May 9, 1967 TOKU HOJO ETAL 3,318,284

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES OF RECORDS

Filed Jan. 27, 1965

FIG. 1

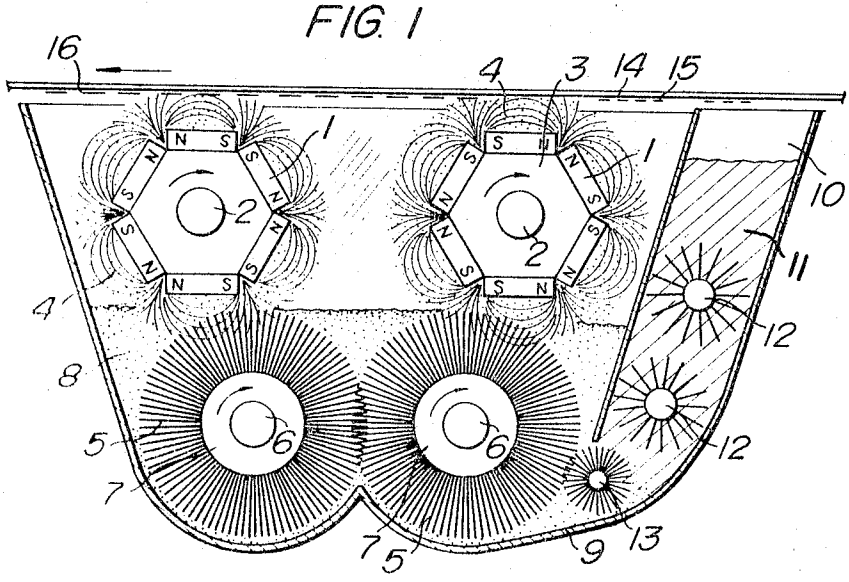
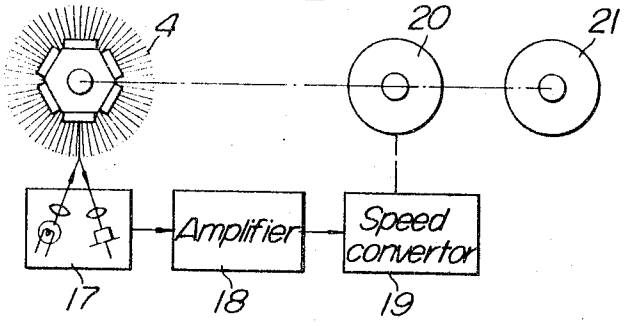


FIG. 2



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United States Patent Office 3,318,284
Patented May 9, 1967

3,318,284

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Filed Jan. 27, 1965, Ser. No. 428,455
Claims priority, application Japan, Jan. 30, 1964, 39/4,266
7 Claims. (Cl. 118—637)

This invention relates to apparatus for developing electrostatic images of records.

A method of developing electrostatic latent images of records by use of powder ink is shown, which is called "magnetic brush method," and in which a recording carrier surface having electrostatic latent images imparted thereon is swept by a so-called magnetic brush thereby to develop the latent images, which brush is formed by a magnet having a mixture in appropriate proportion of magnetic powder called "carrier" and thermofusible, colored-powder ink called "toner," adsorbed by the magnet in a brush-like manner. In such a known method, the amount of electrostatic charge as well as the concentration of the toner are very uneven and unstable, and yet, its contact with electrostatic latent images can hardly be uniform. As a result, the concentration of developed images is not uniform with unnecessary fogging contamination formed. Particularly, in case of wide and long web of recording carrier or plural sheets are developed at high speed, the concentration of toner is more difficult to control, resulting in very uneven development and grazing, with concentration difference of development to a great extent between the beginning and ending portions of development. If toner should additionally be fed midway in order to compensate for such default, its commingling with carrier and charging would not be effected sufficiently, and excess free toner attaches to the outer end of magnetic brush, resulting in extraordinary fogging contamination.

An object of the present invention is to provide an apparatus for developing electrostatic latent images formed by electrophotography or other methods of recording by means of electrostatic charging, by use of powder ink, particularly adapted for the cases of long web of recording carrier and plural sheets of recording carriers jointly dealt with.

Another object of the present invention is to provide a compact and economical magnetic brush in the apparatus above-specified, with a permanent magnet having such shape and arrangement that its magnetic field is most effective, and has the most suitable length and flexibility for developing.

