MAGNETICALLY RESPONSIVE POWDER APPLICATOR

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ABSTRACT OF THE DISCLOSURE

An applicator for magnetically responsive, finely divided particulate material comprising a magnetizable shaft, a number of elongate magnetic members disposed in an array about and extending along said shaft in close fitting relation with the radially inner and outer surfaces of adjacent members having opposite polarity, a non-magnetic sleeve disposed about the periphery of said array, and means affording relative rotation between said sleeve and said members.

This invention relates to an applicator for use in presenting magnetically responsive, finely divided particles against the surface of an article for application thereto. The present invention is particularly useful in applying powdered particulate material to an article to develop an image thereon. One example of such use is in developing images by a differentially conductive pattern formed by projecting a light image on a photoconductive web. The photoconductive web being positioned between an insulative layer, backed by an electrode, and a second electrode contacting the particulate or powder which is in electrically conductive contact between the second electrode and the photoconductive web.

Various patents have issued on devices for applying developers, but such devices have had limited success at applying an even deposition of the particulate material or developer powder on an image bearing member with a width of eight and one-half inches to thirteen inches.

Some of the previously known devices which include the use of polarized members or magnetic field-producing members are shown in U.S. Letters Patent Nos. 3,152,924 and 3,176,652. The first of these patented devices uses a plurality of angularly spaced magnets set in a non-magnetic core with a plurality of short magnets aligned axially along the core in end-to-end relation to achieve a desired length for the device and with the magnets aligned so that corresponding poles on the radial edge of the magnets are facing or confronting one another. At each point or area where the magnets butt together the strength of field gradient falls off; also, each magnet has a bit different strength. All of these factors result in an uneven buildup of powder on the surface of the sleeve.

To overcome this the patentees promote the idea of rotating the magnets and the non-magnetic outer sleeve in the same direction but at different speeds; thus the magnets shift their position with respect to the sleeve and tend to keep a uniform deposit of powder forming the brush on the sleeve. This applicator or brush is therefore considered to be unduly complicated and, when used with powders which comprise magnetic particles coated with pigment, resin or other like materials, unsatisfactory.

The device described in the second patent, No. 3,176,652, particularly with reference to FIGURE 3 thereof, employs a fixed magnetic member which can be generally cylindrical in shape but which is formed with axially extending alternating flutes and ribs with each rib constituting a magnetic pole of a polarity opposite to that of the next adjacent rib. This spacing between poles of opposite polarity, while providing a magnetic field which varies direction around the periphery, produces areas between the ribs having a reduced field. Consequently the amount of magnetic material held on the sleeve and the powder movement are decreased because the field varies with weak tangential magnetic field being present opposite the flutes. This deficiency was attempted to be cured by the use of a rough exterior surface on the sleeve. Also, since it is very difficult to form a strong magnetic member in this way, magnetized with different adjacent poles, this structure is not satisfactory commercially or functionally. Both of these earlier devices thus fail short of having the capability of developing an image of uniform density.

The device of the present invention affords an applicator having a uniform field along its length and strong fields around its circumference.

The present invention provides an applicator for applying to a wide surface a dimensionally uniform deposition of magnetically responsive particulate material.

In practicing the present invention a plurality of magnetic members, which are formed preferably of oriented anisotropic permanent magnet material dispersed in a non-magnetic immobilizing matrix, are disposed in a circular array about a core formed of a high magnetic permeability and low loss such as soft iron and a relatively rotatable non-magnetic sleeve which supports the particulate image-forming material to be moved from a hopper to engaging relation with an image carrying surface.

The novel features and advantages of the present invention will become more apparent to those skilled in the art after reading the following detailed description which refers to the accompanying drawing wherein:

FIGURE 1 is a vertical sectional view of an applicating roller formed in accordance with the present invention;

FIGURE 2 is a diagrammatic view showing the roller of the present invention in cross-section and its relation to other elements in a coating assembly;

FIGURE 3 is a perspective view illustrating one magnetic member;

FIGURE 4 is a graph showing the magnitude of the radial and tangential components of the circumferential magnetic field; and

FIGURE 5 is a graph showing the longitudinal magnetic field.

