EUROPEAN PATENT SPECIFICATION

DEVELOPING DEVICE USING A ONE-PACK DEVELOPING AGENT

EINKOMPONENTEN-ENTWICKLER VERWENDENDE ENTWICKLUNGSVORRICHTUNG
DISPOSITIF DE DEVELOPPEMENT UTILISANT UN AGENT DEVELOPPATEUR A UN ELEMENT

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Description

The present invention relates to a developing apparatus which develops an electrostatic latent image held on an image carrier, such as a photosensitive material or a dielectric, by a mono-component developer.

In electronic photocopying machines, electronic photocopiers, and other electrostatic recording apparatuses, an electrostatic latent image is first formed on an image carrier such as a photosensitive material or a dielectric. The electrostatic latent image is developed electrostatically as a charged toner image by means of a developer and then the charged toner image is electrostatically transferred to a recording medium such as recording paper. It is then fixed on the recording medium by heat, pressure, light, etc.

In general, a widely known developer used in the development process is a two-component developer comprised of a toner component (fine particles of a colouring resin) and a magnetic component (fine magnetic carrier). A developing apparatus using a two-component developer is provided with a developer holding container, an agitator for agitating the two-component developer in the developer holding container and causing frictional charging between the toner particles and the magnetic carrier, and a magnetic roller for attracting part of the magnetic carrier by magnetic force and forming a magnetic brush, i.e. a development roller. Part of the development roller is arranged to be exposed from the developer holding container and face the image carrier. Toner particles electro-statically deposit on the magnetic brush formed on the circumference of the development roller. Rotation of the development roller causes the toner particles to be transported to the region facing the image carrier along with the magnetic brush, that is, the development region, where the electrostatic latent image is developed. In short, the magnetic carrier in the two-component developer has two functions: (1) frictionally charging the toner and (2) transporting the toner to the development region.

A developing apparatus for a two-component developer has the advantage that the transportability of the toner particles (which governs the quality of the developed toner image, i.e. the quality of the recorded toner image) is relatively excellent. However, to maintain this excellent toner transportability, the ratio of the components of the toner particles and the magnetic carrier has to be maintained within a predetermined range and the magnetic carrier has to be periodically replaced. The toner component is consumed by the development and therefore must be suitably resupplied. Also, the magnetic carrier must be replaced when degraded.

Therefore, attention has been focused on a developing apparatus using a mono-component developer comprised of only fine particles of a colouring resin, so that the developing apparatus does not require the troublesome maintenance as in the case of a two-component developer. However, in the case of a mono-component developer, especially a nonmagnetic type mono-component developer, how the toner particles are charged and how they are transported to the development region become important issues. That is to say that the quality of the developed toner image (i.e. the quality of the recorded toner image) is largely governed by the charging characteristic of the toner component and the transportability of the toner component.

In a conventional developing apparatus using a mono-component developer, an elastic development roller (formed from an electroconductive synthetic rubber material, an electroconductive porous synthetic rubber material, etc) is used for transporting the toners to the development region. The elastic development roller is located inside the toner holding container so that a part of it is exposed from the toner holding container to be in contact with the image carrier. When the elastic development roller is made to rotate, toner particles deposit on the rotating circumferential surface by a frictional force so that a toner layer is formed. The toner particles are transported to the development region in this manner. To develop the electrostatic latent image with a uniform development density, however, the thickness of the toner layer must be kept uniform.

Therefore, use has been made of a blade, roller, or other thickness-regulating member for the elastic development roller. This removes excess toner from the toner layer and helps make the toner layer uniform. On the other hand, regarding the charging of the toner, use is made of frictional static electricity on the elastic development roller or thickness-regulating member, but this frictional static electricity is easily affected by changes in the environment, such as temperature and humidity. Therefore, one practice is to form the thickness-regulating member from a conductive material and apply a voltage of a predetermined polarity so as to implant positively a charge to the individual toner particles at the time of regulating the thickness of the toner layer. Of course, when frictional static electricity is used, the material of the toner component, the material of the elastic development roller, and the material of the thickness-regulating member are selected so as to give a predetermined charge of the desired polarity to the toner particles. Furthermore, when charge implantation is used, the material of the thickness-regulating member is limited to an electroconductive material.

It has been pointed out a problem with the developing apparatus for a mono-component developer such as the one explained above is that it is difficult to maintain the uniformity of the thickness of the toner layer by the thickness-regulating member stably over a long period. For example, it has been proposed to use, as the thickness-regulating member able to perform charge implantation, a rigid metal blade having a sharp edge. The edge portion is engaged elastically with the elastic development roller to remove the excess toner particles and thereby make the toner layer uniform in thickness. To ensure the uniformity of the thickness of the toner
layer, it is necessary to make the processing precision of the sharp edge portion 2 \mu m or less. This is because the size of individual toner particles is generally from about 5 to about 10 \mu m, so if the processing precision of the edge portion is more than 2 \mu m, uneven streaks will be left on the surface of the toner layer. These streaks will appear as white streaks or black streaks in the recorded toner image. Even if it were possible to make the processing precision of the sharp edge portion of the rigid metal blade 2 \mu m or less, such an edge portion would be susceptible to damage and also the processing cost would become extremely high, so it would be extremely difficult to commercialize this.

It has also been proposed to bring the flat surface of a rigid metal blade or the rotational surface of a metal roller into press-contact with the elastic development roller to regulate the pressure on the toner layer. It is possible to process the flat surface or the rotational surface at a relatively low cost and a high precision, but the pressure of the metal blade or metal roller applied to the elastic development roller to regulate the thickness of the toner layer to a predetermined thickness must be made considerably large. Therefore, the toner particles are crushed and can physically become fixed to the flat surface or the rotational surface. In this case, uneven streaks will remain on the surface of the toner layer and those streaks will appear in the recorded toner image. Note that, when a hard polymer material etc. is used as the material of the thickness-regulating member, it is not possible to control the charging of the toner particles by charge implantation.

It has also been proposed to use a leaf spring member as a metal thickness-regulating member which is able stably to regulate the thickness of the toner layer over a long period and which can be processed at a relatively low cost and a high precision. This leaf spring member is chamfered at its front edge to give it roundness. The rounded front edge is elastically pressed against the elastic development roller by the spring force of the leaf spring member itself. In this way, the thickness of the toner layer is regulated. When such a leaf spring member is used as the toner layer thickness-regulating member, the majority of the excess toner is removed from the toner layer formed on the circumference of the elastic development roller by the rounded front edge of the leaf spring member. The flat surface of the leaf spring member is then used to regulate the thickness of the toner layer. Thus the pressing force of the flat surface on the elastic development roller can be made relatively small and thus it is possible to prevent the toner particles from becoming fixed on the flat surface. Furthermore, the high precision processing of the flat surface of the leaf spring member and the high precision processing of the rounded front edge of the same can be performed at a relatively low cost. In addition, the rounded front edge is far less susceptible to damage compared with the sharp edge portion of the rigid metal blade mentioned above.

However, a problem with the leaf spring member explained above is the ease of vibration of the leaf spring member L and the consequent cyclic fluctuation of the thickness of the toner layer at the time of regulation of the thickness of the toner layer. Of course, if the leaf spring member vibrates and the thickness of the toner layer fluctuates, the development density of the electrostatic latent image will be affected. Also, at areas where the toner layer has become thicker, the charge of the toner particles will become insufficient and thus there will be contamination of the background region of the electrostatic latent image by the toner particles, i.e., so-called "fogging".

On the other hand, even with a leaf spring member, when regulating the thickness of the toner layer and charging the toner particles by charge implantation, the thickness of the toner layer must be made equal to the diameter of the toner particles. In other words, the toner layer should be formed as a single layer of toner particles. This is because, when the thickness of the toner layer is greater than the diameter of the toner particles, the toner layer will include toner particles not able directly to contact the leaf spring member. Such toner particles will not be sufficiently implanted with charge and the amount of charge will become insufficient. Of course, toner particles with insufficient charging are a cause of fogging.

Also in the prior art, JP-A-63-202771 and JP-U-59-147160 disclose developing apparatuses for mono-component developers which include control blades for regulating the thickness of the toner layer on the development roller.

An object of the present invention is to provide a developing apparatus using a mono-component developer comprised of just a toner component, which developing apparatus is constructed using a metal leaf spring member as the thickness-regulating member so as to enable charge implantation of the toner particles, the leaf spring member being prevented from vibrating at the time of regulation of the toner layer thickness.

Another object of the present invention is to provide such a developing apparatus which is constructed so that substantially all of the toner particles included in the toner layer can be sufficiently charged by charge implantation.

