Bewegung des Entwicklerträgers 0,8- bis 1,5mal so hoch wie die Umfangsgeschwindigkeit der Bewegung des Bildträgerelements ist.

15. Verfahren nach einem der Ansprüche 4, 8, 9, 12 oder 14, bei dem die Ketten aus den magnetischen Teilchen an der Entwicklungsstelle mit dem Bildträgerelement in Berührung gebracht werden und bei dem das Volumenverhältnis V_d des Gesamtvolumens der an der Entwicklungsstelle vorhandenen magnetischen Teilchen zu dem Volumen des Raums, der an der Entwicklungsstelle durch die Oberfläche des Bildträgerelements und des Entwicklerträgers abgegrenzt wird, 1,5 bis 30 % beträgt.

16. Verfahren nach Anspruch 2, bei dem die Ketten aus den magnetischen Teilchen einen spezifischen Widerstand von 10^6 bis 10^{15} Ohm.cm haben.

17. Verfahren nach Anspruch 16, bei dem die magnetischen Teilchen eine mittlere Teilchengröße von 30 bis 100 μ m haben.

18. Verfahren nach einem der vorhergehende Ansprüche, bei dem die magnetischen Teilchen mit Harz beschichtete Ferriteilchen sind.

19. Entwicklungsvorrichtung zum Entwickeln eines elektrostatischen Ladungsbildes mit



einem beweglichen Entwicklerträger (22), auf dem beim Betrieb eine Schicht aus einem Entwickler gebildet wird, der magnetische Teilchen (27) enthält, wobei die magnetischen Teilchen elektrisch geladene Tonerteilchen (28) aufweisen, die darauf festgehalten werden,

einem zum Tragen eines elektrostatischen Ladungsbildes dienenden Bildträgerelement (1), das der Oberfläche des Entwicklerträgers (22) mit einem Zwischenraum gegenüberliegt,

einer ersten Magnetfelderzeugungseinrichtung (23b), die quer zu dem erwähnten Entwicklerträger angeordnet ist, zum Erzeugen eines Magnetfeldes, damit die magnetischen Teilchen an der Entwicklungsstelle mit dem Bildträgerelement in Berührung gebracht werden, um aus den magnetischen Teilchen (27) und den Tonerteilchen (28) eine Bürste zu bilden,

einem Entwicklereinstellelement (24), das in bezug auf die Bewegung der Oberfläche des Entwicklerträgers stromaufwärts bezüglich der Entwicklungsstelle und mit Abstand von der Oberfläche des Entwicklerträgers (22) angeordnet ist, zum Einstellen des Entwicklers, der zu der Entwicklungsstelle getragen wird,

einer zweiten Magnetfelderzeugungseinrichtung (23a), die quer zu dem erwähnten Entwicklerträger und in bezug auf die Bewegung stromaufwärts bezüglich des erwähnten Entwicklereinstellelementes (24) angeordnet ist,

einer Wechselfelderzeugungseinrichtung (34) zum Erzeugen eines elektrischen Wechselfeldes an der Entwicklungsstelle, damit wenigstens die Tonerteilchen (100), die auf dem Entwicklerträger (22) getragen werden, auf das Ladungsbildträgerelement (1) übertragen werden,

dadurch gekennzeichnet, daß

die Vorrichtung derart ist, daß beim Betrieb die Entwicklerschicht weitere elektrisch geladene Tonerteilchen (100) in Form einer Tonerteilchenschicht enthält, die auf der Oberfläche des Entwicklerträgers (22) festgehalten wird,

die Übertragung der Tonerteilchen (28) von der Bürste auf das Bildträgerelement von einer beträchtlichen Übertragung der weiteren Tonerteilchen von dem Entwicklerträger (22) auf das Bildträgerelement (1) begleitet ist und

die Bürste durch Ketten (51) aus den magneti-

schen Teilchen gebildet wird, die ausreichend spärlich sind, um die Übertragung der weiteren Tonerteilchen (100) zu erlauben.

20. Vorrichtung nach Anspruch 19, bei der das Volumenverhältnis V_d des Gesamtvolumens der an einer Entwicklungsstelle vorhandenen magnetischen Teilchen zu dem Volumen des Raums, der an der Entwicklungsstelle durch die Oberfläche des Bildträgerelementes und des Entwicklerträgers abgegrenzt wird, 1,5 bis 30 % beträgt.

21. Vorrichtung nach Anspruch 20, die ferner ein Entwicklerumlauf-Beschränkungselement (26) aufweist, das in bezug auf die Bewegung stromaufwärts bezüglich des erwähnten Einstellelementes (24) angeordnet und fähig ist, derart mit dem erwähnten Entwicklerträger (22) zusammenzuwirken, daß damit ein Zwischenraum gebildet wird, wobei das Beschränkungselement (26) eine Querschnittsfläche (261) hat, die von einer stromaufwärts gelegenen Seite in Richtung auf das erwähnte Einstellelement (24) allmählich abnimmt, wobei die erwähnte zweite Magnetfelderzeugungseinrichtung (23a) dem erwähnten Beschränkungselement (26) gegenüberliegt.

22. Vorrichtung nach Anspruch 21, bei der der erwähnte Entwicklerträger (22) drehbar ist und ein von dem Drehpunkt des erwähnten Entwicklerträgers aus gesehenen Winkel θ , der zwischen einem Einstellteil des erwähnten Entwicklereinstellelementes (24) und der erwähnten zweiten Magnetfelderzeugungseinrichtung (23a) gebildet ist, nicht weniger als 2 Grad und nicht mehr als 40 Grad beträgt.

23. Vorrichtung nach Anspruch 21, bei der die Menge der magnetischen Teilchen in einem Bereich, der durch das erwähnte Beschränkungselement (26) und den erwähnten Entwicklerträger (22) abgegrenzt wird, größer ist als die in dem anderen Bereich eines Entwicklerbehälters (21), der gemischte Tonerteilchen (28) und magnetische Teilchen (27) enthält, und bei dem das Volumenverhältnis V der magnetischen Teilchen in dem definierten Bereich der Beziehung $0,1 \leq V_d/V \leq 1,0$ genügt.

24. Vorrichtung nach Anspruch 20 oder 21, bei der die Menge der auf dem erwähnten Entwicklerträger aufgetragenen Tonerteilchenschicht nicht weniger als $0,05 \times 10^{-3} \text{ g/cm}^2$ und nicht mehr als $1,0 \times 10^{-3} \text{ g/cm}^2$ beträgt.

25. Vorrichtung nach Anspruch 19 oder 22, bei der



das Masseverhältnis zwischen den Tonerteilchen (100) in der Tonerteilchenschicht und den Tonerteilchen (101) auf den Oberflächen der magnetischen Teilchen 2:1 bis 1:10 beträgt.

5

10

15

20

25

30

35

40

45

50

55

23