Referring now to the drawing, there is shown in FIGURES 1 and 2 a developing assembly comprising an applying roll assembly 10 advantageously supported between suitable insulated side frame members 11 and 12. The assembly 10 comprises a core or shaft 13 formed of a material having a high magnetic permeability and low loss, e.g. soft iron, supported at opposite ends in the frame members. Positioned about the shaft 13 are an even number of magnetic members 14 and 15, which will be described in greater detail hereinafter. The members 14 and 15 are positioned between a fixed washer 16 and a clamping washer 17. Rotatably mounted relative to the shaft 13, as by bearing mounted end caps 18 and 19, is a non-magnetic cylindrical sleeve 20 formed of a material which will not shield the magnetic field from members 14 and 15. On each end of sleeve 20 is a drive ring 21 against which and in which driving contact therewith are drive discs 22 supported by a driven shaft 23. Shaft 23 is journaled and driven and is not shown. The frame members 11 and 12 and has a drive pulley 24 on one extended end thereof which may be suitably driven from a belt 25 from a motor (not shown).

As desired in some copying applications, the applying roll should serve as an electrode; therefore it is desired to connect the sleeve 20 to a source of electrical potential; and in the illustrated embodiment a connector 26 is at-
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3. Attached to the shaft 13, to which a lead from a source of potential may be coupled. The sleeve 20 is electrically connected to shaft 13 by a sliding leaf 27 of U-shaped resilient conductive material. The sleeve in this example is preferably formed of aluminum but could be formed of another non-magnetic material such as glass with an electrically conductive, non-magnetic surface coating.

The roll assembly 10, in operation, is positioned above a tray 30, methoded between the guide frame members 11 and 12 and positioned for parallel aligned spaced relation to a rotating drum surface as illustrated at 31 or to a linear or conveyly supported moving belt or web. In any instance if the relatively moving surface 31 is to be coated it carries an undeveloped image pattern to which is to be applied an even coating of particulate image-forming magnetically responsive material hereinafter referred to as powder 33, which may be supplied to the roll assembly 10 from a supply disposed in the hopper-like tray 30.

The tray 30 has an adjustable doctor blade 34 mounted along a forward upturned lip which permits spatial adjustment relative to the outer surface of sleeve 20. In operation, depending on how compressed or how much powder is desirable at the nip area between the sleeve 20 and surface 31, the doctor blade 34 may be adjusted between 0.010 inch and 0.05 inch. The position of the sleeve 20 is also adjustable toward and away from the surface 31 to afford light contact between the powder 33 and the surface 31 or some compressive pressure on the powder at the interface between the sleeve and the surface. Suitable means, such as slots in frame members 11 and 12 and pivoted mounting brackets, may be provided as illustrated in the drawing to permit movement of the sheaths 13 and 23 relative to the surface to be coated; and suitable means, such as a screw adjusted lever arm key to shaft 13, permits rotatable adjustment of shaft 13. This adjustment of shaft 13 allows accurate positioning of either a radial edge to be normal to the surface to be coated or permits the rotation of shaft 13 to position the center of a magnetic member 14 or 15 nearest the surface to be coated.

The magnetic members 14 and 15 are alternately magnetically polarized elongate members which are generally shaped as sectors of a ring or sectors of a hollow cylinder having radially inner faces 35 concavely curved and convex radially outer surfaces 36 joined by radially extending edge walls 37. The shape of the members result in some vagaries in the dimensions and, although the members generally contact each other, a slight gap may exist in the array between one or more members and not disturb the performance. The members 15 are polarized to have a magnetic pole on the outer surface facing an inner face; for example, the north pole indicated at N is on the outer surface 36, and the south pole indicated at S is along the inner face 35. The members 14 would be oppositely polarized with N on the inner face S along the outer surface.

