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(54) **Toner supply roll and production method therefore**

(57) A toner supply roll comprises a shaft (1) and a soft polyurethane sponge layer (2) provided on an outer circumferential surface of the shaft, wherein not less than 90% of cell walls defining boundaries between respective adjacent cells have openings. The soft polyurethane sponge layer of the toner supply roll is of an open-cell foam structure in which the cells are three-dimensionally connected to one another via the openings in the cell walls, so that air contained in the sponge layer smoothly flows out when the sponge layer is depressed. Therefore, the sponge layer has a lower hardness than a soft polyurethane sponge layer of a closed-cells foam structure. Since not less than 90% of the cell walls defining the boundaries between the respective adjacent cells have openings, toner fluidity can properly be maintained. Therefore, the toner supply roll can minimise degradation of the toner during prolonged use and stably maintain toner scrapability and toner supplying capability, thereby ensuring formation of high quality images for an extended period of time.

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Description

[0001] THE PRESENT INVENTION relates to a toner supply roll for use in a developing unit of an image forming apparatus such as copying machine, a printer or a facsimile machine.

[0002] Conventionally, an image forming apparatus such as a copying machine, a printer or a facsimile machine is adapted to form an electrostatic latent image on an image carrier, such as an electro-photographic, photo-conductive material or an electro-statographic dielectric material, and to develop the electrostatic latent image into a visible toner image. The developing unit of the apparatus incorporates a toner supply roll for supplying a toner (developer) from a hopper onto the image carrier.

[0003] In recent years, toners (particularly, non-magnetic mono-component colour toners) having smaller particle diameters and lower melting points have been employed for the formation of higher quality images at higher rates. Therefore, imaging failures such as fogging, reduction in image density and formation of a ghost image are more problematic than ever, these failures being caused by changes in the electrostatic characteristics and fluidity of the toner which occur due to degradation of the toner during use. A non-magnetic mono-component toner developing system employs a toner supply roll which comprises a shaft and a soft polyurethane sponge layer (urethane foam layer) provided on the outer circumferential surface of the shaft. the soft polyurethane sponge layers maybe of a closed-cell foam structure in which individual cells are predominantly independent of each other, or of an open-cell foam structure in which some of the cells communicate with one another via openings formed in the cell walls. Typically, a substantial proportion of the cells in an open-cell foam structure are actually closed-cells.

[0004] In use, cells on the surface of the soft polyurethane sponge layer of a closed-cells foam structure are liable to become clogged with degraded toner, so that the toner fluidity is reduced. This reduced fluidity prevents the toner from being smoothly scraped or supplied, which thereby results in fogging, reduction in image density, formation of a ghost image, and like imaging failures. The contrary, in the case of the soft polyurethane sponge layer having the open-cell foam structure, the toner easily flows in the surface of the roll, so that the roll surface is constantly supplied with fresh toner and has a satisfactory scrapability. In addition, such a sponge layer has a lower hardness. For this reason, the soft polyurethane sponge layer of the open-cell foam structure is mainly employed for toner supply rolls currently used in practical applications.

[0005] However, the toner fluidity in the soft polyurethane sponge layer of the open-cell foam structure is liable to be reduced during a prolonged use because toner is gradually accumulated in the sponge layer. This degrades the toner, and reduces the toner scrapability and the toner supplying capability of the toner supply roll. As a result, the aforesaid imaging failures will tend to occur, particularly near the end of the service life of the toner supply roll.

[0006] In view of the foregoing, it is an object of the present invention to provide a toner supply roll which ensures formation of high quality images for an extended period of time, and to provide a production method for such a toner supply roll.

[0007] In accordance with a first aspect of the present invention to achieve the aforesaid object, there is provided a toner supply roll comprising a shaft, and a soft polyurethane sponge layer provided on an outer circumferential surface of the shaft, the sponge layer defining a plurality of adjacent cells wherein not less than 90% of cell walls defining boundaries between respective adjacent cells have openings.

[0008] In accordance with a second aspect of the present invention, there is provided a method of producing a toner supply roll, the method comprising the steps of forming a soft polyurethane sponge layer on an outer circumferential surface of a shaft by foaming a polyurethane material, the sponge layer defining a plurality of adjacent cells, and jetting a high pressure gas onto the soft polyurethane sponge layer so that no less than 90% of cell walls defining boundaries between respective adjacent cells in the soft polyurethane sponge layer have openings.

