(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 November 2004 (25.11.2004)

PCT

(10) International Publication Number
WO 2004/102141 A2

(51) International Patent Classification[7]: G01L

(21) International Application Number:
PCT/FI2004/050062

(22) International Filing Date: 13 May 2004 (13.05.2004)

(25) Filing Language: Finnish

(26) Publication Language: English

(30) Priority Data:
20030718 13 May 2003 (13.05.2003) FI

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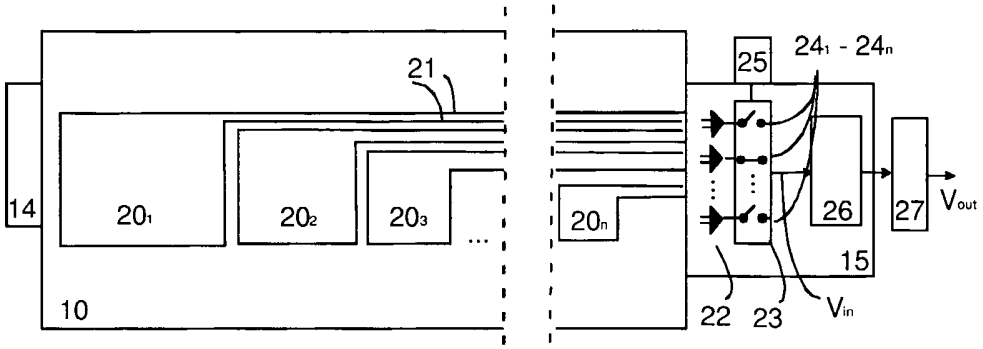
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR MONITORING THE STATE OF A MACHINE ELEMENT



(57) Abstract: The invention relates to an apparatus and a method for monitoring the state of a machine element (10) in a paper machine or finishing machine for paper. The apparatus comprises a magnetized conductor (20), for example a copper fiber coated with a magnetic materiel. The conductor (20) can be placed in a rotating machine element (10), such as a roll or the like, wherein the element in contact with the roll surface produces pressure in the conductor (20), as well as an electrical signal corresponding to the pressure. The magnetized conductor (20) can be advantageously arranged as a loop-shaped measurement sensor, wherein several of these sensors can be placed in different sections of the machine element (10). The variable measured by the sensors is transmitted forward as an electrical signal.

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APPARATUS AND METHOD FOR MONITORING THE STATE OF A MACHINE ELEMENT

The present invention relates to an apparatus described in the preamble of the independent claim 1 for monitoring the state of a machine element in a paper machine or finishing machine for paper. The invention also relates to a method described in the preamble of the independent claim 9 for monitoring the state of a machine element in a paper machine or finishing machine for paper.

In connection with papermaking, a wide paper web is conveyed in different sections of a paper machine, wherein it is important to constantly monitor the travel of the web, especially its tension and other properties, such as the pressure exerted thereon in different nips. To monitor these properties, to adjust the devices and to avoid web breaks it is important to monitor the properties of machine elements relating to the process of conveying and treating the paper web. In addition to this, it is of primary importance to measure the properties of paper (weight, thickness, moisture) constantly to attain a final product of as good a quality as possible.

Finnish patent 80522 (US 5052233) discloses an apparatus arranged for measuring the web tension. The apparatus according to the publication is based on the measurement of the pressure of an air cushion between a paper web moving at high speed and a curved surface in different locations in the transverse direction of the web. The measurement beam extending in the cross-machine direction has a curved surface containing openings at fixed intervals, the pressure of the air cushion affecting the corresponding pressure sensors inside the beam via said openings. The pressure difference sensors used as measurement sensors measure the local pressure effective through the opening when compared to the reference pressure produced inside the beam. To take the entire width of the web into account in the measurement, there must be measurement sensors and drilled openings densely in the cross-machine direction. It is obvious that this increases manufacturing costs.