Another object of the present invention is to provide the apparatus above-specified, in which a stirring brush formed by strong metal wires planted on and insulated from a rotating shaft is associated with the magnetic brush in deep intersection, and immersed mostly into the developing agent of mixed carrier and toner in a reservoir for utilizing its commingling, charging, carrying and combining effects, whereby toner on the magnetic brush being consumed in the developing is effectively supplemented for keeping the amount of charge and concentration of toner held by the magnetic brush within the required range, and at the same time, for maintaining the magnetic brush in uniform combining and flexible condition to sweep the surface of electrostatic latent images in the best condition.

A further object of the present invention is to provide the apparatus above-specified, in which the consumption of toner of the developing agent in a reservoir can be supplemented at a suitable rate from an associated toner storeroom having stirring and feeding brush, intermittently or continuously.

A still further object of the present invention is to provide the apparatus above-specified, in which the concentration of toner held by the magnetic brush may be detected when required, for controlling the rotating speed of magnetic brush to obtain the best result of development, whereby clear and homogeneous development can be effected with least fogging contamination.

There are other objects and particularities of the present invention, which will be made obvious from the following detailed description of the invention, with reference to the accompanying drawings, in which;

FIG. 1 is a sectional side view of the essential portion of an apparatus embodying the present invention; and

FIG. 2 is a block diagram of the speed control system for the magnetic brush shown in FIG. 1.

Referring to FIG. 1, the apparatus shown comprises a pair of magnetic brushes, each consisting of a plurality of permanent magnets **1** of large coercive magnetic force, secured to respective side faces of a polygonal, say hexagonal, non-magnetic supporter bar **3** with equal spacings, with the same poles placed in opposition, the supporter bar being fixed to a rotating shaft **2**, and a magnetic brush element **4** formed by collection of iron-powder carriers adsorbed to the magnets **1**. In association with the magnetic brushes, a pair of stirring brushes **5** are rotatably mounted, each consisting of a rotating shaft **6**, an insulated hub **7** fixed thereto, and a flexible card clothing wound around and secured to the hub **7** and having, planted thereon, a large number of strong bristles of fine steel wires, hereinafter called "insulated brush." The insulated brushes are mostly immersed into a developing agent consisting of a mixture in appropriate proportion of iron-powder carrier and toner powder for generating electrostatic charge of requisite polarity by friction with the iron powder and the insulated brushes. The developing agent is received in a reservoir **9** formed by non-magnetic material. In continuation with the reservoir **9**, a storeroom **10** is formed, with a non-magnetic partition wall disposed therebetween partly, and receives therein toner powder **11** for supplementary use. The storeroom **10** has a side wall partly formed by transparent material. Within the storeroom **10**, coarse steelwire brushes **12** are rotatably mounted for dispersing supplementary toner **11** that is apt to coagulate together. Between the storeroom **10** and the reservoir **9**, a rotating steel wire brush **13** is disposed, and is consisting of a rotating shaft and fine steel wires closely planted thereon, for controlling feed of supplementary toner **11** to the developing agent **8**. The brush **13** is hereinafter called "supplementary brush." An electrostatic recording carrier **14** passes on the magnetic brushes **4** in light contact therewith in the direction of arrow. The recording carrier **14** has, on its lower surface, electrostatic images **15** imparted thereto by an electrostatic image forming device, not shown, and the images as shown by **16** are developed by the developing apparatus.

The first one of features of the present invention is the shape and arrangement of permanent magnets **1**. The magnetic flux of each permanent magnet **1** before adsorption thereto of iron-powder carrier exists also within the non-magnetic hexagonal supporter bar **3**, but after the magnetic brush **4** is formed by adsorption thereto of iron-powder carrier, the magnetic flux of permanent magnet **1** is wholly concentrated substantially outside the permanent magnet, because of the fact that the magnet brush **4** is of ferromagnetic material with very low magnetic resistance, while the supporter bar **3** is non-magnetic. Little leakage flux may exist in the supporter bar **3**, but the magnetic force wholly contributes to the formation of magnetic brush **4** with least or no vain. According to

the present invention, the permanent magnets 1 are so arranged that the adjacent magnets 1 have their same poles in opposition to each other. If the adjacent magnets 1 should be disposed with their opposite poles in opposition, that is, contrary to the present invention, magnetic flux extending remotely from the magnets to the outside space would be remarkably decreased, even though there is little flux in the supporter bar 3, resulting in short and hard magnetic brush in the neighbourhood only of magnet poles. According to the present invention, however, long and large flexible magnetic brush 4 is formed all around the series of permanent magnets 1 as shown in FIG. 1. Our experiments have shown that permanent magnets arranged in any manner other than our invention result in far poor magnetic brush, unless far strong and consequently extremely uneconomical permanent magnets are used than ours.