[0009] As a result of intensive studies conducted mainly on a soft polyurethane sponge layer to obtain a desired toner supply roll, the inventors of the present invention have found that, if the soft polyurethane sponge layer is of the open-cell foam structure, but only a low percentage of cell walls defining boundaries between respective adjacent cells in the sponge layer have openings, the sponge layer fails to ensure sufficient toner fluidity. As a consequence, the cells are liable to be clogged with the toner and thereby promote the degradation of the toner. The inventors have further conducted studies on the openings in the cell walls and consequently found that, if not less than 90% of the cell walls defining the boundaries between the respective adjacent cells have openings, the toner fluidity is properly maintained so that the degradation of the toner during prolonged use can be minimised. In addition, such a toner supply roll stably maintains toner scrapability and toner supply capability, whereby formation of high quality images can be ensured for an extended period of time. Thus, the inventors have attained the present invention.

[0010] The toner fluidity can be stably maintained during prolonged use, even if the average cell diameter D is reduced, if the soft polyurethane sponge layer has an air permeability A (cc/min.cm²) and an average cell diameter D (μm) which satisfy a relationship represented by $A/D > 7$.

[0011] Furthermore, when the average cell diameter of the soft polyurethane sponge layer is within a particular range such as 100 μm to 500 μm, reduction in the toner fluidity and uneven toner supply can be further suppressed.

Where the soft polyurethane sponge layer has a hardness within a particular range, such as 50 g to 500 g, reduction in the toner scrapability and degradation of the toner can be further suppressed.

[0012] The foregoing and other objects, features and effects of the present invention will become more apparent from the following description of the preferred embodiment with reference to the attached drawings, in which:

FIGURE 1 is a diagram, partially in section, showing an exemplary toner supply roll according to the present invention,

FIGURE 2 is a sectional view illustrating an exemplary mould employed in a production method for the toner supply roll according to the present invention,

FIGURE 3 is a diagram showing a method for measuring the air permeability of the soft polyurethane sponge layer of the toner supply roll, and

FIGURES 4 (a) and 4 (b) are a plan view and a side view, respectively, showing a method for measuring the hardness of the soft polyurethane sponge layer of the toner supply roll.

[0013] Embodiments of the present invention will be described in detail.

[0014] As shown in Figure 1, a toner supply roll according to the present invention comprises a shaft 1 and a soft polyurethane sponge layer 2 provided on an outer circumferential surface of the shaft 1. The soft polyurethane sponge layer 2 contains cells 3, three-dimensionally connected to one another via openings formed in cell walls 4. In Figure 1, reference numeral 6 denotes a cell frame.

[0015] The construction of the shaft 1 is not particularly limited, but a solid metal core bar or a hollow metal cylinder may be employed, as the shaft 1. Examples of a material for the shaft 1 include stainless steel, aluminum and plated iron.

[0016] A polyurethane material for the soft polyurethane sponge layer 2 is formed from materials comprising a polyol component and an isocyanate component of types which are commonly employed for the production of a soft polyurethane foam. Examples of the polyol component include polyether polyols, polyester polyols and polymer polyols, which may be used either alone or in combination. The isocyanate component is not particularly limited as long as it is a polyisocyanate having two or more functional groups, and examples thereof include 2,4- or 2,6-tolylene diisocyanate (TDI), o-toluidine diisocyanate (TODI), naphthylene diisocyanate (NDI), xylylene diisocyanate (XDI), 4,4'-diphenylmethane diisocyanate (MDI), carbodiimide-modified MDI, polymethylene polyphenyl isocyanate and polymeric polyisocyanates, which may be used either alone or in combination.

[0017] As required, a cross-linking agent, a foaming agent (water, a low boiling-point substance, a gas or the like), a surfactant, a catalyst, a flame retardant, a filler, a conductivity imparting agent, an anti-static agent and the like may be blended with the polyurethane material including the polyol component and the isocyanate component.

[0018] The soft polyurethane sponge layer 2 is of an open-cell foam structure in which the cells defined by the cell frame 6 are three-dimensionally connected to one another and not less than 90% of the cell walls 4 defining boundaries between respective adjacent cells have openings 5. If the percentage is lower than 90%, the sponge layer fails to ensure sufficient toner fluidity and, therefore, is liable to be clogged with the toner. Clogging promotes the degradation of the toner, making it impossible to ensure formation of high quality images for an extended period of time.

