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(54) **Developer roll and process for making it**

(57) A drawn stainless steel magnetic development roll (78) having a coating-free developer-receptive surface. A process for making such a development magnetic roll draws it from stainless steel, by a cold drawing process through die (90). The stainless steel rolls (78) are drawn to have a desired grooved surface (92) finish, diameter, straightness, runout, and other mechanical tolerance requirements.

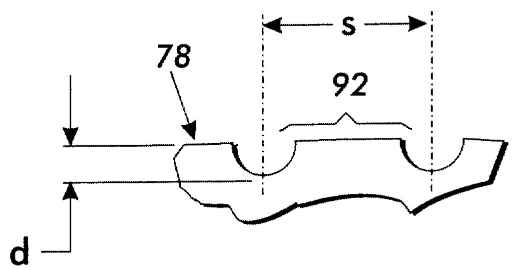

FIG. 6

EP 1 107 074 A2

Description

[0001] This invention relates generally to a development apparatus for ionographic or electrophotographic imaging and printing apparatuses and machines, and more particularly is directed to a magnetic developer roll having a stainless steel sleeve.

[0002] Generally, the process of electrophotographic printing includes charging a photoconductive member to a substantially uniform potential to sensitize the surface thereof. The charged portion of the photoconductive surface is exposed to a light image from either a scanning laser beam, an LED source, or an original document being reproduced. This records an electrostatic latent image on the photoconductive surface. After the electrostatic latent image is recorded on the photoconductive surface, the latent image is developed. Two-component and single-component developer materials are commonly used for development. A typical two-component developer comprises magnetic carrier granules having toner particles adhering triboelectrically thereto. A single-component developer material typically comprises toner particles. Toner particles are attracted to the latent image, forming a toner powder image on the photoconductive surface. The toner powder image is subsequently transferred to a copy sheet. Finally, the toner powder image is heated to permanently fuse it to the copy sheet in image configuration.

[0003] A non-interactive magnetic brush development method employs permanently magnetized carrier beads operating with a rotating multipole magnet within a conductive and nonmagnetic sleeve, such as of aluminum or stainless steel. Magnetic field lines form arches in the space above the sleeve surface and form chains of carrier beads. The developer mass is held in contact with the sleeve and out of direct contact with the photoreceptor by gradients provided by the multipole magnet. As the core rotates in one direction relative to the sleeve, the magnetic field lines beyond the sleeve surface rotate in the opposite sense, moving carrier in a tumbling action which transports developer material along the sleeve surface. The strong mechanical agitation very effectively dislodges toner particles generating a rich powder cloud which can be developed to the adjacent photoreceptor surface under the influence of development fields between the sleeve and the electrostatic image.

[0004] In magnetic brush developing, a hollow tube or roll containing fixed magnets is used to move the developer to the photoreceptor. As the tube, such as of stainless steel, rotates around the magnets and through a sump of developer, the magnets attract the metallic carrier beads in the developer. The carrier beads closest to the magnetic roll become magnetized, enabling more carrier beads to stick. As a result, the developer builds up to form bristles like a brush. This attraction of developer to the magnetic roll is called a magnetic brush. The magnetic force on the magnetic roll is just enough to allow the developer to build up on the roll. As the magnetic roll or tube continues to rotate, it moves the developer brush past a trim bar. The trim bar limits the length of the brush by shearing off the portions of the developer bristles that extend beyond a certain length. The trim bar ensures that a desired bead height is obtained.

[0005] Conventional stainless steel developer rolls, sleeves or tubes, generally extruded or drawn, have smooth surfaces which are not sufficiently receptive to electrophotographic developer materials. Therefore their manufacture requires the subsequent step of overspraying the surface with a developer-receptive layer such as of tungsten carbide. This substantially increases the material cost and manufacturing cost of such rolls. In addition such coatings are not wear/scratch resistant over extended time periods. Thus, these coatings permit wear/scratching to form on the toner transporting means, which in turn adversely affects image copy quality. Also, toner particles can permanently adhere to the surface of such coatings which can result in undesirable high background deposits on the resulting developed images.