According to the present invention, there is provided a developing apparatus for developing an electrostatic latent image held on an image carrier by a mono-component developer, said apparatus comprising:

- a developer-holding container for holding the mono-component developer;
- an electroconductive, elastic development roller rotatably provided inside the developer-holding container so that a portion thereof is exposed from the developer-holding container to contact the image carrier, rotation of the development roller causing the mono-component developer to be deposited on
the surface thereof and form a mono-component developer layer thereon, the mono-component developer being transported to the image carrier for development of the latent image formed on the image carrier, and an electroconductive leaf spring member for regulating the thickness of the mono-component developer layer on the development roller, one end of said leaf spring member being supported integrally by a rotatable rigid support member and the other end pressed elastically against the development roller, the centre of rotation of the rigid support member and the plane of the leaf spring member being aligned substantially on a tangent of the elastic development roller,

characterised in that the front edge of said other end of the leaf spring member is positioned within a predetermined distance (d) of a line of contact on the development roller where a radial plane (SL) of the development roller perpendicularly intersects the tangent on which the centre of rotation of the rigid support member and the plane of the leaf spring member are substantially aligned.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a schematic view of a laser printer using a developing apparatus according to the present invention;
Figure 2 is an enlarged view showing the development roller, the leaf spring member, and the rigid support member of the developing apparatus shown in Fig. 1;
Figure 3(a) and Fig. 3(b) are schematic views showing comparative examples of the present invention;
Figure 4(b) is a schematic view showing the development roller, leaf spring member, and rigid support member of the developing apparatus arranged according to the present invention, while Fig. 4(a) and Fig. 4(c) are schematic views showing comparative examples of the construction of Fig. 4(b);
Figure 5 is an explanatory view of a method for measuring the thickness of the toner layer on the development roller by laser microscanning;
Figure 6 is a graph showing the results of measurement of the thickness of the toner layer on the development roller according to the measurement method of Fig. 5 for the arrangements of Fig. 4(a), Fig. 4(b), and Fig. 4(c);
Figure 7 is an explanatory view of a method for measuring the surface potential of the development roller by a surface potentiometer in the state where a toner layer is formed on the surface of the development roller;
Figure 8 is a graph for explaining the output trend of the surface potentiometer in the case of measurement of the surface potential of the development roller by the surface potentiometer in accordance with the method illustrated in Fig. 7;
Figure 9(a), Fig. 9(b), and Fig. 9(c) are graphs showing the results of measurement when actually measuring the surface potential of the development roller in accordance with the measurement method of Fig. 8 for each of the arrangements of Fig. 4(a), Fig. 4(b), and Fig. 4(c);
Figure 10(b) is a schematic view showing the development roller, leaf spring member, and rigid support member of the developing apparatus arranged according to the present invention, while Fig. 10(a) and Fig. 10(c) are schematic views showing comparative examples of the construction of Fig. 10(b);
Figure 11 is a graph showing the results of measurement of the thickness of the toner layer on the development roller according to the measurement method of Fig. 5 for the arrangements of Fig. 10(a), Fig. 10(b), and Fig. 10(c);
Figure 12(a), Fig. 12(b), and Fig. 12(c) are graphs showing the results of measurement when actually measuring the surface potential of the development roller in accordance with the measurement method of Fig. 8 for each of the arrangements of Fig. 10(a), Fig. 10(b), and Fig. 10(c);
Figure 13 is a graph showing the relationship between the radius of the rounded front edge of the leaf spring member and recording quality;
Figure 14(a), Fig. 14(b), and Fig. 14(c) are graphs showing the relationship between the press-contact force of the leaf spring member with the development roller and the thickness of the toner layer leaf spring members with rounded front ends of differing radius;
Figure 15 is an enlarged view showing the development roller, leaf spring member, and rigid support member taken out of the developing apparatus shown in Fig. 1, which view explains other characteristics in accordance with embodiments of the present invention;
Figure 16 is a schematic view showing a support apparatus for the leaf spring member constituted so as to enable replacement of the rigid support member of the leaf spring member in the developing apparatus;
Figure 17 is a partial enlarged view showing an enlargement of the contact portion between the leaf spring member of the support apparatus shown in Fig. 16 and the development roller;
Figure 18 is a schematic view of the attachment of the rigid support member supporting the leaf spring member to the support apparatus shown in Fig. 16 so that the flexible length of the leaf spring member is 2 mm;
Figure 19 is a schematic view of the attachment of the rigid support member supporting the leaf spring
member to the support apparatus shown in Fig. 16 so that the flexible length of the leaf spring member is 3 mm;

Figure 20 is a schematic view of the attachment of the rigid support member supporting the leaf spring member to the support member shown in Fig. 16 so that the flexible length of the leaf spring member is 4 mm;

Figure 21 is a schematic view of the attachment of the rigid support member supporting the leaf spring member to the support member shown in Fig. 16 so that the flexible length of the leaf spring member is 5 mm;

Figure 22 is a graph showing the results of measurement of the thickness of the toner layer on the development roller according to the measurement method of Fig. 5 for the flexible lengths of the leaf spring members shown in Fig. 18 to Fig. 21;

Figure 23 is a graph showing the evaluation of the recording quality when making a running recording of 20,000 sheets of recording paper for each of the flexible lengths of the leaf spring members of Fig. 18 to Fig. 21;

Figure 24 is an enlarged view showing the development roller, leaf spring member, and rigid support member taken out of the developing apparatus shown in Fig. 1, which view explains other characteristics in accordance with embodiments of the present invention;

Figure 25 is a schematic view showing a support apparatus constituted so as to enable adjustment of the position of the leaf spring member with respect to the development roller of the developing apparatus;

Figure 26 is a partial enlarged view showing an enlargement of the contact portion of the development roller and the leaf spring member shown in Fig. 25, which view shows the relationship of arrangement of the development roller and leaf spring member of the developing apparatus;

Figure 27 is a partial enlarged view the same as Fig. 26, which view shows another arrangement of the development roller and leaf spring member of the developing apparatus;

Figure 28 is a partial enlarged view the same as Fig. 26, which view shows still another arrangement of the development roller and leaf spring member of the developing apparatus;

Figure 29 is a graph showing the results of measuring the thickness of the toner layer on the development roller according to the measurement method of Fig. 5 for each of the arrangement positions of the various types of leaf spring members illustrated in Fig. 26 to Fig. 28;

Figure 31(a) and Fig. 31(b) are graphs showing the results of measuring the surface potential of the development roller for each of the arrangement positions of the various types of leaf spring members illustrated in Fig. 27 and Fig. 28;

Referring to Fig. 1, a laser printer is schematically shown as an example of an electrostatic recording apparatus using a developing apparatus in accordance with the present invention. The laser printer uses a photosensitive drum 10 as the image carrier. The photosensitive drum 10 has a photoconductive layer, e.g. a photosensitive film layer, on the surface of a cylindrical substrate made of aluminum. The photosensitive material may be made of, for example, an organic photosensitive material, a selenic photosensitive material, an amorphous silicon photosensitive material, etc. In the illustrated embodiment, the photosensitive drum 10 is rotated in the direction shown by the arrow a. The rotational speed is set so that the peripheral speed of the photosensitive drum 10 is 70 mm/s.

A negative charge is given to the photosensitive film layer of the photosensitive drum 10 by a suitable charger 12, for example, a scorotron charger. The surface potential of the charged region is made, for example, -650V. Note that in the illustrated embodiment, use is made of an organic photosensitive material as the photosensitive material, so a negative charge is given to the photosensitive drum 10. However, when use is made of a selenic photosensitive material, a positive charge is given to the photosensitive drum 10 and, when use is made of an amorphous silicon photosensitive material, either a negative or a positive charge is given. An electrostatic latent image is drawn in the charged region of the photosensitive drum 10 by a laser beam scanning unit 14. This drawing of the electrostatic latent image is performed by repeatedly scanning a laser beam LB emitted from the laser beam scanning unit 14 along the generatrix direction of the photosensitive drum 10 and turning on and off the laser beam LB based on the binary image data from a word processor or microcomputer, for example. The charges of the locations where the laser beam LB is irradiated are drained (the aluminum cylindrical substrate of the photosensitive drum 10 is earthed), whereby an electrostatic latent image is formed by the potential difference in the charged region. The locations where the charges are drained by the irradiation of the laser beam LB are called charge wells, the potentials of which are raised from about -650V to about -100V (falling as absolute value).

The electrostatic latent image drawn by the laser beam scanning unit 14 is developed as a charged toner image by developing apparatus 16. The developing apparatus 16 is provided with a developer holding container 16a which holds the mono-component developer.
comprised of just the toner component, and a development roller 16b which is arranged in the developer holding container 16a and is arranged to rotate in the direction of rotation indicated by the arrow in the figure. As the nonmagnetic type mono-component developer, use is made of, for example, a polyester negative polarity toner having a bulk resistance of $4 \times 10^{14}\Omega\text{cm}$ and an average particle size of 12 μm. Part of the development roller 16b is exposed from the developer holding container 16a and is pressed against the photosensitive drum 10. The shaft of the development roller 16b is connected and driven through a suitable transmission gear train (not shown) to the drive source (not shown) of the photosensitive drum 10. Further, the development roller 16b is rotated so that its peripheral speed is 175 mm/s, about 2.5 times the peripheral speed (70 mm/s) of the photosensitive drum 10. The development roller 16b comprises an electroconductive elastic roller, and preferably is formed by an electroconductive porous rubber material. As such an electroconductive porous rubber material, use may be made, for example, of a porous polyurethane rubber material, a porous urethane rubber material, or a porous silicone rubber material into which has been mixed carbon black etc. as a conductivity imparting agent. In the present embodiment, use is made of an electroconductive porous urethane rubber material (made by Toyo Polymer, brandname Rubicel). The average pore size of this electroconductive porous urethane rubber material is 10 μm, the number of pore cells is 200 cells/inch, the bulk resistance is $10^4$ to $10^7\Omega\text{cm}$, and the Asker C hardness is 23. The development roller 16b formed from this material has a superior toner particle transportability. When the development roller 16b is rotated, the toner particles deposit on the rotating surface by frictional force and a toner layer is successively formed.