[0019] The percentage of the cell walls having openings with respect to the total cell walls defining the boundaries between the respective adjacent cells is determined, for example, in the following manner. The soft polyurethane sponge layer is first cut into a section, and then the number of the cell walls having openings in the section is counted with the use of an optical microscope as well as the total number of cells. The percentage of the cell walls having openings with respect to the total number of the cell walls is then calculated. The percentage is an average of values of the percentage obtained on several sections taken in two directions, i.e., axially and circumferentially (or perpendicularly to the axis) of the toner supply roll.

[0020] The toner supply roll according to the present invention can be produced, for example, in the following manner. First, as shown in Fig. 2, a mold is prepared which comprises a hollow cylindrical member 21 having a length substantially equal to the length of the soft polyurethane sponge layer 2 of the toner supply roll, and caps 22, 23 for closing opposite ends of the hollow cylindrical member 21. When the opposite ends of the hollow cylindrical member 21 of the mold are closed by the caps 22, 23 while the shaft 1 is positioned within the hollow cylindrical member 21 and supported by the caps 22, 23, a mold cavity 24 which provides an intended final shape (outer diameter) of the toner supply roll is defined in the mold. The polyurethane material is injected into the mold cavity 24 and then foamed and solidified. Subsequently, the resulting product as removed from the mold comprises the shaft 1 and a soft polyurethane sponge layer 2 formed on an outer circumferential surface of the shaft 1. Then, while the shaft 1 formed with the soft polyurethane sponge layer 2 is rotated at a predetermined rotational speed, a high pressure gas (air, nitrogen gas or a like

gas) is jetted from a nozzle or the like onto the soft polyurethane sponge layer 2. Through the high pressure jetting process, the high pressure gas diffuses into the soft polyurethane sponge layer 2 alongside the shaft 1 which serves as a resistance, thereby efficiently breaking through the walls of the cells in the soft polyurethane sponge layer 2 thereby forming openings in the cell walls. Thus, the toner supply roll is provided in which not less than 90% of the cell walls 4 defining the boundaries between the respective adjacent cells in the soft polyurethane sponge layer 2 have openings 5.

[0021] Alternatively, the toner supply roll according to the present invention may be produced, for example, by forming the soft polyurethane sponge layer 2 on the outer circumferential surface of the shaft 1 in the aforesaid manner and then performing a so-called roll crushing process. In the roll crushing process, a counter metal roller is pressed against the soft polyurethane sponge layer 2 so as to depress the sponge layer by not less than 30%, preferably not less than 50%, of the thickness thereof while being rotated in the same direction or in the opposite direction with respect to the shaft 1.

[0022] In the present invention, the method for the formation of the soft polyurethane sponge layer 2 on the outer circumferential surface of the shaft 1 is not limited to the aforesaid method which employs the mold shown in Fig. 2, but an ordinary slab forming method may also be employed.

[0023] The method for breaking through the cell-walls for forming openings in not less than 90% of the cell walls defining the boundaries between the respective adjacent cells is not limited to the high pressure jetting process and the roll crushing process described above, but other exemplary methods therefor include a method of removing the cell walls during the foam molding, a method of treating the cell walls with a chemical agent such as an alkaline solution, and a method of removing the cell walls by utilizing the explosive energy of an explosive gas.

[0024] In the toner supply roll thus obtained in accordance with the present invention, the soft polyurethane sponge layer has an air permeability A and an average cell diameter D which preferably satisfy the relationship represented by $A/D > 7$. When the relationship $A/D > 7$ is satisfied, the toner fluidity can stably be maintained during prolonged use, even if the average cell diameter D is reduced.

[0025] The soft polyurethane sponge layer preferably has an average cell diameter D of about 100 μm to 500 μm , particularly preferably about 200 μm to 400 μm . If the average cell diameter D is smaller than about 100 μm , the toner fluidity may be reduced. On the other hand, if the average cell diameter D is greater than about 500 μm , uneven toner supply may occur. The average cell diameter D is determined, for example, by taking a photograph of a section of the soft polyurethane sponge layer by means of an optical microscope and a CCD camera, counting the number of cells aligned on a line of a given length (μm), and dividing the length by the number of cells. The shape of the cells in the soft polyurethane sponge layer is not particularly limited, but may be either elliptical or circular.