From the economical point of view, permanent magnets 1 used in the present invention should preferably be anisotropic ferrite magnets of high coercive magnetic force with little fear of being demagnetized during treatment, which are, after magnetization, suitably combined together and arranged in a required outline. The size of permanent magnets 1 should be such that the length (length between poles) is about 15 to 25 mm. and the thickness is about one third of the length, for obtaining the most large effective magnetic field. Without to say, the width of permanent magnet 1 should be determined according to the width of images to be developed. The spacing between adjacent permanent magnets 1 should preferably be about 2 to 5 mm. In one example, permanent magnets 1 were made from anisotropic ferrite magnets manufactured by Tohoku Metal Industry Co., having magnetic strength of about 3000 gausses in closed magnetic circuit, and the above-mentioned dimensional relation. Reduced iron powder of about 100-mesh particle size were adsorbed to the permanent magnets, and we obtained extremely satisfactory and soft magnetic brush elements 4 of about 20 mm. thickness. In this example, a hexagonal hub 3 was used, but other even number orthopolygonal hub may also be used. Alternatively, permanent magnets 1 of arcuate shape may be employed and arranged on a round-bar hub 3. The absolute condition is that adjacent magnets 1 should be arranged to have the same poles in opposition.

The second feature of the present invention is in the effect of insulated brushes 5. The insulated brush 5 is in deep intersection with the magnetic brush 4 and mostly immersed into the developing agent 8. During the rotations of magnetic brush 4 and insulated brush 5, the magnetic brush 4 is pressed down and hardened by the recording carrier 14 to be developed, but upon commencement of intersection with the insulated brush 5, the hardened magnetic brush 4 is partly scraped down by the insulated brush 5, and partly combed thereby to be softened. The scraped portion of the magnetic brush 4 is supplemented by developing agent 8 adsorbed to the permanent magnets 1 during intersection with the insulated brush 5, and combed, evenly soft magnetic brush 4 is re-formed. The rotation of insulated brush 5 in the developing agent 8 accomplishes commingling of iron-powder carrier and toner, and in this process, the peculiar charging and carrying actions of the insulated brush 5 are effected. When the developing agent 8 was first charged into the reservoir 9, it is a mixture of iron-powder carrier and toner in appropriate proportion, but the mixture is not necessarily uniform and charging states of iron powder and toner are unstable. The rotation of insulated brush 5 in the developing agent 8 in such a condition causes to take place frictional movement therebetween. The iron powder and toner, as well as the insulated brush 5, are so selected and co-related that electrostatic charge produced by friction is of the same polarity in the iron powder and insulated brush 5, and of the opposite polarity in the toner, and consequently, the rotation of insulated

brush 5 causes iron powder and toner to be increasingly charged in opposite polarities to attract to each other, while steel wires of the insulated brush 5, being insulated from each other, accumulate charge of polarity opposite to that of toner, to increase the absolute value of their potential, for having toner of the opposite polarity adsorbed thereto increasingly. On the other hand, the magnetic brush 4 as first formed is of iron powder only with no toner carried, but along with the rotation of insulated brush 5 to comb the magnetic brush 4, friction takes place between the magnetic brush 4 and the toner adhering to the insulated brush 5, and the iron powder is charged thereby in the opposite polarity to the toner, whereby the toner having been adsorbed weakly to the othermost portion of insulated brush 5 is partly transferred and adsorbed to the magnetic brush 4 by virtue of attracting force of the magnetic brush 4 which is stronger than that of the insulated brush 5. As the rotations of magnetic brush 4 and insulated brush 5 are continued, the above-described charging and carrying actions are repeated, and each particle of iron powder on the magnetic brush becomes completely covered by charged toner to obtain ample concentration of toner thereon for enabling the development of latent images on the recording carrier 14. The toner concentration of magnetic brush 4 increases promptly along with the rotations of magnetic brush 4 and insulated brush 5, until each iron particle has been covered completely by charged toner, but after then, it becomes saturated, so that the upper limit of its concentration required for development is not exceeded, even when the concentration of toner in the developing agent 8 is very high, while the amount of toner consumed by developing is promptly supplemented by the insulated brush 5. Thus, the requisite range of toner concentration for developing is kept without fail, provided that toner in the developing agent 8 is not decreased below a requisite concentration therein, and yet, excess free toner is completely prevented from attaching to the magnetic brush 4, contrary to conventional ones. This is one of the important features of the present invention, and enables development of long length of recording carrier webs and large number of recording carrier sheets to be effected continuously in homogeneous and satisfactory manner with least fogging contamination, provided that the initial concentration of toner in the developing agent 8 is raised to the upper limit; the developing operation can be continued without supplementing toner until its concentration lowers to the lower limit. Consequently, extremely delicate and difficult, continuous feed of toner as required in the conventional art is not necessary. Thus, according to the invention, toner may be supplemented intermittently and in light-hearted manner for maintaining the toner concentration in developing agent 8 above the predetermined lower limit. Even when continuous feed of toner is desired, its regulation is very easy and can be accomplished by remarkably simple control device.