The developing apparatus 16 is provided with a thickness-regulating member 16c for regulating the thickness of the toner layer formed on the development roller 16b to a predetermined thickness. This thickness-regulating member is formed from a suitable metal material as a leaf spring member. In this embodiment, the thickness-regulating member, i.e. the leaf spring 16c, is formed from stainless steel (SUS304-CSP-3/4H) with a thickness of 0.1 mm. The leaf spring member 16c is fixed to a rotatable rigid support member 16d such that one end thereof protrudes from the front end of the rigid support member 16d. The rigid support member 16d is supported on a shaft 16e rotatably supported between the two walls of the developer holding container 16a. A suitable spring means, for example a coil spring 16f, acts on the rigid support member 16d, as shown in Fig. 1. Accordingly, the rigid support member 16d is elastically biased in the direction shown by the arrow in Figure 1. The protruding end of the leaf spring member 16c is pressed against the development roller 16b by a linear pressure of, for example, 35 g/cm. The front edge of the protruding end of the leaf spring member 16c is chamfered to give it roundness. The radius of the rounded front edge is, for example, 0.05 mm. Therefore, when the development roller 16b is rotating, the majority of the excess toner particles is removed from the successively formed toner layer by the rounded front edge of the leaf spring member 16c. Then, the flat surface of the leaf spring member 16c regulates the thickness of the toner layer. Even if the pressing force of the flat surface on the development roller 16b is comparatively small, it is possible to regulate the thickness of the toner layer to a desired thickness and it is possible to prevent the toner particles from being fixed to the flat surface.

When the developing apparatus 16 is operating, a voltage of, for example, -400V is applied to the leaf spring member 16c, whereby a negative charge implantation is positively performed on the toner particles of the toner layer so that the toner particles are charged with a negative charge. On the other hand, a development bias voltage of -300V is applied to the development roller 16b. Therefore, the charged toner particles can electrostatically deposit on the electrostatic latent image region, but deposition of the charged toner particles on the background region is prevented and therefore the electrostatic latent image is developed. In the present embodiment, the leaf spring member 16c is made of stainless steel, but other metal materials, for example, phosphor bronze, cupronickel, cold rolled steel sheet, constant-modulus alloy, beryllium-copper alloy, etc. may be used.

The developing apparatus 16 is further provided with a toner reclamation and supply roller 16g, a rotational paddle 16h, and a toner agitating blade 16i. The toner reclamation and supply roller 16g preferably is formed from an electroconductive sponge material, for example, an electroconductive sponge material having about 40 pore cells/inch and a bulk resistance of $10^6\Omega\text{cm}$ (made by Bridgestone, Everlight TS-E). The roller 16g is pressed against the development roller 16b and rotated in the same direction as the development roller 16b so that its peripheral speed is 228 mm/s. The toner reclamation and supply roller 16g functions to scrape off from the development roller 16b the residual toner particles not used for the development of the electrostatic latent image at one side (the right side in Fig. 1) of the region of press-contact with the development roller 16b, and positively supplies and deposits toner particles on the development roller 16b at the opposite side (the left side of Fig. 1) of the press-contact region. Furthermore, a voltage of -400V, for example, may be applied to the toner reclamation and supply roller 16g. In this way, entry of toner particles into the sponge material of the toner reclamation and supply roller 16g is electrostatically inhibited and the supply of the toner particles to the development roller 16b is performed electrostatically as well. The rotational paddle 16h is rotated so that the toner particles inside the developer holding container 16a are supplied to the toner supply side of
the toner reclamation and supply roller 16h. The toner agitator blade 16l is rotated so as to remove the dead stock of developer in the developer holding container 16a. Note that in Fig. 1, reference numeral 16f indicates a deformable sealing material, for example, a soft sponge. The outflow of the toner particles is inhibited by the sealing material 16f.

The charged toner image obtained by the development process is next electrostatically transferred on the recording medium, for example, recording paper P, by a suitable transfer device, for example, a corotron transfer device. That is, a charge of a polarity opposite to the charged toner image (in this case, a positive charge), is given to the recording paper P from the corotron transfer device 18, whereby the charged toner image is electrostatically transferred from the photosensitive drum 10 to the recording paper P. The recording paper P is fed out from a paper cassette (not shown), then it is stopped once at the location of a pair of resist rollers 20, 20. Next, when the pair of resist rollers are driven at a predetermined timing, the recording paper P is introduced between the photosensitive drum 10 and the corotron transfer device 18, whereby the charged toner image is transferred from the photosensitive drum 10 onto the recording paper P at a predetermined location of the same. Just after passing through this transfer process, the recording paper P is given a negative charge by a charge eliminator 22, whereby a part of the positive charge of the recording paper P is neutralized and therefore the electrostatic attraction force between the recording paper P and the photosensitive drum 10 is weakened. In this way, the recording paper P is kept from being electrostatically attracted by the photosensitive drum 10 and becoming entangled with it. Next, the recording paper P is sent to a heat fixer 24, where the transferred toner image is heat fixed on the recording paper P. The heat fixer 24 comprises a heat roller 24a and a backup roller 24b. When recording paper P is passed between the two rollers 24a, 24b, the transferred toner image melts and is strongly fixed on the recording paper P.

In Fig. 1, reference numeral 26 shows a toner scraping blade for removing residual toner particles left on the photosensitive drum 10 without being transferred from the photosensitive drum 10 to the recording paper P in the transfer process. The toner removed by the toner scraping blade 26 is housed in a toner receiving container 28. Reference numeral 30 shows an LED array functioning as a charge-eliminating lamp. Using the LED array 30, the residual charge is removed from the photosensitive drum 10, whereby the corotron charger 12 can form a uniform negatively charged region on the photosensitive material film of the photosensitive drum 10 once again.

The centre of rotation of the rigid support member 16d and the plane of the leaf spring member 16c are positioned substantially on a tangent of the development roller 16b, whereby vibration of the leaf spring member 16c at the time of regulating the thickness of the toner layer can be prevented. As shown in Fig. 2, when the pressing force of the coil spring 18f on the rigid support member 16d is released, the centre of rotation of the rigid support member 16d, that is, the centre of the shaft 16e, is positioned on the tangent of the development roller 16b in which the plane of the leaf spring member 16c lies. Thus, when the thickness of the toner layer is regulated, the frictional force F received by the leaf spring member 16e from the development roller 16b is oriented to the centre of rotation of the rigid support member 16d, so that the frictional force F does not act as a rotational moment on the rigid support member 16d and therefore the vibration of the leaf spring member 16c can be effectively prevented.

Referring to Fig. 3(a) and Fig. 3(b), comparative examples of the present invention are shown. In these figures, L indicates the leaf spring member, S the support of the leaf spring member L, and D the elastic development roller. The free end edge of the leaf spring L is chamfered to give it roundness. The leaf spring L is held by the support S so that its rounded free end edge is made to press elastically against the elastic development roller D. In the example of Fig. 3(a), the leaf spring member L is pressed against the elastic development roller D by the spring force by the elastic deformation of the member itself. In the example of Fig. 3(b), the support S receives an elastic deviation force from the direction indicated by the arrow A2, whereby the leaf spring member L is pressed against the elastic development roller D. Even with such an arrangement and construction, during rotation of the elastic development roller D, the majority of the excess toner is removed from the toner layer successively formed there by the rounded free end edge of the leaf spring member L. The thickness of the toner layer is then regulated by the flat surface of the leaf spring member L, so the pressing force of the flat surface on the elastic development roller D may be kept relatively small. Thus it is possible to prevent the toner particles from being fixed on the flat surface.

However, vibration occurs with the leaf spring members L shown in Fig. 3(a) and Fig. 3(b) during regulation of the thickness of the toner layer and therefore the thickness of the toner layer fluctuates cyclically. In the example shown in Fig. 3(a), the leaf spring member L receives a frictional force F1 in the tangential direction during rotation of the elastic development roller D. Due to the frictional force, the free end edge of the leaf spring member L moves up and down in the direction indicated by the arrow A2. Therefore, the leaf spring member L vibrates in the direction indicated by the arrow A2. Even in the example shown in Fig. 3(b), the leaf spring member L receives a frictional force F2 in the tangential direction during rotation of the elastic development roller D. Due to the force component F3 of the frictional force F2, a rotational moment acts on the support S, whereby the support S vibrates about the axial line of rotation (arrow A3). The vibration naturally affects the leaf spring
member L as well. If the leaf spring member L vibrates in this way, the thickness of the toner layer fluctuates and therefore, not only is the development density of the electrostatic latent image affected, but also the charge of the toner particles at the locations where the thickness of the toner layer is greater becomes insufficient and fogging occurs.