[0006] The present invention provides a process for making a drawn stainless steel development magnetic roll having a coating-free developer-receptive surface. The present invention provides a process for making a development magnetic roll drawn from stainless steel and having a developer-receptive, non-abrasive integral surface.

[0007] The present invention further provides a process of making a magnetic roll having improved stability, durability, toner tribo charging characteristics and toner loading characteristics. The invention provides an electrophotographic printing system having a developer sump with an uncoated magnetic roll that is of lower cost and ease to manufacture.

[0008] The present invention also provides a magnetic roll and a process for making a magnetic roll by cold drawing stainless steel rolls having a desired grooved surface finish, diameter, straightness, runout, and other mechanical tolerance requirements.

[0009] A particular embodiment in accordance with this invention will now be described with reference to the accompanying drawings; in which:-

Figure 1 is a schematic elevational view of an illustrative electrophotographic printing or imaging machine or apparatus incorporating a development roll having the features of the present invention therein;

Figure 2 is a developer station of Figure 1;

Figure 3 is a schematic illustration of the cold-drawing of a stainless steel developer roll, tube or sleeve by pulling it through a die having surface-scoring members;

Figure 4 is a plan view, in partial cross-section, of a non-magnetic stainless steel developer roll, tube or sleeve according to the present invention;

Figure 5 is a cross-sectional view taken along the line 5-5 of Fig. 4; and,

Figure 6 is a cross-sectional view of the section 6 of the roll, tube or sleeve of Fig. 5.

[0010] Referring to FIG. 1 of the drawings, there is shown a xerographic type reproduction machine 8 incorporating the magnetic grooved stainless steel roll of the present invention, designated generally by the numeral 80. Machine 8 has a suitable frame (not shown) on which the machine xerographic components are operatively supported. Briefly, and as will be familiar to those skilled in the art, the machine xerographic components include a recording member, shown here in the form of a rotatable photoreceptor 14. In the exemplary arrangement shown, photoreceptor 14 comprises a drum having a photoconductive surface 16. Operatively disposed about the periphery of photoreceptor 14 are a charge corotron 18 for placing a uniform charge on the photoconductive surface 16 of photoreceptor 14; an exposure station 22 where the previously charged photoconductive surface 16 is exposed to image rays of a document 9 being copied or reproduced; development station 24 where the latent electrostatic image created on photoconductive surface 16 is developed by toner; and transfer detack corotrons 28 and 30 for assisting transfer of the developed image to a suitable recording substrate material such as a recording sheet 32 brought forward in timed relation with the developed image on photoconductive surface 16. Residual toner is removed from the photoconductive surface at cleaning station 34.

[0011] Recording sheets 32a are brought forward to the transfer area by feed roll pair 40, sheet guides 42,43 serving to guide the sheet through an approximately 1800 turn prior to the transfer area. Following transfer, the sheet 32 is carried forward to a fusing station 48 where the toner image is fixed by fusing roll 49. After fusing, the recording sheet 32 is discharged to an output tray.

[0012] Further details of the construction and operation of development station 22 of the present invention are provided below referring to FIG.2. Development station 24 includes a developer housing 65 in which a toner dispensing cartridge 66 is rotatably mounted so as to dispense tone particles downward into a sump area assisted by the augers 67 and 68.

[0013] Continuing with the description of operation of developing station 24, a developing member 80 is disposed in predetermined operative relation to the photoconductive surface 16 of photoreceptor 14, the length of developing member 80 being equal to or slightly greater than the width of photoconductive surface 16, with the functional axis of developing member 80 parallel to the photoconductive surface and oriented at a right angle with respect to the path of photoreceptor 14. Advancement of developing member 80 carries the developer blanket into the development zone in proximal relation with the photoconductive surface 16 of photoreceptor 14 to develop the electrostatic image therein.