The members 14 and 15 are formed by extrusion of a non-magnetic matrix which may be a resinous or plastic composition, an elastomeric semi-solid, or viscous liquid, capable of hardening, setting or being cured to a solid state in which is evenly dispersed anisotropic ferrite domain-sized particles, which particles are capable of achieving physical orientation when acted upon by internal shear stresses. Examples of the particles are certain fine grain permanent magnet materials particularly the ferrites of barium, lead and strontium which are easily magnetized to saturation. The matrix may be natural rubber with compound agents, plasticizers, vulcanizing agents, and the like to provide the hardness of the matrix desired, or may be a thermoplastic or thermo-setting material, as for example polyvinyl chloride. Preferably the ferrite particles are oriented such that each particle (as illustrated diagrammatically in FIGURE 3 at 40) is positioned with its magnetic poles positioned radially relative to each other.

An even number of the wedge-shaped members 14 and 15 are alternately placed in a circular array about each member and extends axially along the shaft 13 for the length of application desired. The members 14 and 15 provide, with a 1 to 1 ratio between the radial dimension and the circumferential dimension, a surprisingly high flux density and, in the preferred annular array, provide a circumferential field with strong radial and tangential components. In FIGURE 4 the flux density about the array of magnetic members 14 and 15 is plotted in gauss with the radial field component plotted in solid lines and the tangential field component plotted in dotted lines. The maximum radial field exists along a radial line bisecting the magnetic members, and the plot illustrates the flux density at the poles of 500 gauss. An optimum design is between 500 and 750 gauss at the poles. The tangential flux density peaks between the magnetic members and is illustrated on the plot at 300 gauss.

FIGURE 5 shows a graph along the length of the magnetic members and illustrates the readings above one pole as it is scanned from end to end. This graph illustrates the uniformity of the magnetic field along the entire length of the magnetic members and that the field falls only at the ends. This uniformity of field affords a very uniform powder application by a roll assembly constructed in accordance with this invention.

In operation, rotation of the sleeve 20, which sleeve has a smooth outer surface with a diameter of approximately 1.250 inches and inside diameter of 1.180 inches, with a minimum clearance about the surface of the magnetic members of about .005 inch, carries the developing powder 33 from the tray 30 across the doctor blade 34. The powder particles appear to tumble under the effects of the changing directions of the magnetic field and move in the direction of rotation of the sleeve 20. The powder appears as a dark stripe on the areas of the sleeve above the poles and gray above the joint between the magnetic members. As the orientation of the ferromagnetic particles achieve a more exacting radial orientation in the matrix, the gray stripe is reduced to a line. The tumbling powder stands on the sleeve surface as “tree” rows and, when carried by clockwise rotation of sleeve 20 toward the clockwise rotating or oppositely moving surface 31, they will contact the surface to be deposited in the desired manner.

The spacing between the outer sleeve 20 and surface 31 relative to the spacing between doctor blade 34 and the sleeve will determine the amount of powder per unit area placed in contact with the surface 31. The uniform axial field along the sleeve provides for uniform coverage across the surface 31 to be coated. In most applications the surface to be coated has a width of from 8½ to 14 inches, or the width or length of copy sheets.

Magnetic members formed of metallic alloys such as for example the materials sold under the trade name “Alnico” cannot be produced with a uniform field in lengths greater than 3 to 6” because, during the heat treatment, they warp and are unusable in this type of application. The short segment require to be cemented together; and at each joint the uniformity of the field along the axis of the roller is disrupted because the field falls off sharply at the ends of the segments and the segments are not identical. The uniformity achieved by a developing roll assembly formed in accordance with the present invention appreciably reduces the variations in powder buildup on the roller or variations in density on the developed image.

Having thus described the present invention with reference to one embodiment, it is realized that one skilled in the art may make certain modifications without departing from the spirit and scope of this invention as defined in the pending claims.