As opposed to this, in the apparatus of the present invention, as mentioned above, the centre of rotation of the rigid support member 16d is substantially positioned on the tangent of the leaf spring member 16c and the development roller 16b, so that vibration of the leaf spring member 16c can be prevented when the thickness of the toner layer is regulated. The term "substantially" means that, if the vibration of the leaf spring member 16c is inhibited, the centre of rotation of the rigid support member 16d may deviate slightly from the tangent of the elastic development roller 16b in which the leaf spring member 16c lies. That is, as shown in Fig. 2, when the pressing force of the coil spring 16f on the rigid support member 16d is released, if the axis of rotation of the rigid support member 16d is positioned on the tangent of the development roller 16b in which the leaf spring member 16c lies, the pressing force of the coil spring 16f affects the rigid support member 16d. Thus, even if the centre of rotation of the rigid support member 16d deviates somewhat from the tangent of the development roller 16b in which the leaf spring member 16c lies, it is possible to prevent vibration of the leaf spring member 16c.

As explained above, vibration of the leaf spring member 16c is prevented when regulating the thickness of the toner layer, so the thickness of the toner layer will not fluctuate, but will be held constant. Therefore, a high quality developer toner image, i.e. recorded toner image, can be obtained. The inventors conducted various tests to confirm this in practice. This will be explained in detail below.

First, as shown in Fig. 4, the shaft 16e is supported on a mounting seat 32 replaceable in the horizontal direction, while the rigid support member 16d is attached to or detached from the mounting seat 32.

Elongate holes 32a are formed in the mounting seat 32. Through these elongate holes 32a, the rigid support member 16c can be detachably mounted to the mounting seat 32 using stop screws 32b. Thus, the shaft 16e can be displaced in the horizontal direction with respect to the rigid support member 16d. First, as shown in Fig. 4(b), the rigid support member 16d is affixed to the mounting seat 32 so that the tangent of the leaf spring member 16c and the development roller 16b passes through the centre of the shaft 16e. Under these conditions, the thickness of the toner layer is regulated.

Next, as shown in Fig. 4(a), the shaft 16e is displaced to be far from the rigid support member 16, the rigid support member 16d is affixed to the mounting seat 32, and under these conditions the thickness of the toner layer is regulated. Note that in Fig. 4(a), the line connecting the contact point between the leaf spring member 16c and the development roller 16b, and the centre of the shaft 16e forms an angle of 5° with respect to the tangent of the development roller 16b in which the leaf spring member 16c lies. This angle is conveniently defined as a angle of deviation of the shaft 16e of -5°.

Next, as shown in Fig. 4(c), the shaft 16e is displaced so as to be near the rigid support member 16, the rigid support member 16d is affixed to the mounting seat 32, and under these conditions the thickness of the toner layer is regulated. Note that in Fig. 4(c), the line connecting the contact point between the leaf spring member 16c and the development roller 16b and the centre of the shaft 16e forms an angle of 5° with respect to the tangent of the development roller 16b in which the leaf spring member 16c lies. This is a deviation angle of 5°.

The thickness of the toner layer obtained under the conditions shown in each of Fig. 4(a), Fig. 4(b), and Fig. 4(c) was measured. The following procedures were followed for the measurement:

1. The thickness of the toner layer was regulated under the conditions of each of Fig. 4(a), Fig. 4(b), and Fig. 4(c). Then the development roller 16b was gently taken out from the developing apparatus 16 and was set on a laser scan micrometer apparatus 34 as shown in Fig. 5. The laser scan micrometer apparatus 34 is provided with a light emitting unit 34a and a light receiving unit 34b. Located centrally between them is disposed a reference shielding wall 34c for blocking part of the laser beam emitted from the light emitting unit 34a.

In Fig. 5, the toner layer formed at the circumference of the development roller 16b is illustrated in an exaggerated fashion and is indicated by the reference symbol TL. The development roller 16b is set with respect to the laser scan micrometer apparatus 34 so that the location where the thickness of the toner layer is regulated by the leaf spring member 16c and not reaching the photosensitive drum 10 is positioned at the top of the reference blocking wall 34c.

2. In this setting, first the distance L1 is measured.

3. Next, with the development roller 16b set in the laser scan micrometer apparatus 34, nitrogen gas is blown on the development roller 16b to completely remove the toner layer from the same. The distance L2 is then measured.

4. Next, the thickness of the toner layer is calculated by the computation of L2-L1.

5. The above measurement is repeated five times under the conditions of each of Fig. 4(a), Fig. 4(b), and Fig. 4(c), and the mean value of the thickness of the toner layer and the variation of the measurement values are found.

The above results of measurement are shown in the
graph of Fig. 6. As will be clear from the graph, when the deviation angle of the shaft 16e is -5° (Fig. 4(a)), the macroscopic toner layer average thickness is 13.8 μm and the variation ∆μ (where μ is the standard deviation) is a large 7.3 μm. When the deviation angle of the shaft 16e was +5° (Fig. 4(c)), the macroscopic toner layer average thickness was 8.7 μm and the variation ∆μ was 4.5 μm. When the deviation angle of the shaft 16e was 0° (Fig. 4(b)), i.e., when the centre of the shaft 16e was placed on the tangent of the leaf spring member 16c and the development roller 16b, the macroscopic toner layer average thickness was 10.2 μm and the variation ∆μ was 2.2 μm.

Next, the state of occurrence of vibration of the leaf spring member 16c under the conditions of each of Fig. 4(a), Fig. 4(b), and Fig. 4(c) was observed. Note that the vibration of the leaf spring member 16c in question here is a fine one not visibly discernable, so the observation was performed indirectly by the method shown in Fig. 7. The photosensitive drum 10 was removed from the developing apparatus 16, and a surface potentiometer 36 was put in its place. The developing apparatus 16 was operated and the surface potential of the development roller 16b was measured, whereby it was possible to observe the state of occurrence of the vibration of the leaf spring member 16c. In Fig. 7, Vφ indicates the development bias voltage -300V applied to the development roller 16b. Vφ1 indicates the charge implantation voltage -400V applied to the leaf spring member 16c, and Vφ indicates the voltage -400V applied to the toner reclamation and supply roller 16g.

If it is assumed that no vibration occurs at the leaf spring member 16c, when the developing apparatus 16 of Fig. 7 is actuated and the voltages Vφ, Vφ1, and Vφ are applied to the development roller 16b, the leaf spring member 16c, and the toner reclamation and supply roller 16g respectively, the surface potential of the development roller 16b should immediately rise to Vφ1, as shown in the graph of Fig. 8, and then stabilize there. This is because the leaf spring member 16c is made to contact the development roller 16b just through a toner layer of a predetermined thickness, so the surface potential Vφ must depend on the certain development bias voltage Vφ applied to the development roller 16b and the potential Vφ of the toner layer. On the other hand, if it is assumed that vibration occurs in the leaf spring member 16c (i.e. if it is assumed that the leaf spring member 16c vibrates continuously with respect to the thin toner layer on the development roller 16b during vibration), a substantially direct contact can occur locally between the leaf spring member 16c and the development roller 16b. In this case part of the charge implantation voltage, as well as the development bias voltage is applied to the development roller 16b, so the surface potential Vφ becomes extremely unstable in state. If the operation of the developing apparatus 16 is stopped and Vφ, Vφ1, and Vφ return to the ground level (zero volts), the surface potential should swiftly fall from Vφ1 to the potential Vφ of the toner layer.

The results of measurement of the surface potential of the development roller 16b under the conditions of each of Fig. 4(a), Fig. 4(b), and Fig. 4(c) are shown in Fig. 9. Note that in Fig. 9(a), the standard length shown by the arrow SL corresponds to 10 seconds. This is the same for Fig. 9(b) and Fig. 9(c). As is clear from each of the graphs of Fig. 9(a) and Fig. 9(c), when the deviation angle of the shaft 16e is -5°, the surface potential of the development roller 16b is unstable at the peak region. This shows that vibration is occurring at the leaf spring member 16c. As opposed to this, under the conditions of Fig. 4(b), when the deviation angle of the shaft 16e is 0°, the surface potential of the development roller 16b stabilizes at the peak region. This shows that no vibration occurs at the leaf spring member 16c.

With a deviation angle of the shaft 16e of -5°, when the leaf spring member 16c receives frictional force in the tangential direction from the development roller 16b, one of the force components acts to separate the leaf spring member 16c from the development roller 16b. The leaf spring member 16c is made to vibrate by this separating action. Due to this vibration of the leaf spring member 16b, the regulating force on the thickness of the toner layer becomes weaker, so the thickness of the toner layer becomes relatively larger. This matches with the results of the graph of Fig. 6. That is, along with the increase in the thickness of the toner layer, the average charge of the toner particles falls. This means that there are toner particles close to an uncharged state in the toner particles. These uncharged toner particles cause fogging. When a recording operation was performed under a high temperature and high humidity environment (40°C, relative humidity of 80 percent RH) with the deviation angle of the shaft 16e set to -5°, fogging of an optical reflection density (OD) of over 0.04 occurred on the recording paper. Fluctuations also occurred in the recording density. The quality of the recorded toner image was inferior.

When the deviation angle of the shaft 16e was +5°, when the leaf spring member 16c received the frictional force in the tangential direction from the development roller 16b, one of the force components acted to cause the leaf spring member 16c to bite into the development roller 16b. Due to this biting action, the leaf spring member 16c vibrated. Due to this vibration of the leaf spring member 16c, the regulating force on the thickness of the toner layer grew stronger, so the thickness of the toner layer became relatively smaller. This matches with the results of the graph of Fig. 6. However, when the recording operation was actually performed with the deviation angle of the shaft 16e set to +5°, fogging with an optical reflection density (OD) of over 0.04 occurred on the recording paper. This result appears to contradict the above explanation, but regarding the occurrence of fogging, it is guessed that the leaf spring member 16c bites into the development roller 16b, then immediately the
leaf spring member 16c rebounds from the development roller 16b and, at this time, the thickness of the toner layer becomes greater and the average charge of that portion of the toner particles drops.