The above-described charging and carrying effects can be accomplished only by so selecting elementary bristle wires of the insulated brush 5 that the wires are frictionally charged to the polarity opposite to toner, and by completely insulating the wires from the rotating shaft thereof to have the electrostatic capacity of each wire as low as possible. If bristle wires of the insulated brush 5 should be planted direct on the rotating shaft in conductive manner, electric charge would not be accumulated in each bristle wire, so that toner may not adhere to the wires sufficiently to accomplish the intended purpose.

As a practical example, steel wires of 0.35 mm. in diameter and 15 mm. in length, each, were planted on a flexible card clothing with a density of one wire per 20 sq. mm., and the card closing was wound around a rotating shaft with a phenol-resin sleeve insulating them from each other, so that the finished outer diameter of the brush becomes 60 mm. Such insulated brushes 5

were combined with the aforementioned magnetic brushes **4**. The developing agent **8** was formed by reduced iron powder of about 100-mesh particle size mixed with 15 weight percent of toner of average particle size of about 5 microns, which toner was made from 90 parts of "Piccolastic 385A" resin manufactured by Pennsylvania Chemical Co. and 10 parts of "Seast Sharp 116 Carbon Black" manufactured by Tokai Electrode Co., thermally fused and mixed together, and after cooling, pulverized. The magnetic brushes **4** and the insulating brushes **5** were rotated at speeds of about two revolutions and one revolution per second, respectively, in the directions of arrows as shown in FIG. 1, and a wide and long web of recording carrier **14** running at a speed of about 25 meters per minute was continuously developed over 500 meters length, without supplementing toner at all. Images thus developed were extremely homogeneous and clear. The developed toner-powder images were fused to the recording carrier web to obtain visible permanent images, by means of preliminary conduction heating and finishing radiation heating.

The third feature of the present invention is in the toner feeding arrangement. Toner **11** in the storeroom **10** is extraordinarily apt to coagulate, but by continuous rotation of steel brushes **12**, the toner is finely divided and carried to the feed brush **13** along the wall surface of storeroom **10**. During such movement of toner, it is electrically charged by virtue of friction, and its division is further facilitated. The feed brush **13** has steel bristle wires planted closely and is in shallow intersection with an insulated brush **5**, so that supplemental commingling of toner into developing agent **8** may be regulated at will be controlling its amount of rotation. The toner that has entered into the reservoir **9** out of the feed brush **13** is promptly dispersed into the developing agent **8** in the reservoir **9** by means of insulated brushes **5**. As hereinbefore described, the toner concentration of magnetic brushes **4** becomes saturated state by virtue of the charging and carrying effects of insulated brushes **5**, and consequently, steel-wire brushes **12** and **13** may either be rotated intermittently or continuously, for accomplishing enough the purpose of toner feeding. Since the side wall of storeroom **10** is partly made transparent, toner consumption can readily be observed by sight judgment, and supplementary toner may be supplied into the storeroom **10** at will very simply.

In the example above-described, magnetic brushes **4**, insulated brushes **5**, and steel-wire brushes **12**, are respectivtly provided in pairs, but the number of such brushes used should be determined according to whether or not the electrostatic latent images are of clear contrast, such as letters, whether or not intermediate tones should be reproduced, such as in photograph images, or whether developing speed is high or low. Besides the number of such brushes used, their sizes as well as rotating speeds should also be designed according to the above-mentioned matters.