What is claimed is:

1. An applicating roller for placing a uniform layer of magnetically responsive dry particulate material in contact with a surface moved past the peripheral surface
of said roller, said applicating roller comprising a shaft of high magnetic permeability material, a plurality of elongate, generally sector-shaped in cross section magnetic members formed of fine grain permanent magnet material dispersed in a non-magnetic immobilizing matrix, which members are positioned with the edges thereof generally radial and in side-by-side relation to define a circular array around said shaft, and the radially inner and radially outer faces of each member being arcuate with said radially inner and radially outer faces of adjacent members in said array being oppositely polarized, a uniform non-magnetic hollow cylindrical sleeve positioned over said array of magnetic members and extending axially relative to said shaft, and means for mounting said sleeve and said shaft for relative rotation to carry a quantity of said particulate material on the outer surface of said sleeve.

2. An applicating roller as claimed in claim 1 wherein said dispersed material in the magnetic members is oriented antistatic domain size particles of a permanent magnet material.

3. An applicating roller as claimed in claim 1 wherein said dispersed material consists of substantially domain size particles of material selected from the class consisting of the ferrites of barium, strontium and lead.

4. An applicating roller as claimed in claim 1 wherein eight magnetic members form a circular array about the shaft.

5. An applicating roller as claimed in claim 1 wherein said sleeve is electrically conductive.

6. An applicating roller as claimed in claim 1 wherein each of said magnetic members has an axial length of between 8 and 14".

7. A powder applicator comprising in combination: (a) an applicating roller for applying magnetically responsive dry powdered material onto a surface moved past the periphery of said roller, said applicating roller comprising a shaft formed of high magnetic permeability and low loss material; a plurality of elongate generally truncated sector-shaped magnetic members formed of ferrite permanent magnet substantially domain sized particles oriented in a non-magnetic matrix, which members are arranged in side-by-side contacting relation and form a circular array about said shaft with radially outer surfaces of adjacent magnetic members having opposite polarity; a thin-walled hollow cylindrical sleeve formed of non-magnetizable material positioned about and approximates to said array of magnetic members; and means for mounting said sleeve and said shaft for relative rotation, each of said magnetic members extending along a substantial portion of said shaft and covered by said cylinder;

(b) a tray for storing a supply of a said developer material in which said sleeve may come in contact; and

(c) means for rotating said sleeve and said shaft relative to each other to carry developer material from said tray about the surface of the sleeve into contact with surface to be developed.

8. A powder applicator as claimed in claim 7 wherein said shaft and magnet members are fixed and said sleeve is rotated about said shaft.

9. A powder applicator as claimed in claim 7 wherein said sleeve has an electrically conductive outer surface and is connected to a source of electrical potential.

10. A powder applicator as claimed in claim 8 wherein said sleeve has an electrically conductive outer surface and is connected to a source of electrical potential.

11. A powder applicator as claimed in claim 10 wherein means are provided for adjusting the position of said shaft.

12. An applicator for developing an image on a surface with a pigmented finely divided dry magnetically responsive developer material comprising in combination, a tray adapted to receive said developer material, an applicating roller positioned relative to said tray for moving said developer material out of said tray, said applicating roller comprising a shaft of high magnetic permeability material, a plurality of elongate, generally sector-shaped in cross section, magnetic members which are formed of oriented fine grain permanent magnet material dispersed in a non-magnetic immobilizing matrix and which have longitudinal edges which are generally radial and positioned with said edges in side-by-side contacting relation to form an arcuate array on the outer circular periphery of said shaft, said members also having arcuate radially inner and radially outer faces with said radially inner and radially outer faces of adjacent members in said array being oppositely polarized, and a uniform non-magnetic hollow cylindrical sleeve positioned over said array and mounted for rotation relative to said shaft and said magnetic members and rotatable relative to said tray, a doctor blade adjustably mounted on an edge of said tray adjacent the periphery of said sleeve for limiting the amount of said developer material which may be carried by said sleeve out of said tray upon rotation of said sleeve, and means for rotating said sleeve.

13. An applicator as defined in claim 12 wherein a tangential magnetic field is formed between each of said adjacent magnetic members directly above said contacting edges where the field gradient is large, which field on the surface of said sleeve has a value of at least about 300 gauss.

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