[0014] With continued reference to Figure 2, augers 67 and 68, are mounted rotatably to mix and transport developer material. The augers have blades extending spirally outwardly from a shaft. The blades are designed to advance the developer material in the axial direction substantially parallel to the longitudinal axis of the shaft. As successive electrostatic latent images are developed, the toner particles within the developer material are depleted. Fresh toner particles are furnished to the developer material in the chamber from the toner dispenser. The augers in the chamber of the housing mix the fresh toner particles with the remaining developer material so that the resultant developer material therein is substantially uniform with the concentration of toner particles being optimized. In this manner, a substantially constant amount of toner particles are maintained in the chamber of the developer housing.

[0015] The present magnetic member 80 includes a hollow drawn stainless steel tube or sleeve 78 enclosing a magnetic assembly 81 containing fixed magnets which are used to move the developer to the photoreceptor. As the tube rotates about the magnets and through a sump of developer, the magnets attract the metallic carrier beads in the developer. The carrier beads closest to the magnetic roll become magnetized, enabling more carrier beads to stick. As a result, the developer builds up to from bristles like a brush. This attraction of developer to the magnetic roll is called a magnetic brush. The magnetic force on the magnetic roll is just enough to allow the developer to build up on the roll. The magnetic force has little effect on the charge either on the toner or on the photoreceptor. As the magnetic roll or tube continues to rotate, it moves the developer brush past a trim bar 90. The trim bar limits the length of the brush by knocking off the portions of the developer bristles that extend beyond a certain length. The trim bar ensures that a desired bead height is obtained.

[0016] According to the present invention, and as illustrated by Fig. 3, a non-magnetic 300 series stainless steel sleeve having the desired inner and outer diameters is formed by a conventional cold-drawing method and drawbench apparatus used for producing hollow, tubular stainless steel pipes and conduits. In such process a seamed or seamless stainless steel sleeve is first cold-drawn by pulling it on a mandrel or table through a circular draw die 90 of the desired diameter to simultaneously or subsequently form a plurality of axial depressions or straight grooves 92 having the desired depth and uniform spacing around the outer circumference of the formed sleeve. The grooves 92 are formed by displacing material on the outer surface of the sleeve 78 by a corresponding plurality of metal displacement members 91 projecting from the inner surface of the die 90, to form the grooves 92 as the sleeve 78 is cold-drawn to the desired diameter.

[0017] The depth and radius of the grooves 92 generally is between about 0.01mm and 0.5mm, preferably between about 0.1mm and 0.45mm, and most preferably about 0.4mm, but deeper grooves can be formed to allow for any secondary surface-machining operation necessary to meet specifications.

[0018] As illustrated by Figs. 4, 5 and 6, the present non-magnetic stainless steel developer rolls 78 as illustrated have a length "L" of about 412mm, an outer diameter "O.D." of about 63.4mm, an inner diameter of about 60.4mm, and a wall thickness of about 3mm in areas between the longitudinal grooves 92.

[0019] In the illustrated embodiment, the grooves 92 are hemispherical in cross-section is shown in Fig. 6, have a depth "d" of about 0.4mm and are uniformly spaced from one-another, center-to-center, by a space "s" of about 1.5mm to 2.5mm around the circumference of the roll 78. Thus, with the dimensions given, there are about 105 straight grooves 92 evenly spaced by about 1.9mm and substantially parallel along the length of the roll.

[0020] The grooves 92 illustrated by Fig. 6 are formed as illustrated by Fig. 3, using hemi-cylindrical metal displacement members 91 which displace the cold drawn aluminum from the surface of the roll to increase the wall thickness in areas underlying the grooves. For this reason counterbores 93 are made inwardly from each end of the drum, tube or sleeve 92 and extending a distance of about llmm to provide uniform inner diameter portions of about 60.6mm for mounting purposes. Generally the wall thickness is between about 2.5mm and 3.5mm, most preferably about 3mm.