[0026] The soft polyurethane sponge layer preferably has an air permeability A of not less than about 2,000 $\text{cc/min} \cdot \text{cm}^2$, particularly preferably about 3,000 $\text{cc/min} \cdot \text{cm}^2$. The air permeability A can be determined with the use of an apparatus as shown in Fig. 3. More specifically, a sample 31 of the soft polyurethane sponge layer cut out of the toner supply roll to have an axial length of about 25 mm is first press-fitted in a cylinder 32 having an inner diameter which is slightly smaller than the outer diameter of the sample 31. Then, one of opposite ends of the cylinder 31 is exposed to atmosphere, while the other end is connected to a vacuum pump 34 via a flow meter 33. Pressure is measured at the side of the cylinder 32 connected to the vacuum pump 34 by means of a pressure gage 35, and the vacuum pump 34 is operated so that the pressure is kept at 1 kPa. At this time, an air flow rate (cc/min) is measured by means of the flow meter 33, and divided by the cross sectional area of the soft polyurethane sponge layer so as to yield a determination of the air permeability.

[0027] The soft polyurethane sponge layer of the toner supply roll according to the present invention preferably has a hardness of about 50 g to 500 g, particularly preferably about 100 g to 350 g. If the hardness is less than about 50 g, toner scrapability is not sufficient. On the other hand, if the hardness is greater than about 500 g, degradation of the toner is accelerated.

[0028] The hardness of the soft polyurethane sponge layer is determined, for example, in the following manner. As shown in Fig. 4(a), the opposite ends of a shaft 41 of the toner supply roll are supported, and the soft polyurethane sponge layer 42 is depressed at a rate of 10 mm/min by means of a jig 43 having a planar depression surface (50 mm x 50 mm, and a thickness of 7 mm). The hardness is determined by the load (g) applied to the sponge layer when the sponge layer is depressed by 1 mm. The load is an average of values of the load obtained at eight (2 x 4) measuring points located in a circumferentially 90-degree spaced relation along two circumferential lines axially spaced from each other. A higher average load means that the soft polyurethane sponge layer 42 has a higher hardness, i.e., is harder.

[0029] The soft polyurethane sponge layer preferably has the smallest possible density, but the density is typically within a range between about 0.05 g/cm^3 and 0.3 g/cm^3 .

[0030] The soft polyurethane sponge layer typically has a thickness of about 2 mm to 8 mm, preferably about 3 mm to 5 mm.

[0031] Next, Examples and Comparative Examples will be explained.

[0032] Prior to implementation of Examples and Comparative Examples, polyurethane materials A to C were prepared according to the formulations shown in Table 1.

Table 1

(Parts by weight)			
Formulation	Polyurethane materials		
	A	B	C
Polyether polyol *1	90	90	90
Polymer polyol *2	10	10	10
Diethanolamine	2	2	-
Silicon foam stabilizer *3	3	-	3
Silicon foam stabilizer *4	-	0.1	-
Water	2	2	2
Tertiary amine catalyst *5	0.5	0.5	0.5
Tertiary amine catalyst *6	0.1	0.1	0.1
DBTDL	0.1	-	-
Isocyanate *7	32.5	32.5	26.9

*1: EP-828 (OH-value=28) available from Mitsui Chemical Co.

*2: POP-31-28 (OH-value=28) available from Mitsui Chemical Co.

*3: L-5309 available from Nippon Unicar Co. Ltd.

*4: SZ-1142 available from Nippon Unicar Co. Ltd.

*5: KAORIZER No. 31 available from Kao Corp.

*6: TOYOCAT HX-35 available from Toso Co. Ltd.

*7: SUMIDULE VT-80 (NCO%=45) available from Sumitomo Bayer Urethane Co. Ltd.

Example 1

[0033] A mold as shown in Fig. 2 was prepared, and a shaft 1 (a metal core bar of SUS304 having a diameter of 5 mm) was placed in a hollow cylindrical body 21. Then, the polyurethane material A was injected into a mold cavity 24 of the mold, and was foamed and solidified. Thereafter, the resulting product was removed from the mold. Thus, a soft polyurethane sponge layer having a thickness of 5.5 mm was formed on an outer circumferential surface of the shaft 1. While the shaft formed with the soft polyurethane sponge layer was rotated at a rotational speed of 1,000 RPM, high pressure air (0.5 MPa) was jetted onto the soft polyurethane sponge layer from an air nozzle (diameter: 3 mm) which was spaced about 10 mm from the sponge layer and was directed generally perpendicularly to the sponge layer. Thereafter, the air nozzle was slowly moved axially along the sponge layer (at about 10 mm/sec) so that the air was jetted evenly over the sponge layer. Thus, the intended toner supply roll was produced.