According to the present invention, still further uniform developing effect may be accomplished by controlling the rotating speed of magnetic brush **4** depending upon the toner concentration thereof in the manner to be described. Referring to FIG. 2, the toner concentration of magnetic brush **4** is detected by measuring the amount of optical reflection thereof by means of a suitable transducing device **17**. The electrical output of the latter is amplified by an amplifier **18**, whose output controls a speed converter **19** for controlling the change ratio of a speed changer **20**. An electric motor **21** is driven through the speed changer **20** for rotating the magnetic brush **4** and insulated brush **5**. The amount of toner adsorbed to latent images **15** in FIG. 1 depends, of course, upon the toner concentration of magnetic brushes **4**, but experiments have shown that the same changes also widely depending upon the rotating speed of magnetic brushes **4**, that is to say, the extended length of magnetic brush **4** that has swept over each point of latent images **15**. For example, in the embodiment hereinbefore disclosed, when the recording carrier **14** travels at a speed of 25 meters per minute, the ratio of amounts of toner adsorbed to latent images **15** for 0.5-revolution and 2-revolutions per second, respectively, of magnetic-brush rotation, is about 1:2 for 3 weight-percent toner concentration on magnetic brushes **4**, about 5:7 for 7 weight-percent toner concentration, about 14:17 for 15 weight-percent toner concentration. On the other hand, the amount of optical reflection of magnetic brush **4** is inversely proportional to the toner concentraton of magnetic brush **4**. By utilization of these factors, as may readily be understood, development of even concentration can be obtained without fail, by so designing and arranging detector device **17**, amplifier **18**, speed converter **19**, and speed changer **20**, that magnetic brush **4** rotates at decreased speed when its toner concentration is high or increased, while it rotates at increased speed when its toner concentration is low or decreased. Such a method of control is particularly effective when uniform development is required for reproduction of intermediate tones, such as in photographic image development, by appropriate adjustment of devices **17**, **18** and **19**, and experiments have shown that the maximum effect is obtained within 3–10 weight-percent range of toner concentration of magnetic brush **4**.

As is clear from the foregoing description, the present invention has succeeded to utilize the effect of permanent magnet to the maximum extent, for forming long and large, flexible magnetic brushes of compactness, light weight, and low cost, and in their combination with commingling, charging, carrying, and combining actions of peculiar insulated brushes of simple construction and low cost, as well as toner supplementing action of toner feed mechanism under extremely easy control, the present invention enables the magnetic brushes to be maintained always in soft and even condition with the amount and concentration of electric charge of toner on the magnetic brushes kept within a predetermined range suitable for development. Thus, according to the present invention, a large amount of electrostatic record carriers can be subjected to high speed developing operation, for obtaining clearly developed images of even concentration with least fogging contamination.

What is claimed is:

1. An apparatus for developing electrostatic images of record, comprising a magnetic brush for development, rotating in light pressure contact with the surface of a running electrostatic recording carrier, known per se, and an insulated brush having a large number of fine metal wires planted around a rotating shaft, said insulated brush being in deep intersection with said magnetic brush during rotation, and also being mostly immersed into developing agent in a reservoir.

2. The apparatus according to claim **1**, in which said magnetic brush is formed by a plurality of permanent magnets of high coercive magnetic force arranged around a nonmagnetic even number ortho-polygonal bar, with adjacent same poles in mechanical opposition, said magnets being respectively disposed on and fixed to the side faces of said polygonal bar.

3. The apparatus according to claim **1**, additionally comprising a toner storeroom connected to said reservoir, and a feed brush disposed between said toner storeroom and said reservoir and rotating in shallow intersection with said insulated brush.

4. The apparatus according to claim **1**, additionally comprising a storeroom for supplementing toner to said reservoir, and a toner dividing brush rotatably mounted in said storeroom and having fine metal wires coarsely planted.

5. The apparatus according to claim **1**, additionally comprising a storeroom for supplementing toner to said

reservoir and divided therefrom by a non-magnetic partition wall, said storeroom having a side wall partly formed by transparent material.

6. The apparatus according to claim 1, additionally comprising means for detecting the concentration of toner held by said magnetic brush to control the rotating speed of said magnetic brush.

7. An apparatus for developing electrostatic images of record, comprising a magnetic brush for development, consisting of an even number of permanent magnets arranged around the outer periphery of a non-magnetic supporting member, with adjacent magnets having same poles in opposition, and in equal spacings to one another, and ferromagnetic powder adhering thereto, said magnetic brush rotating in light pressure contact with the surface of a running electrostatic recording carrier, known per se, an insulated brush consisting of tough and fine metal wires planted to and insulated from a rotating shaft, mostly immersed into developing agent in a reservoir and in deep intersection with said magnetic brush during rotation, a toner storeroom connected to said reservoir, a feed brush having tough and fine metal wires closely planted and rotating in shallow intersection with said insulated brush between said reservoir and said storeroom, and a toner dividing brush in said toner storeroom for rotation therein and having tough and fine metal wires coarsely planted, said developing agent reservoir being formed by non-magnetic material, said toner storeroom being divided from said reservoir by a non-magnetic partition wall, and said toner storeroom having a side wall partly formed by transparent material.

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