[0021] The present process is quicker and less expensive than the prior conventional method of machining the outer surface of stainless steel sleeves or tubes, and then spraying with a tungsten carbide layer in order to produce enough surface geometry or roughness to help transport developer material. The present process produces this desired result in an integral, un-coated drawn and grooved stainless steel sleeve or tube, while avoiding the need for abrasive coatings which can deteriorate, wear away and shed over prolonged periods of use.

[0022] Also, the present cold-drawing process enables the reduction of the thickness of the wall of the present stainless steel sleeves or tubes, while meeting the requirements of high mechanical strength.

[0023] Maximum Electrical Conductivity Requirements: The developer roll has a requirement to be conductive, as cited below, but not too conductive. The eddy current heating of the shell imposes this limit. Eddy currents are the result of moving a conductor through a magnetic field, similar to operation of an electrical generator.

[0024] Eddy current heating scales with a) the square of the relative speed between the magnet and the shell, b) with the square of the radial component magnitude of the magnetic field, c) approximately linear with the shell wall thickness, and d) inversely linear with the electrical resistivity (linear with the conductivity).

[0025] Higher speed machines, i.e., 100+PPM process capability, using two component development technologies, produce higher developer roll rotational velocities. This in turn requires stronger magnetic field profiles to maintain control over the developer material. And both of these effects in turn result in potentially higher eddy current losses or head loads with in the developer housing.

[0026] For traditional aluminum developer rolls or shells, experimental measurements indicated eddy current losses on the order of 15 or more watts per developer roll. As a result, non-magnetic stainless steel shells are preferred since they result in significant reduction of the eddy current losses.

[0027] Recent modeling work indicates that for the developer housing as in Fig. 2, magnetic configuration running at a surface speed of 1270 mm/sec{50 ips}, the eddy current losses should be about 16 watts for an aluminum shell and only about 4 watts for a stainless steel shell.

[0028] Similar computations have been done for a TurboMaze type of development system with eddy losses of 12 watts for an aluminum shell and only 5 watts for a non-magnetic stainless steel shell. This modeling assumed a 30.8 mm ID tube, with 0.9 mm thick walls, a 0.25 mm clearance to the mag roll assembly, 16 keystones poles each 22.5 degrees wide and 7 mm deep at a Br of 2.250 Koe, with the magnet rotating relative to the shell at 1000 rpm.

[0029] Thin Wall Requirement: The thin wall requirement arises from several objectives. First, the thinner the wall, the closer the magnet assembly can be located relative to the developer material. Since magnetic fields due to any magnetic assembly decrease at least as rapidly as the 3rd power of the distance from the magnetic, small changes in wall thickness are significant. Second, the thinner the wall thickness, the lighter the overall part weight. This provides benefits in a) lower start up inertial loads hence lower initial drive torque requirements and b) in lower system weight and hence potentially easier serviceability.

[0030] High Mechanical Strength: The mechanical strength requirements arise from the need to maintain dimensional tolerances over the entire length and circumference of the roll. The magnets and developer material interact and effectively apply a significant and non-uniform pressure on the exterior surface of the shell. With the above cited desired thin walls, a high mechanical strength is required to prevent deflection of the tube and maintain the required xerographic tolerances.

Claims

1. Hollow magnetic developer roll for use in an electrophotographic imaging machine, comprising a drawn hollow non-magnetic stainless steel roll having formed in the outer surface of the wall thereof a plurality of narrow axial grooves, each having a

maximum depth of between about 0.01mm and 0.5mm, uniformly-spaced around the outer periphery of the roll.

2. A developer roll according to claim 1, in which said axial grooves are hemispherical in cross-section.

3. A process for producing a hollow stainless steel magnetic developer roll for use in an electrophotographic imaging machine and having improved receptivity for electrophotographic developer materials, comprising cold-drawing a hollow non-magnetic stainless steel roll to the desired wall thickness and cold-drawing a plurality of narrow axial grooves in the outer surface of the wall thereof, each having a maximum depth of between about 0.01mm and 0.5mm, uniformly spaced around the outer periphery of the roll.

4. A process according to claim 3, in which said axial grooves are formed by the displacement of stainless steel from the outer surface of the roll during the cold-drawing step.