When the deviation angle of the shaft 16e is 0°, vibration of the leaf spring member 16c is suppressed and development can be stably performed. The quality of the recorded toner image actually obtained was excellent. That is, the recorded density (OD) measured using an optical reflection densitometer was 1.4. The unevenness of density (OD) was also a relatively small 0.1 or less. Further, the density of the fogging of the background portion on the recording paper was indiscernible (fogging density OD < 0.01).

In the example shown in Fig. 4, the leaf spring member 13c was fixed in place and the position of the shaft 16e was changed. A similar experiment was performed for the case where the shaft 16e was fixed in place and the setting angle of the leaf spring member 16c was changed. That is, as shown in Fig. 10, the rigid support member 16d was rotatably attached to the shaft 16e which was fixed in a predetermined position. The leaf spring member 16c was supported on the rigid support member 16d through a variable-angle mounting seat 3B. Explained in more detail, the leaf spring member 16c is supported by the mounting seat 3B and the mounting seat 3B is attached detachably to the rigid support member 16d by passing stopscrews 3B through the elongate holes 3Ba formed therein. In this way, the angular position of the leaf spring member 16c is freely adjustable. First, as shown in Fig. 10(b), the angular position of the leaf spring member 16c is set so that the tangent of the development roller 16b on which the leaf spring member 16c lies passes through the center of the shaft 16e. Under these conditions, the thickness of the toner layer was regulated. Next, as shown in Fig. 10(a), the mounting seat 3B was angularly displaced in the anticlockwise direction and the thickness of the toner layer was regulated under those conditions as well. Note that in Fig. 10(a), the line connecting the contact point between the leaf spring member 16c and the development roller 16b, and the shaft 16e forms an angle of 5° with respect to the tangent of the leaf spring member 16c and the development roller 16b. This angle is conveniently defined as a displacement angle of the leaf spring member 16c of 5°. Further, as shown in Fig. 10(c), the mounting seat 3B is angularly displaced in the clockwise direction and the thickness of the toner layer was regulated under those conditions as well. Note that in Fig. 10(c), the line connecting the contact point between the leaf spring member 16c and the development roller 16b, and the center of the shaft 16e forms an angle of 5° with respect to the tangent of the leaf spring member 16c and the development roller 16b. This angle is conveniently defined as a displacement angle of the leaf spring member 16c of 5°.

The thickness of the toner layer was measured under the conditions shown in each of Fig. 10(a), Fig. 10(b), and Fig. 10(c). The thicknesses were measured under the same conditions as in the case of Fig. 4(a), Fig. 4(b), and Fig. 4(c). The results are shown in Fig. 11. Further, by the same method as shown in Fig. 7, the surface potential of the development roller 16b was also measured under the conditions of each of Fig. 10(a), Fig. 10(b), and Fig. 10(c). The results are shown in Fig. 12. Note that in Fig. 12(a), the standard length shown by the arrow SL corresponds to 10 seconds. The same applies to Fig. 12(b) and Fig. 12(c).

When the deviation angle of the leaf spring member 16c is -5°, as is clear from the graph of Fig. 11, the macroscopic toner layer average thickness is 7.8 μm and the variation 3p became a large 6.2 μm. When an actual recording operation was performed, unevenness of density of an optical reflection density (OD) of less than 1.3 occurred at the recorded toner image. Further, the optical reflection density (OD) of the fogging became over 0.03, to the extent that the background area of the recording paper was blackened. On the other hand, as shown in Fig. 12(a), the surface potential of the development roller 16b fluctuated violently at the peak region. This closely resembles the case of Fig. 9(c). In short, it is believed that, when the deviation angle of the leaf spring member 16c was -5°, in the same way as in the case of Fig. 9(c), the leaf spring member 16c received a frictional force in the tangential direction from the development roller 16b and one of the force components acted to cause the leaf spring member 16c to bite into the development roller 16b, whereby the leaf spring member 16c vibrated.

When the deviation angle of the leaf spring member 16c was +5°, the macroscopic toner layer average thickness was 18.4 μm and the variation 3p was a large 4.6 μm. When an actual recording operation was performed, unevenness of the density was seen in the recorded toner image and fogging with an optical reflection density (OD) of less than 0.04 occurred. On the other hand, as shown in Fig. 12(c), even the surface potential of the development roller 16b is unstable at the peak region. This closely resembles the case of Fig. 9(a). In short, in the same way as the case of Fig. 9(a), it is believed that the leaf spring member 16c receives a frictional force in the tangential direction from the development roller 16b and one of the force components acts to separate the leaf spring member 16c from the development roller 16b, whereby the leaf spring member 16c vibrates.

When the displacement angle of the leaf spring member 16c is 0°, the macroscopic toner layer average thickness is 10.2 μm and the variation 3p is 2.2 μm. Even in an actual recording operation, an optical reflecting density (OD) of 1.4 was obtained as the printing density. The unevenness of the density was also a small 0.1 or less. Further, the fogging density of the background portion of the recording paper was indiscernible (fogging density OD ≤ 0.01).

As explained above, the front edge of the protecting
edge of the leaf spring member 16c is chamfered to give it roundness, and the radius of the rounded front end is made, for example, 0.05 mm in this embodiment. The radius of this rounded front edge can also be an important factor in obtaining an excellent quality recorded toner image. Therefore, the following experiment was conducted on the relationship of the radius R of the rounded front edge and the quality of the recorded toner image.

Four leaf spring members were prepared from a stainless steel sheet material of a thickness of 0.2 mm (SUS 631-CS-P4G3H). Among these, three leaf spring members were chamfered at one of their respective end portions by a super grindstone to give radii of the rounded front end portions of R=0.10 mm, R=0.07 mm, and R=0.03 mm. The remaining leaf spring member was not chamfered. Using these four leaf spring members, actual recording was performed on recording paper and the quality of the recorded toner image was evaluated. The experiment is summarized below:

1. The centre of the shaft 16e of the rigid support member 16d was positioned on the tangent of the development roller 16b in which the leaf spring member lies.
2. The leaf spring members were pressed into contact with the development roller 16b at a linear pressure of 40 gf/cm.
3. The development processes were performed under an environment where fogging easily occurs, that is, a temperature of 40°C and a relative humidity of 80 percent RH.
4. In the development processes, parallel hatching line pattern development comprised of a large number of one-dot hatching lines at an angle of 45° (pitch between hatching lines in horizontal direction: 8 dots) and all-white development (no exposure of photosensitive drum 10) were performed. The developed toner images were transferred to and fixed on recording paper (A4 size). Note that, in the all-white development, of course, there was no developed toner image to be transferred from the photosensitive drum 10 to the recording paper.
5. For the evaluation, the first recorded toner image and the toner image recorded on the 20,000th recording sheet were selected.

The results of the evaluation are shown in the graph of Fig. 13. Note that the horizontal axis of the graph shows the radius R of the rounded front edge of the leaf spring member. The vertical axis shows the difference between the maximum value (black streak) and minimum value (white streak) of the average optical reflection density OD of a region of a diameter of 4 mm of the parallel hatching line pattern recording. The left vertical axis shows the value of the fogging density of the all-white recording measured by an optical reflection densitometer. As is clear from this graph, in parallel hatching line pattern recording in the case using the leaf spring member without a rounded front edge (R=0), the difference of the average recording densities was a large 0.08. This was far higher than the visually discernible density difference 0.03. Black streaks and white streaks of uneven density were observed on the recording paper. As opposed to this, in the case of the leaf spring members chamfered to give them roundness (R=0.10 mm, R=0.07 mm, and R=0.03 mm), it was learned that the difference in density could be held to below 0.03. Further, in the all-white recording performed under the high temperature and high humidity (40°C/60 percent RH) environment, when use was made of the leaf spring member with R=0.10 mm, the visually discernible limit of a difference of density of 0.01 (value minus optical reflection density OD) of recording paper was exceeded and fogging easily occurred, it was learned. In short, when chamfering the front edge of the protruding end of the leaf spring member (16b), the radius R should be within the following range:

\[ 0.03 \text{ mm} \leq R \leq 0.07 \text{ mm} \]

Further, an experiment was also performed on the three types of leaf spring members (R=0.10 mm, R=0.07 mm, R=0.03 mm) which were chamfered so as to see how the thickness of the toner layer changes in the case of changing the linear pressure with respect to the development roller 16b (that is, the pressure regulating the thickness of the toner layer). The results are shown in the graph of Fig. 14. As is clear from the graph, as a general trend, as the radius R of the rounded front edge of the leaf spring member becomes smaller, the thickness of the toner layer can be kept thin by a much smaller linear pressure. For example, a look at the upper limit (0.07 mm) of the radius R of the rounded front edge of the leaf spring member shows that a linear pressure of at least 30 gf/cm is required with respect to the development roller 16b. Further, the three chamfered leaf spring members were evaluated as to the quality of the recorded toner image after setting the linear pressures with respect to the development roller 16b to 12 gf/cm, 30 gf/cm, 45 gf/cm, and 60 gf/cm and performing a running recording test of 20,000 sheets of recording paper (A4 size) the same as in the above case. As a result, with a linear pressure of 60 gf/cm, with all the leaf spring members, the toner particles were fixed in a crushed manner and black streaks and white streaks of a maximum density difference of 0.16 occurred in the parallel hatching line pattern recording. From the above, it was learned that the linear pressure of the leaf spring member 16c with respect to the development roller 16b is preferably within the range of about 30 gf/cm to about 45 gf/cm.