Finnish patent 89308 (EP 0588776B1) discloses a method for measuring the pressure difference of roll nips in a paper machine or the like, in which method PVDF films (polyvinylidene fluoride) are used as measurement sensors of the pressure difference. The PVDF film is a piezoelectric film, which according to the publication, is coated with metal on both sides. These metallized surfaces function as sensors measuring pressure or force. The sensors are attached on the frame of the roll on the entire surface of rotation of the roll. The mechanical variable measured by the sensors is converted into an electrical variable, and this signal is transferred via guides to a measurement unit from which the measurement values are transferred further via a switch unit to a separate data processing system to be analyzed. The piezoelectric films of the above-described type are, however, sensitive to heat, and it is also difficult to install them.

A method has been developed for monitoring the coatings and surfacings of rolls, because it is known that the damaging of short lifetime coatings causes web breaks in an unpredictable manner. It is known that the composite structure of the roll is reinforced by means of fibers. When for example an optical fiber is added among the fibers, as for example in the publication FI 20000883 (US application 2001/0032924) by the applicant, the degree of damaging of the roll coating and the properties of the web must be monitored closely. Because the optical fiber is relatively expensive, it must be installed on the roll as cost-effectively as possible. For example an optical fiber can be attached to the composite material of the roll in such a manner that the ends of the fiber are positioned at the ends of the roll, wherein it can be coupled to the necessary measurement means. The fiber can be installed around the roll in a spiral-like manner, wherein the measurement conducted by the same extends as widely as possible with as small amount of material as possible. However, this kind of installation is difficult.

It is an aim of the present invention to disclose an apparatus of a new type in which the drawbacks of the earlier solutions have been taken into account. By means of the invention it is possible to attain a less

complex structure and less expensive price for the measurement means of the machine element, such as a roll, when compared to solutions of prior art. Furthermore, in the method according to the invention, to monitor the state of the machine element it is possible to transfer the measurement data simply from an external system to the roll and from the roll to an external system.

To attain these objectives, the apparatus according to the invention is primarily characterized in that the apparatus comprises a magnetized conductor that is located in the machine element, which magnetized conductor is arranged to measure the properties affecting the state of the machine element. Furthermore, the method according to the invention is primarily characterized in that the measurement is conducted by means of a magnetized conductor that is located in the machine element, which magnetized conductor is arranged to measure the properties affecting the state of the machine element.

The magnetized conductor used in the invention comprises a conductive non-magnetic conductor and a magnetic part attached thereto. It is advantageously an electrical conductor coated with a magnetic material, for example a copper conductor. The coating can be produced around the conductor for example electrochemically. The magnetized conductor can be advantageously placed in a machine element, such as a roll or the like that is journalled rotatable, wherein the element which is in contact with the surface of the machine element produces pressure in the conductor, as well as an electrical signal corresponding to the pressure. Such an element can be a continuous element, such as a paper web or a texture of the paper machine or finishing machine itself that forms a loop, which travels past the machine element and over its surface in a certain sector. The element can also be a nip-forming element that is in contact with the surface of the machine element, such as a counter element or a doctor forming a calender nip.

The magnetized conductor can be advantageously arranged as a loop-shaped measurement sensor, wherein several of these sensors can be placed in different points in the area of the surface of the machine ele-

ment. The variable measured by the sensors is transmitted as an electrical signal to the switch unit, from which it is guided further to a telemetry transmitter to be transferred advantageously in a wireless manner to a telemetry receiver outside the machine element that is journalled rotatable. The electrical signal can also be transferred indirectly (non-wirelessly, i.e. with a contact) for example by means of slide rings used for electrifying the rotating machine parts.

The magnetized conductor of the above-described type is substantially affordable when compared for example to optical fibers, wherein it can be considered that its use brings about savings in costs. The measurement technique of the conductor is considerably simple and by means of the same it is possible to measure both force and elongation. Furthermore, the magnetized conductor resists heat well and it is well suited to be installed inside a composite material.

The invention will be described in more detail with reference to the appended drawings, the detailed description following thereafter and to the claims hereinbelow. The invention will be described in more detail by the drawings in which

Fig. 1 shows schematically the main principle of the measurement system according to the invention,

Fig. 2 shows an example of the structure of the magnetized conductor used in the invention, and

Figs 3a to d show some preferred examples of a composite roll that comprises a magnetized conductor.