5. A process according to claim 3 or 4, which comprises cold-drawing axial grooves which are hemispherical in cross-section.

6. A developer roll according to claim 1 or 2 or a process according to claim 3, 4, or 5, in which said axial grooves have a maximum depth between about 0.lmm and 0.45mm and preferably have a maximum depth of about 0.4mm.

7. A developer roll or a process according to any one of the preceding claims, in which said axial grooves are uniformly spaced from each other by a distance between about 1.5mm and 2.5mm, and preferably by a distance of about 1.9mm.

8. A developer roll or process according to any one of the preceding claims, in which the thickness of the wall is between about 2.5mm and 3.5mm.

9. A developer roll or process according to any one of the preceding claims, in which the opposed ends of the hollow roll are counterbored inwardly a short distance to provide them with an exact cylindrical configuration.

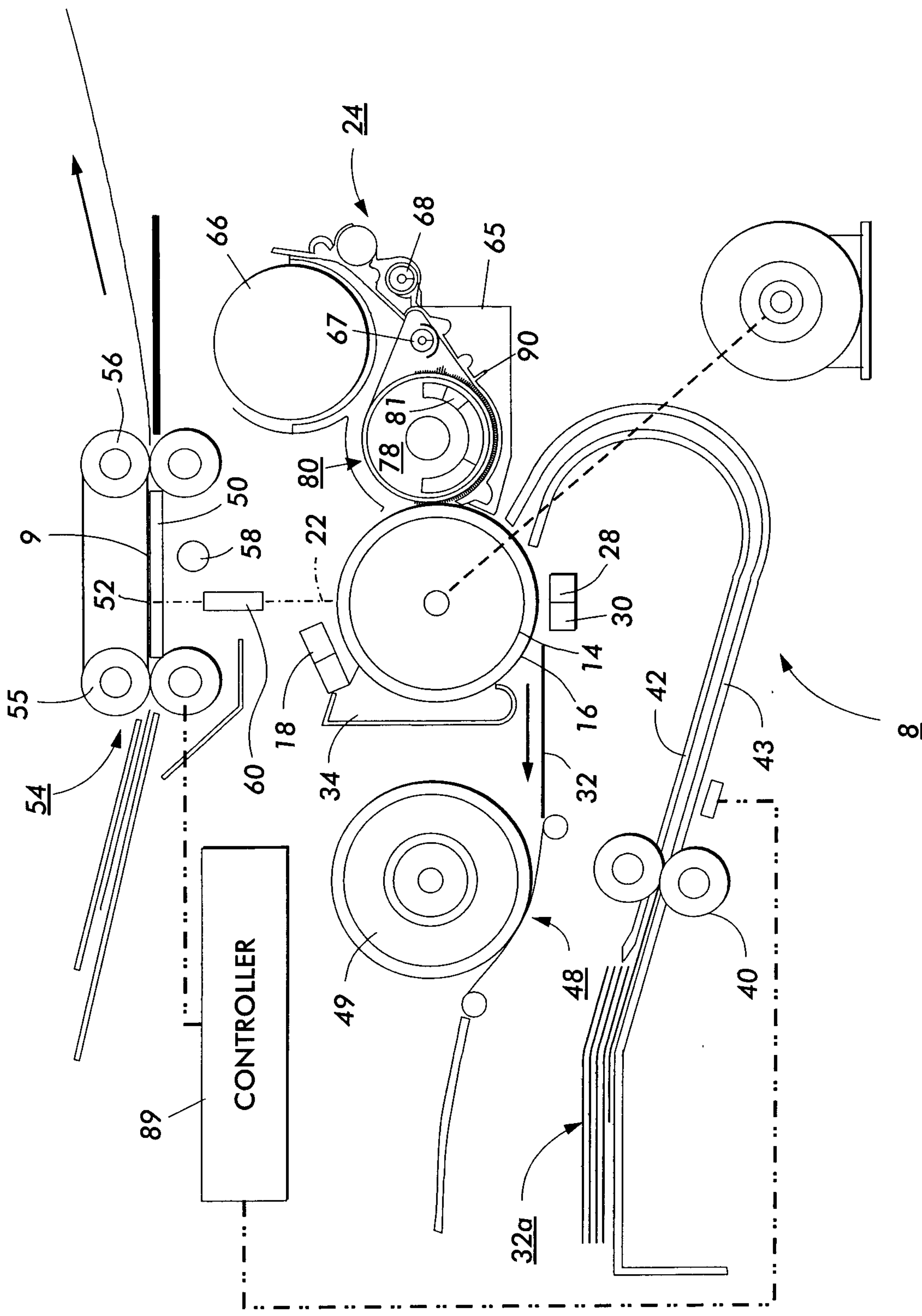
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FIG. 1