Further, in the present invention, as shown in Fig. 15, it was confirmed by the following experiment that the flexible length FL of the protruding end of the leaf spring member 16c (that is, the distance from the front end of
the rigid support member 16d to the rounded front edge of the leaf spring member 16c is closely related to the regulation of the thickness of the toner layer.

First, before the experiment, a support apparatus of the leaf spring member 16c as shown in Fig. 16 was prepared. This support apparatus is provided with a fixed shaft 40 arranged at a predetermined position and a rigid support member 42 detachably attached to the shaft 40. The leaf spring member 16c is supported in the same way as in the case of the rigid support member 16d on the rigid support member 42. A coil spring 44 is made to act on the rigid support member 42, whereby the leaf spring member 16c is elastically pressed against the development roller 16b with a predetermined pressure. The centre of rotation of the rigid support member 42, that is, the centre of the fixed shaft 40, is positioned on the tangent of the development roller 16b on which the leaf spring member lies. Therefore, the frictional force F acting on the leaf spring member 16c (Fig. 17) is oriented towards the centre of the shaft 40, so a force component causing vibration of the leaf spring member 16c is never created from the frictional force F. That is, the support apparatus shown in Fig. 16 is equivalent to the leaf spring member support apparatus shown in Fig. 1.

At the time of the experiment, four types of rigid support members 421, 422, 423, and 424 as illustrated in Fig. 18, Fig. 19, Fig. 20, and Fig. 21, respectively, were prepared. Leaf spring members 16c of the same dimensions were attached to these rigid support members, but the lengths of the support arm portions of the rigid support members, that is, the portions supporting the leaf spring member 16c, were different. In Fig. 18, the distance from the centre of rotation of the rigid support member 421 to the front end of the support arm portion is 23 mm and the length of the protruding end of the leaf spring member 16c protruding from the front end (the flexible length FL1) is 2 mm. In Fig. 19, the distance from the centre of rotation of the rigid support member 422 to the front end of the support arm portion is 22 mm and the flexible length FL of the leaf spring member 16c is 4 mm. In Fig. 20, the distance from the centre of rotation of the rigid support member 423 to the front end of the support arm portion is 20 mm and the flexible length FL of the leaf spring member 16c is 5 mm. Note that the contact width CW (Fig. 15) between the leaf spring member 16c and the development roller 16b was 2.4 mm.

The thickness of the toner layer was regulated under the conditions shown in each of Fig. 18, Fig. 19, Fig. 20, and Fig. 21. The thickness of the toner layer was then measured by the laser scan micromeasurement apparatus 34 of Fig. 5. The measurement of the thickness of the toner layer under the conditions of each of Fig. 18, Fig. 19, Fig. 20, and Fig. 21 was repeated five times. The results of the measurements are shown in the graph of Fig. 22. As is clear from the graph, when the flexible length FL of the leaf spring member 16c was 5 mm (Fig. 21), the macroscopic average thickness of the toner layer was a relatively thick 12.7 µm and the variation 3σ (where σ is the standard deviation) was a large 5.4 µm. The reasons for this may be considered to be that, if the flexible length of the leaf spring member 16c increases, the flexibility increases, so the thickness-regulating force of the toner layer becomes weaker and vibration occurs more easily. Furthermore, not only does the macroscopic average thickness of the toner layer become larger, but so does the variation of the same. As is clear from the graph of Fig. 22, if the variation becomes 5.4 µm, the thickness of the toner layer often exceeds the upper limit of 14.5 µm for maintaining an excellent quality of developed toner image. When the thickness of the toner layer exceeds the upper limit of 14.5 µm, the average toner charge falls and, as a result, fogging easily occurs.

Next, a running recording of 20,000 sheets of recording paper (A4 size) was performed under the conditions of each of Fig. 18 to Fig. 21 to evaluate the recording quality. Parallel hatching line pattern recording comprised of a large number of one-dot hatching lines at an angle of 45° (pitch between hatching lines in horizontal direction: 8 dots), all-white recording (no exposure of photosensitive drum 10) and all-black recording (complete exposure of photosensitive drum 10) were performed on the recording sheets. For the evaluation, the recording on the first sheet and the recording on the 20,000th recording sheet were selected.

The results of the evaluation are shown in the graph of Fig. 23. In the graph, the clear squares show the density difference ΔOD between the maximum value (black streaks) and minimum value (white streaks) of the average optical reflection density (OD) of a 4 mm diameter region for the parallel hatching pattern. The black circles show the fogging density (OD) measured by an optical reflection densitometer in all-white recording. As is clear from the graph of Fig. 23, when the flexible length of the leaf spring member 16c is less than 3 mm, the density difference ΔOD rapidly increases. Only when the flexible length of the leaf spring member 16c is 2 mm (Fig. 18) are black streaks and white streaks of a large density difference ΔOD of 0.06 observed in the parallel hatching pattern recording. This density difference ΔOD of 0.06 is larger than the visually discernable density difference ΔOD of 0.03. Therefore, when the developing apparatus was disassembled and the causes investigated, it was found that toner particles had deposited in the thickness-regulating surface of the leaf spring member 16c and that the locations where the toner particles had deposited matched the front end of the support arm portion of the rigid support member 421 positioned at the back side of the thickness-regulating surface. As to the reason for this, since the flexible length of the leaf spring member 16c is short, the flexibility becomes smaller. Further, the front end of the support arm portion of the rigid support member 421, as is clear from Fig. 18, is positioned in the contact area (CW=2.4 mm) between
the leaf spring member 16c and the development roller 16b. Therefore, during the running recording of 20,000 sheets of recording paper, the protruding end of the leaf spring member 16c is bent so as to become slightly separated from the development roller by the toner particles pushed between that end and the development roller 16b and thus the toner particles are crammed between them. It is believed that the toner particles are crushed against the thickness-regulating surface of the leaf spring member 16c and become affixed there.

On the other hand, when the flexible length FL of the protruding end of the leaf spring member 16c was less than 4 mm and more than the contact area width (CW=2.4 mm) between the leaf spring member 16c and the development roller 16b, the recording quality was evaluated as excellent. Even after running recording of 20,000 sheets of recording paper, a sufficient recording density OD of 1.4 was obtained. Even with all-black recording, the unevenness of density was a small 0.10 and, further, the fogging density was a small value not visually discernible (fogging density OD ≤ 0.01: value obtained by subtracting optical reflection density OD of 0.1 of recording paper). In short, when the contact area width CW between the leaf spring member 16c and the development roller 16b is 2.4 mm, the flexible length FL of the leaf spring member 16c should be made within a range of 2.4 mm to about 4 mm.

As is clear from the graph of Fig. 22, when the flexible length FL of the leaf spring member 16c is within the range of 2.4 mm to 4 mm, the thickness of the toner layer is regulated to about 10 μm. The thickness 10 μm substantially matches the average particle size of the toner particles. This means that the toner layer is regulated as a single layer of toner particles. In this case, it becomes possible to charge individual toner particles by a sufficient charge by charge implantation, so the occurrence of fogging can be greatly suppressed.

Further, in the present invention, to suitably regulate the thickness of the toner layer, the rounded front edge of the protruding end of the leaf spring member 16c has to be positioned within a predetermined range of the contact point between the leaf spring member 16c and the development roller 16b. This was confirmed by the following experiment.

As shown in Fig. 24, when the line perpendicular to the tangent between the leaf spring member 16c and the development roller 16b and passing through the contact point between the two is made the standard line SL, the rounded front edge of the protruding end of the leaf spring member 16c has to be positioned between a location 0.3 mm away from the standard line SL at the upstream side of the moving surface of the development roller 16b and a location 0.5 mm away from the standard line at the downstream side of the moving surface.

First, before the experiment, the support apparatus of the leaf spring member 16c shown in Fig. 25 was prepared. The support apparatus was provided with a fixed shaft 46 placed at a predetermined position and a rigid support member 48 detachably attached to the shaft 40. On this rigid support member 48 was displaceably attached a mounting member 50 affixing and holding the leaf spring member 16c. The mounting member 50 is attached to the rigid support member 48 by passing stop screws 50b through elongate holes 50a formed therein, whereby the mounting member 50 is made displaceable in the direction perpendicular to the standard line SL. Therefore adjustment of the position of the leaf spring member 16c with respect to the standard line SL is possible. The coil spring 38 is made to act on the rigid support member 48, whereby the leaf spring member 16c is elastically pressed against the development roller 16b. The centre of rotation of the shaft 46 of the rigid support member 48 is positioned on the tangent of the development roller 16b on which the leaf spring member 16c lies. In short, except for the point that adjustment of the position of the leaf spring member 16c is possible, the support apparatus of Fig. 25 is equivalent to that shown in Fig. 1.