Example 2

[0034] A toner supply roll was produced in substantially the same manner as in Example 1, except that the polyurethane material B was used and the rotational speed of the metal core rod was 600 RPM.

Example 3

[0035] A toner supply roll was produced in substantially the same manner as in Example 1, except that the polyurethane material C was used and the rotational speed of the metal core rod was 600 RPM and the air pressure for the air jetting process was 0.6 MPa.

Example 4

[0036] A toner supply roll was produced in substantially the same manner as in Example 1, except that the air pres-

sure for the air jetting process was 0.3 MPa.

Comparative Example 1

- 5 **[0037]** A toner supply roll was produced in substantially the same manner as in Example 1, except that the soft polyurethane sponge layer was not subjected to the air jetting process.

Comparative Example 2

- 10 **[0038]** A toner supply roll was produced in substantially the same manner as in Example 2, except that the soft polyurethane sponge layer was not subjected to the air jetting process.

Comparative Example 3

- 15 **[0039]** A toner supply roll was produced in substantially the same manner as in Example 1, except that the air pressure for the air jetting process was 0.2 MPa.

[0040] The toner supply rolls of Examples 1 to 4 and Comparative Examples 1 to 3 were evaluated by determining properties thereof on the basis of the following criteria. The results are shown in Tables 2 and 3.

Evaluation of Images

[0041] The toner supply rolls having an outer diameter of 16 mm were each set in a laser beam printer. With the use of a toner having an average particle diameter

Table 2

	Examples			
	1	2	3	4
Polyurethane material	A	B	C	A
Percentage of open cell walls(%)	>95	>95	>95	90
Air permeability A (cc/min • cm ²)	2,800	3,200	4,500	2,400
Average cell diameter D (μm)	320	370	460	320
A/D	8.8	8.6	9.8	7.5
Hardness (g)	380	340	270	380
Image evaluation				
At initial stage	○	○	○	○
After 5,000 copies were printed	○	○	○	○

Table 3

	Comparative Examples		
	1	2	3
Polyurethane material	A	B	A
Percentage of open cell walls(%)	70	80	87
Air permeability A (cc/min • cm ²)	1,800	1,500	2,000
Average cell diameter D (μm)	320	370	320
A/D	5.6	4.1	6.3
Hardness (g)	380	350	380
Image evaluation			
At initial stage	○	○	○
After 5,000 copies were printed	X	X	△

of 7 μm to 10 μm, 5,000 copies of an image including 5% characters were printed out under low temperature and low humidity conditions (15°C, 10%). A solid portion of an image printed out at the initial stage of the printing test was compared with a solid portion of an image printed out at the end of the printing test. The evaluation criteria are as follows: the mark "○" indicates that a reduction in image density was not greater than 10% and no streaking was observed; the mark "△" indicates that a reduction in image density was greater than 10% but not greater than 25% and some streaking was observed; and the mark "X" indicates that a reduction in image density was greater than 25% but not greater than 50% and some streaking was observed.

[0042] It can be understood from Tables 2 and 3 that, in the case of the toner supply rolls of Examples 1 to 4, in which not less than 90% of cell walls defining boundaries between respective adjacent cells in the soft polyurethane sponge layer thereof had openings, the reduction in image density was relatively small and no streaking was observed after the 5,000 copies were printed. Thus, the toner supply rolls ensured formation of high quality images for an extended period of time.

[0043] To the contrary, in the cases of the toner supply rolls of Comparative Examples 1 and 2 in which a lower percentage of cell walls defining boundaries between respective adjacent cells in the soft polyurethane sponge layer thereof had openings because the toner supply rolls were not subjected to the air jetting process, the reduction in image density was relatively great and some streaking was observed after the 5,000 copies were printed. Thus, the toner supply rolls caused imaging failures after a prolonged use. Although the toner supply roll of Comparative Example 3 was subjected to the air jetting process, less than 90% of cell walls defining boundaries between respective adjacent cells in the soft polyurethane sponge layer thereof had openings. Therefore, the toner supply roll caused imaging failures after a prolonged use.