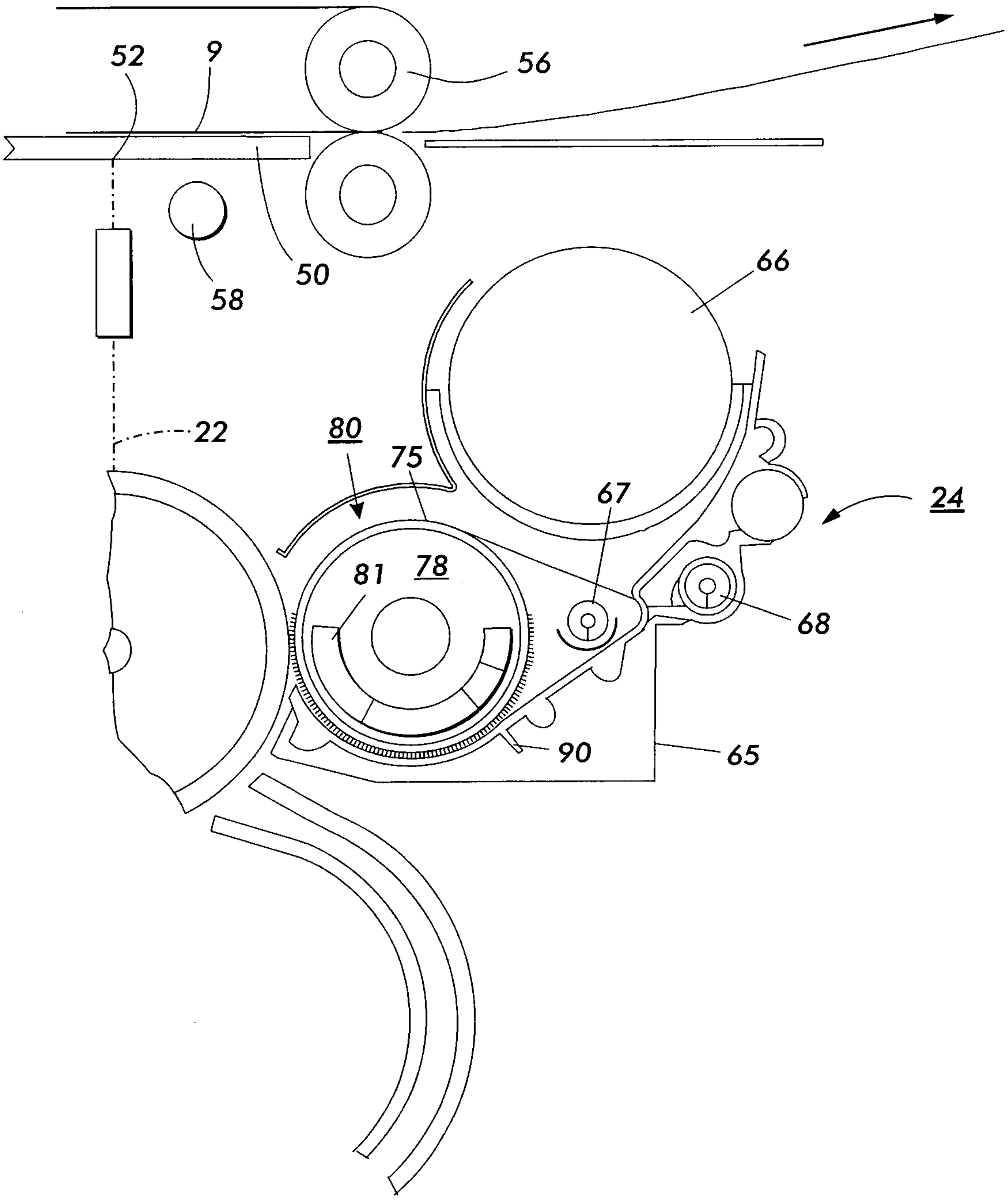

FIG. 2

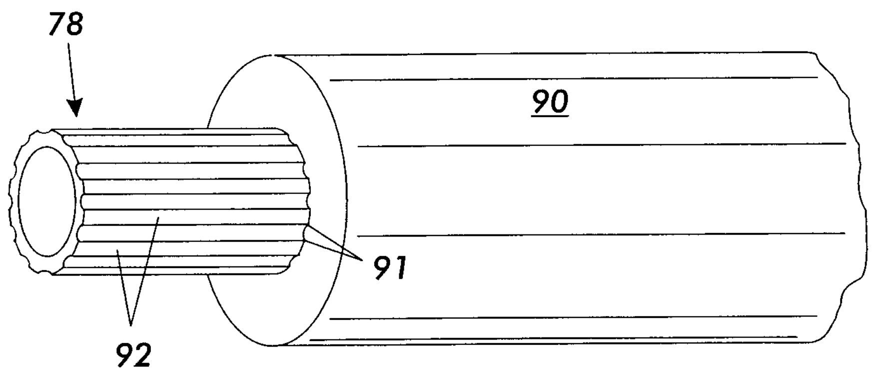

FIG. 3

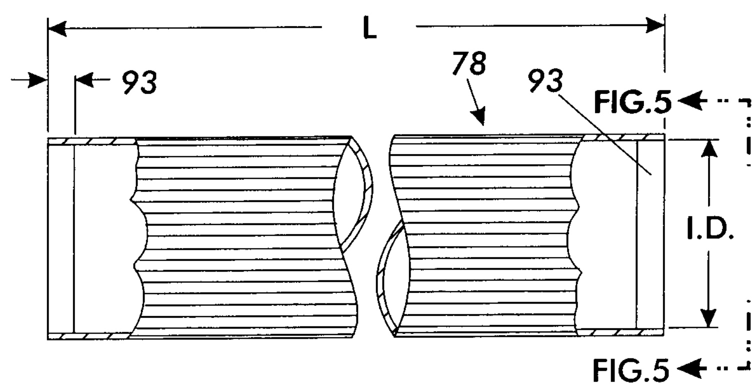

FIG. 4

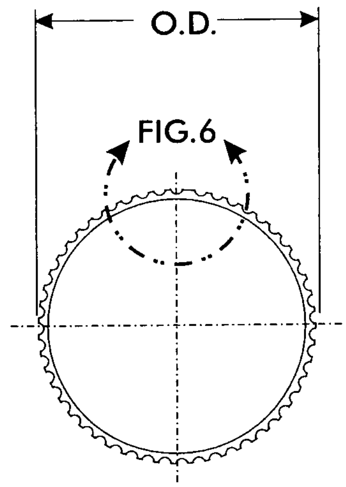

FIG. 5

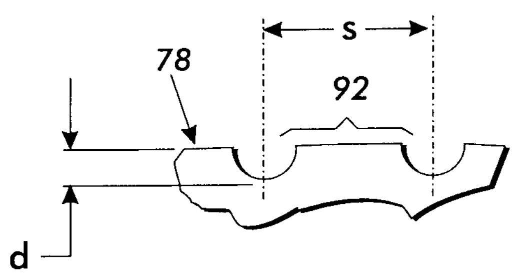

FIG. 6