In Fig. 25, reference symbol D shows the coordinate axis perpendicularly intersecting with the standard line SL. The point of intersection forms the origin of the coordinates. The position of the rounded front edge of the leaf spring member 16c with respect to the standard line SL is specified by the coordinate axis D as that the leaf spring member 16c protrudes from the standard line SL. When the protruding end of the leaf spring member 16c actually protrudes from the standard line SL as shown in Fig. 25, the distance from the standard line SL to the rounded front edge is defined as a positive protrusion amount d. When the protruding end of the leaf spring member 16c does not actually protrude from the standard line SL, the distance from the rounded front edge to the standard line SL is defined as a negative protrusion amount d. Of course, when the rounded front edge of the protruding end of the leaf spring member 16c is positioned on the standard line SL, the amount of protrusion is defined as zero.

Figures 26 to 28 each show an enlargement of the rounded front edge of the protruding end of the leaf spring member 16c. In Fig. 26, the protrusion amount d is a positive amount, while in Fig. 27 and Fig. 28, the protrusion amounts d are negative amounts. The protrusion amounts d1 and d2 are equal to -0.50 mm and 0.30 mm, respectively. The range is the same as that shown in Fig. 24.

In the experiment, the protruding end of the leaf spring member 16c was made to protrude by six amounts, that is, -0.85 mm, -0.50 mm, 0 mm, 0.30 mm, 0.50 mm, and 0.80 mm. The thickness of the toner layer was regulated with the leaf spring member 16c protruding by these amounts, then the thickness of the toner layer was measured by the laser scan micromeasurement apparatus 34 of Fig. 5. The measurement of the thickness of the toner layer was repeated five times for each of the protrusion amounts. The results are shown in the graph of Fig. 29. The fogging at the photosensitive
drum 10 was measured in parallel with the measurement of the thickness of the toner layer by sticking scotch mending tape on the surface of the photosensitive layer of the photosensitive drum 10, then peeling the tape from it and measuring the sticking side of the tape with an optical reflection densitometer. The results are shown in the graph of Fig. 30.

As shown in the graph of Fig. 29, when the protrusion amount d is over 0.6 mm (for example, Fig. 26), it is learned that the average thickness of the toner layer and also the variation fall out of the suitable range of 6 to 14.5 μm where an excellent recording quality is obtained. On the other hand, as is clear from the graph of Fig. 30, when d ≥ 0.3 mm, the fogging density (CD) rapidly rises. When the protrusion amount d of the leaf spring member 16c is over d ≥ 0.3 mm, the scraping off effect of the toner layer by the rounded front edge falls and therefore the amount of the toner which passes through the leaf spring member 16c increases. If the thickness of the toner layer is increased, the average charge of the toner particles falls and this becomes a cause of fogging.

Further, as shown by the graph of Fig. 30, even when d ≤ -0.50 mm, the fogging density rapidly rises. When the protrusion of the leaf spring member 16c is less than -0.50 mm, as shown by the graph of Fig. 29, the thickness of the toner layer is relatively small. This is an effect contradictory to the above explanation. The reason is believed to be that, when d ≤ -0.50 mm, the rounded front edge of the leaf spring member 16c bites into the development roller 16b as shown in Fig. 28, so the leaf spring member 16c violently vibrates and there is a great fluctuation in the thickness of the toner layer.

From the above results, the protrusion d of the leaf spring member 16c should be set within the predetermined range mentioned above, that is, the following range:

\[ 0.50 \text{ mm } (d_1) \leq d \leq 0.3 \text{ mm } (d_2) \]

This range can change somewhat around the standard line SL, that is, at the contact point with the development roller 16b, due to differences in the diameter of the development roller 16b. However, if the rounded front edge of the leaf spring member 16c is positioned near the contact point, that position will be included in the desired range, so there is no need to find the desired range of the protrusion of the leaf spring member for each individual development roller with a different diameter.

Next, the occurrence of vibration of the leaf spring member 16c when the protrusion d of the leaf spring member 16c is less than -0.50 mm as examined by the method shown in Fig. 7. The results of measurement of the surface potential of the development roller 16b in the case where 0≤d≤0.3 mm and where d≤-0.50 mm are shown in Fig. 31. As is clear from the graph of Fig. 31 (a), when 0≤d≤0.3 mm, the surface potential of the development roller 16b stabilizes at the peak region. This shows that no vibration occurs at the leaf spring member 16c. As opposed to this, when d≤0.50 mm, the surface potential of the development roller 16b is unstable at the peak region. This shows that vibration occurs at the leaf spring member 16c.

Further, the recording quality was evaluated by performing a running recording of 20,000 sheets of recording paper (A4 size) at each of the above protrusion amounts. All-black recording (exposure of the entire surface of the photosensitive drum 10), all-white recording (no exposure of the photosensitive drum 10), and parallel hatching line pattern recording comprised of a large number of one-dot hatching lines at an angle of 45° (pitch between hatching lines in horizontal direction: 8 dots) were performed on the recording sheet. For the evaluation, the recording of the first recording sheet and the recording of the 20,000th recording sheet were selected. As a result, black streaks and white streaks appeared in the all-black recording and parallel hatching line pattern recording only when d≤0.50 mm. In the case of the parallel hatching line pattern recording, the difference between the maximum value (black streak) and minimum value (white streak) of the average optical reflectance density OD* for a 4 mm diameter region was evaluated, whereupon an average recording density difference of 0.10 appeared in the parallel hatching line pattern recording after the running recording of 20,000 sheets of recording paper. This was far higher than the visually discernible density difference of 0.03. Therefore, the developing apparatus was disassembled and the cause was investigated, whereupon it was found that the toner particles deposited at the thickness-regulating surface of the leaf spring member 16c and that the locations where the toner particles were deposited matched the location of the front end of the mounting member 50 positioned at the back side of the thickness-regulating surface. It is believed that the reason for this is that, since the protrusion amount d (0.80 mm) of the leaf spring member 16c is large, the contact point between the leaf spring member 16c and the development roller 16b overly approaches the location of the front end of the mounting member 50 and the flexibility of the leaf spring member 16c is lost. Thus, during running recording of 20,000 sheets of paper, the lower portion of the leaf spring member 16c bends to become somewhat away from the development roller 16b at the front end location of the mounting member 50 and the toner particles are crammed therebetween. These toner particles are believed to be crushed against the thickness-regulating surface of the leaf spring member 16c and deposited there. On the other hand, with a protrusion of -0.50 mm ≤ d ≤ 0.3 mm, the recording quality was evaluated as excellent. Even after running recording of 20,000 sheets, a sufficient recording density OD of 1.4 was obtained. Further, the unevenness of density was a small 0.10, even with all-black recording. Further, the fogging
density was a small value unable to be visually discerned (logging density OD ≤ 0.01; value obtained by subtracting optical reflection density OD 0.1 of recording paper).

Claims

1. A developing apparatus for developing an electrostatic latent image held on an image carrier (10) by a mono-component developer, said apparatus comprising:

   a developer-holding container (16a) for holding the mono-component developer;
   an electroconductive, elastic development roller (16b) rotatably provided inside the developer-holding container (16a) so that a portion thereof is exposed from the developer-holding container (16a) to contact the image carrier (10), rotation of the development roller (16b) causing the mono-component developer to be deposited on the surface thereof and form a mono-component developer layer thereon, the mono-component developer being transported to the image carrier (10) for development of the latent image formed on the image carrier (10); and
   an electroconductive leaf spring member (16c) for regulating the thickness of the mono-component developer layer on the development roller (16b), one end of said leaf spring member (16c) being supported integrally by a rotatable rigid support member (16d) and the other end pressed elastically against the development roller (16b), the centre of rotation of the rigid support member (16d) and the plane of the leaf spring member (16c) being aligned substantially on a tangent of the elastic development roller (16b).

   characterised in that the front edge of said other end of the leaf spring member (16c) is positioned within a predetermined distance (d) of a line of contact on the development roller (16b) where a radial plane (SL) of the development roller (16b) perpendicularly intersects the tangent on which the centre of rotation of the rigid support member (16d) and the plane of the leaf spring member (16c) are substantially aligned.

2. A developing apparatus as claimed in claim 1, wherein said predetermined distance (d) from the line of contact and said front edge of the leaf spring member (16c) is about 0.3 mm or less in the direction of movement of the development roller (16b) and about 0.5 mm or less in the opposite direction.

3. A developing apparatus as claimed in claim 1 or claim 2, wherein the flexible length (FL) by which said other end of the leaf spring member (16c) extends from said rigid support member (16d) is less than 4 mm.

4. A developing apparatus as claimed in claim 3, wherein the flexible length (FL) is more than the contact width (CW) between the leaf spring member (16c) and the development roller (16b).

5. A developing apparatus as claimed in any one of the preceding claims, wherein, when the elastic press contact state of the leaf spring member (16c) with respect to the development roller (16b) is released, the centre of rotation of the rigid support member (16d) is made to match the tangent on which the centre of rotation of the rigid support member (16d) and the plane of the leaf spring member (16c) are substantially aligned.

6. A developing apparatus as claimed in any one of the preceding claims, wherein said leaf spring member (16c) is formed from a metal material and is connected to an electrical energy source to give a charge of a predetermined polarity to the mono-component developer by charge implantation at the time of regulating the thickness of the mono-component developer layer.