[0044] As described above, the soft polyurethane sponge layer of the toner supply roll according to the present invention is of the open-cell foam structure in which the cells are three-dimensionally connected to one another via the openings in the cell walls, so that air contained in the sponge layer smoothly flows out when the sponge layer is depressed. Therefore, the sponge layer has a lower hardness than a soft polyurethane sponge layer of a closed-cell foam structure. Since not less than 90% of the cell walls defining the boundaries between the respective adjacent cells have openings, toner fluidity can properly be maintained. Therefore, the toner supply roll can minimize degradation of the toner during prolonged use and can stably maintain the toner scrapability and the toner supplying capability, thereby ensuring the formation of high quality images for an extended period of time. The toner supply roll according to the present invention, which ensures formation of high quality images for an extended period of time, can be produced very easily by foaming the polyurethane material on the outer circumferential surface of the shaft so as to form the soft polyurethane sponge layer and then jetting a high pressure gas onto the sponge layer.

[0045] Where the air permeability A and average cell diameter D of the soft polyurethane sponge layer satisfy the relationship represented by $A/D > 7$, toner fluidity can be stably maintained during prolonged use, even if the average cell diameter D is reduced.

[0046] When the average cell diameter of the soft polyurethane sponge layer is within the defined range, the reduction in toner fluidity and uneven toner supply can further be suppressed.

[0047] When the hardness of the soft polyurethane sponge layer is within the defined range, reduction in toner scrapability of the toner supply roll and degradation of the toner can further be suppressed.

[0048] While the present invention has been described in detail by way of embodiments thereof, it should be understood that the foregoing disclosure is merely illustrative of the technical principles of the present invention but not limitative of the same. The scope of the present invention is to be determined only by the appended Claims.

Claims

1. A toner supply roll comprising a shaft, and a soft polyurethane sponge layer provided on an outer circumferential surface of the shaft, the sponge layer defining a plurality of adjacent cells wherein not less than 90% of cell walls defining boundaries between respective adjacent cells have openings.
2. A toner supply roll as set forth in Claim 1, wherein the soft polyurethane sponge layer has an air permeability A (cc/min.cm²) and an average cell diameter D (μm) which satisfy a relationship represented by $A/D > 7$.
3. A toner supply roll as set forth in Claim 1 or 2, wherein the soft polyurethane sponge layer has an average cell diameter of 100 μm to 500 μm.
4. A toner supply roll as set forth in Claim 1, 2 or 3, wherein the soft polyurethane sponge layer has a hardness of 50 g to 500 g.
5. A method of producing a toner supply roll, the method comprising the steps of forming a soft polyurethane sponge layer on an outer circumferential surface of a shaft by foaming a polyurethane material, the sponge layer defining a plurality of adjacent cells, and jetting a high pressure gas onto the soft polyurethane sponge layer so that no less than 90% of cell walls defining boundaries between respective adjacent cells in the soft polyurethane sponge layer have openings.