7. A developing apparatus as claimed in any one of the preceding claims, wherein said development roller (16b) is formed from an electroconductive, porous rubber material.

8. A developing apparatus as claimed in any one of the preceding claims, wherein said front edge of the other end of the leaf spring member (16c) is chamfered to give it roundness.

9. A developing apparatus as claimed in claim 8, wherein the radius (R) of the rounded front edge is in the range of from 0.03 mm to 0.07 mm.

Patentansprüche

1. Entwicklungsgerät zum Entwickeln eines auf einem Bildträger (10) gehaltenen elektrostatischen Latentbildes durch einen Monokomponenten-Entwickler, wobei das Gerät umfaltet:

   einen Entwickler-Aufnahmebehälter (16a) zum Aufnehmen des Monokomponenten-Entwicklers;
   eine elektrisch leitfähige, elastische Entwicklungswalze (16b), die innerhalb des Entwickler-Aufnahmebehälters (16a) so drehbar angeord-
net ist, daß ein Bereich derselben von dem Entwickler-Aufnehmehalter (16a) freigegeben wird, um den Bildträger (10) zu berühren, wobei eine Rotation der Entwicklungswalze (16b) be- 5 wirkt, daß der Monokomponenten-Entwickler sich auf der Oberfläche derselben absetzt und eine Monokomponenten-Entwicklerschicht auf dieser bildet, wobei der Monokomponenten-Entwickler zum Entwickeln des auf dem Bildträger (10) ausgebildeten Latentbildes zu dem Bildträger (10) transportiert wird; und ein elektrisch leitfähiges Blattfederelement (16c) zum Regulieren der Dicke der Monokomponenten-Entwicklerschicht auf der Entwicklungs- 10 walze (16b), wobei ein Ende dieses Blattfederelementes (16c) fest von einem drehbar- ren starren Trägerelement (16d) gehalten wird und das andere Ende elastisch gegen die Entwick- lungs- 15 lingswalze (16b) angedrückt wird, wobei das Drehzentrum des starren Trägerelementes (16d) und die Ebene des Blattfederelementes (16c) im wesentlichen auf einer Tangente an die elastische Entwicklungswalze (16b) auf ei- ner Linieausgerichtet sind.

dadurch gekennzeichnet, daß die Vorderkante des anderen Endes des Blattfederelementes (16c) innerhalb einer vorgegebenen Distanz (d) ei- ner Kontaktlinie auf der Entwicklungswalze (16b) positioniert ist, wo eine Radialebene (SL) der Entwicklungs- 20 walze (16b) die Tangente senkrecht schneidet, auf welcher das Drehzentrum des star- ren Trägerelementes (16d) und die Ebene des Blattfederelementes (16c) im wesentlichen in einer Linie hintereinander angeordnet sind.

2. Entwicklungsgerät nach Anspruch 1, bei welchem die vorgegebene Distanz (d) von der Kontaktlinie und der Vorderkante des Blattfederelementes (16c) etwa 0,3 mm oder weniger in der Bewegungsrichtung der Entwicklungswalze (16b) und etwa 0,5 mm oder weniger in der entgegengesetzten Richtung ist.

3. Entwicklungsgerät nach Anspruch 1 oder Anspruch 2, bei welchem die flexible Länge (FL), um die das andere Ende des Blattfederelementes (16c) sich von dem starren Trägerelement (16d) aus erstreckt, kleiner als 4 mm ist.

4. Entwicklungsgerät nach Anspruch 3, bei welchem die flexible Länge (FL) größer als die Kontaktbreite (CW) zwischen dem Blattfederelement (16c) und der Entwicklungswalze (16b) ist.

5. Entwicklungsgerät nach einem der vorangehenden Ansprüche, bei welchem dann, wenn der elastische Andruckkontaktzustand des Blattfederelementes (16c) gegenüber der Entwicklungswalze (16b) auf- gehoben wird, das Drehzentrum des starren Trä- gerelementes (16d) veranlaßt wird, mit der Tangen- te zusammenzufallen, auf welcher das Drehzen- trum des starren Trägerelementes (16d) und die Ebene des Blattfederelementes (16c) im wesentli- chen in einer Linie hintereinander angeordnet sind.


7. Entwicklungsgerät nach einem der vorangehenden Ansprüche, bei welcher die Entwicklungswalze (16b) aus einem elektrisch leitfähigen, porösen Gummi material hergestellt ist.

8. Entwicklungsgerät nach einem der vorangehenden Ansprüche, bei welcher die Vorderkante des an- deren Endes des Blattfederelementes (16c) ange- fast ist, um diesem eine Abrundung zu geben.

9. Entwicklungsgerät nach Anspruch 8, bei welchem der Radius (R) der abgerundeten Vorderkante im Bereich von 0,03 mm bis 0,07 mm liegt.

Revisions

1. Dispositif de développement pour développer une image électrostatique latente, portée par un support d'image (10), à l'aide d'un révélateur monocompas- sant, dit dispositif comprenant :

un conteneur à révélateur (16a) pour contenir le révélateur monocompascant ;

un rouleau élastique de développement (16b), conducteur de l'électricité, disposé de manière mobile en rotation à l'intérieur du conteneur à révélateur (16a) avec une partie accessible de l'extérieur du conteneur à révélateur (16a) pour contacter le support d'image (10), la rotation du rouleau de développement (16b) faisant que le révélateur monocompasant se dépose sur sa surface et y forme une couche de révélateur monocompasant, le révélateur monocompasant étant amené au support d'image (10) pour développer l'image latente formée sur le sup- port d'image (10) ; et

un élément formant ressort à lame (16c), conduc- teur de l'électricité, pour régler l'épaisseur de la couche de révélateur monocompasant sur le rouleau de développement (16b), une ex-
trémité dudit élément formant ressort à lame (16c) étant supportée par un élément formant support rigide mobile en rotation (16d) dont elle fait partie intégrante, et l'autre extrémité étant poussée élastiquement contre le rouleau de développement (16b), le centre de rotation de l'élément formant support rigide (16d) et le plan de l'élément formant ressort à lame (16c) étant sensiblement alignés sur une tangente du rouleau élastique de développement (16b) : 

caractérisé en ce que le bord avant de ladite autre extrémité de l'élément formant ressort à lame (16c) est situé en deçà d'une distance prédéterminée (d) d'une ligne de contact sur le rouleau de développement (16b) où un plan radial (SL) du rouleau de développement (16b) coupe perpendiculairement la tangente sur laquelle sont alignés sensiblement le centre de rotation de l'élément formant support rigide (16d) et le plan de l'élément formant ressort à lame (16c).

2. **Dispositif de développement selon la revendication 1, dans lequel ladite distance prédéterminée (d) entre la ligne de contact et ledit bord avant de l'élément formant ressort à lame (16c) est d'environ 0,3 mm, au maximum, dans le sens de déplacement du rouleau de développement (16b) et d'environ 0,5 mm, au maximum, dans le sens contraire.**

3. **Dispositif de développement selon la revendication 2, dans lequel la longueur flexible (FL), dont s'étend ladite autre extrémité de l'élément formant ressort à lame (16c) depuis l'élément formant support rigide (16d), est plus petite que 4 mm.**

4. **Dispositif de développement selon la revendication 3, dans lequel la longueur flexible (FL) est plus grande que la largeur de contact (CW) entre l'élément formant ressort à lame (16c) et le rouleau de développement (16b).**

5. **Dispositif de développement selon l'une quelconque des revendications précédentes, dans lequel, lorsque l'on libère l'état de contact à pression élastique de l'élément formant ressort à lame (16c) par rapport au rouleau de développement (16b), on fait coïncider le centre de rotation de l'élément formant support rigide (16d) avec la tangente sur laquelle sont alignés sensiblement le centre de rotation de l'élément formant support rigide (16d) et le plan de l'élément formant ressort à lame (16c).**

6. **Dispositif de développement selon l'une quelconque des revendications précédentes, dans lequel ledit élément formant ressort à lame (16c) est fait d'une matière métallique et est connecté à une source d'énergie électrique, pour donner une char-
Fig. 3(a)

Fig. 3(b)
Fig. 6

Fogging due to high temperature and high humidity

Reduction of printing density

Deviation angle

Developer layer thickness (µm)
Fig. 9(a)

Surface potential of developer carrier (v)

Fig. 9(b)

Surface potential of developer carrier (v)

Fig. 9(c)

Time
Deviation angle 5°
Fig. 11

Fogging due to high temperature and high humidity

Reduction of printing density
Fig. 12(a)  Fig. 12(b)  Fig. 12(c)

Surface potential of developer carrier (V)

Time
Deviation angle -5°

Time
Deviation angle 0°

Time
Deviation angle 5°
Fig. 13

- Fogging density O D
- Density difference Δ O D

![Graph showing the relationship between fogging density and density difference as a function of R (mm).]
Fig. 20

Fig. 21
Fig. 22

Black streaks and white streaks due to fixing of developer

Fogging due to high temperature and high humidity

Contact width

Layer thickness (μm)

Flexible length (mm)
Fig. 25
Fig. 31(a)

Surface potential of developer carrier (V)

Fig. 31(b)

Surface potential of developer carrier (V)

\( d \geq 0.50 \)

\( 0.3 \leq d \leq 0.70 \)