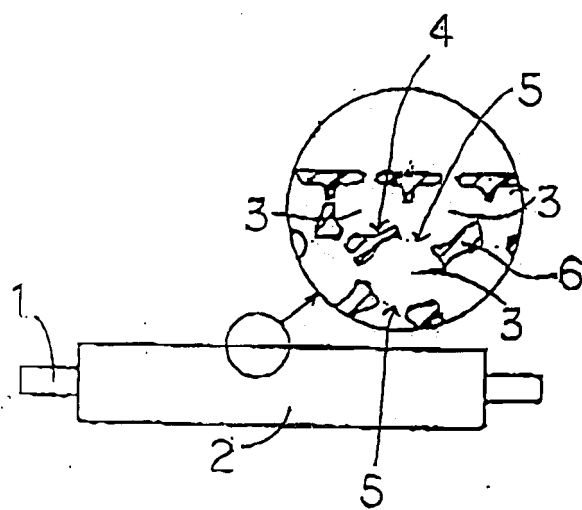


Fig. 1

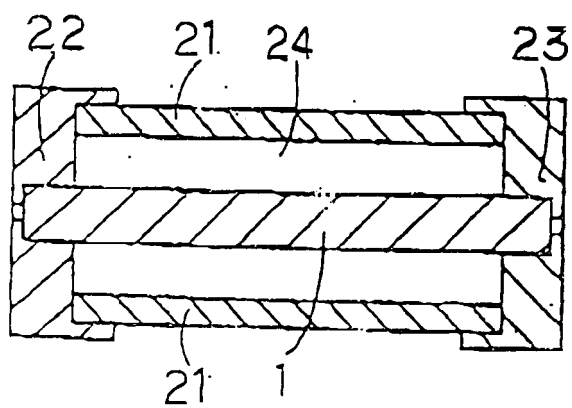


Fig. 2

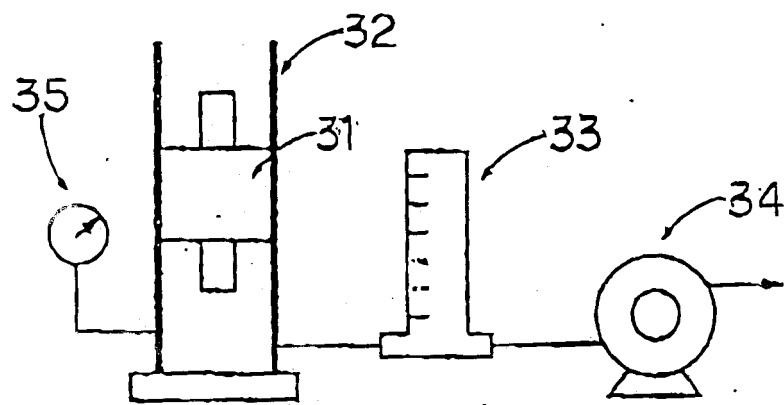


Fig. 3

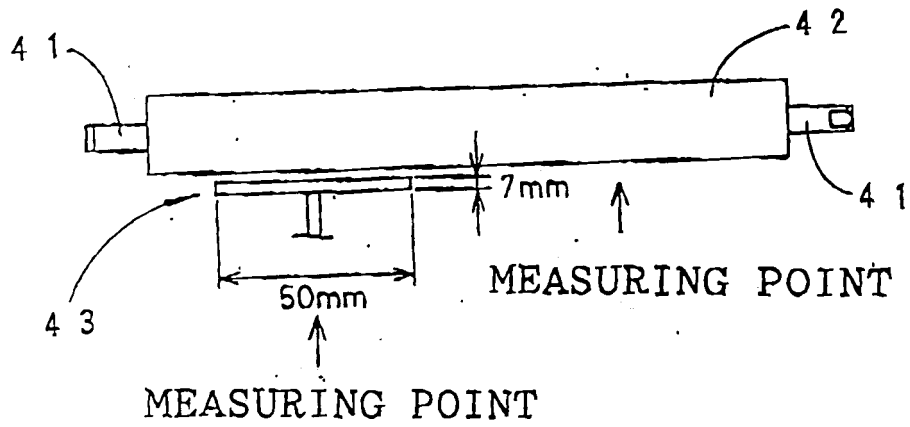


Fig. 4 (a)

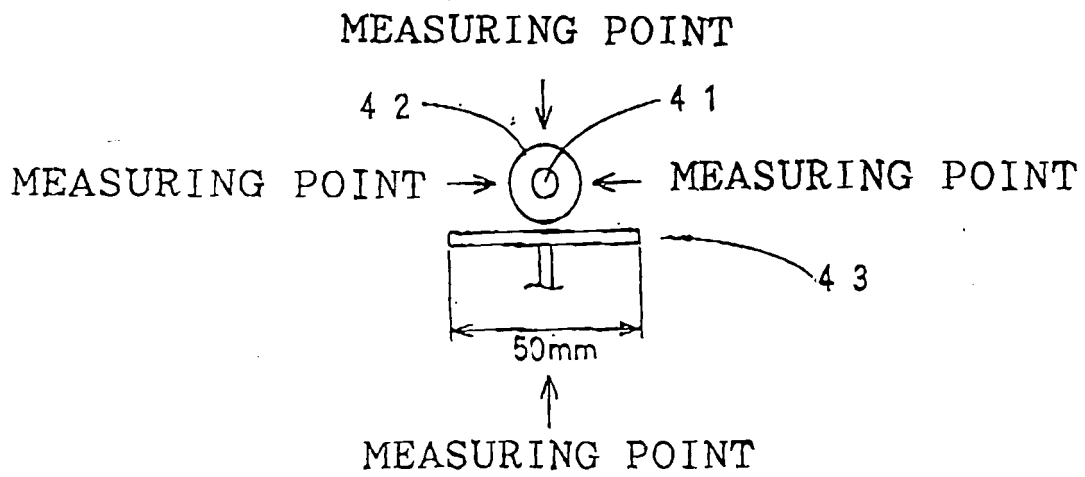


Fig. 4 (b)