It should be mentioned in this context that the examples are presented in the dimensions shown in the drawings for the sake of clarity. It is, however, obvious that these dimensions do not restrict the embodiments, but the actual dimensions can deviate from those presented in the drawings.

Fig. 1 is a principle drawing of the apparatus according to the invention. The apparatus contains such a machine element whose characteristics must be measured to attain a final product of as good a quality as possible. Advantageously such a machine element is a roll 10 comprising an elastic coating, for example a polyurethane coating. Such a machine element can also be a doctor that is arranged to remove impurities from the surface of the roll.

When a roll is used as an example, it is possible to mention the tension exerted on the surface of the roll and the elongation of the coating as characteristics to be measured. To measure the above-described properties, the roll 10 comprises at least one measurement sensor 20 that can be located directly on the frame of the roll 10 or inside the coating, for example between the layers of the coating or on the inner surface of the coating. In some exceptional cases the measurement sensor 20 can also be located directly on the outer surface of the roll 10. When there are several measurement sensors 20 (n units), they can be positioned in series. Advantageously measurement sensor series are positioned on the roll 10 substantially on the entire surface of rotation of the roll 10. There are advantageously n = 3 to 10 units of measurement sensors 20_i to 20_n. It is also possible to utilize the measurement sensors to measure other characteristics of the roll or the roll nip, such as the pressure of the roll nip and its distribution especially in the cross-machine direction (nip pressure profile), temperatures of the rolls, different temperature distributions and deflections of the rolls.

Control current is supplied to the conductor as alternating current with a suitable frequency. The measured variables are guided from the measurement sensors 20 in voltage signals via cables 21 to preamplifiers 22. The output voltage is dependent on the loading exerted on the conductor. There is advantageously one preamplifier 22 per each sensor 20. It is obvious that there can also be only one preamplifier 22 that serves all sensors 20 for example when the measured signals are within a particular voltage area. The measurement signals are adjusted to the desired voltage level by means of the preamplifiers

22, wherein they are transferred further to the switch unit 23. The switch unit 23 is controlled by a pulse sensor 25 that takes into account the rotation of the roll 10. During each revolution of the roll 10, a triggered signal is transferred from the pulse sensor 25 to the switch unit 23, said signal controlling the switch unit 23 in such a manner that the switch 24_i that was closed at the time of arrival of the pulse is opened, and the next switch 24_{i+1} is closed.

It can be seen in Fig. 1 that the switch 24_2 is closed when the other switches are open, wherein it transmits a voltage signal from the sensor 20_2 further to a telemetry transmitter 26. The telemetry transmitter 26 is a radio transmitter, an optical transmitter or another radiating transmitter, from which the signal T is advantageously guided wirelessly to a telemetry receiver 27. For telemetry, it is possible to utilize for example a system applying wireless data transmission technology, such as a radio modem, Bluetooth, WLAN, GSM modem or GPRS modem. It should also be noted that instead of wireless telemetry it is also possible to utilize a data transmission system applying an indirect contact method, such as the above-mentioned slide ring. Instead of data transmission taking place substantially concurrently with the measurement it is also possible to apply reading of information at longer intervals. In this context it is also possible to utilize an escort memory. In that case the measured values are collected in a memory or a log file during the operation of the machine element that functions as a measurement target, from which they can be read for example when the machine stands idle, for example during maintenance breaks or the like.

The telemetry receiver 27 provides an output signal V_{out} that contains the measurement signals $V_{out\ i}$ (i=1...n) of each measurement sensor 20_i successively. When the entire series of sensors 20 has been processed, the next measurement sequence starts from the beginning.

It should be noted that only one telemetry channel is necessary in the above-described measurement system, which simplifies the system substantially. The unit 15 in connection with the roll 10 comprises

amplifiers 22, switch units 23 and a telemetry transmitter 26. Said unit 15 can be formed as a battery-operated small-sized module in which for example the switch unit 23 is a standard microcircuit. The measurement unit 15 is positioned in a rotating roll 10, for example on its shaft 14, preferably at the end of the shaft.

In the measurement arrangement according to the invention the measurement sensors 20 are implemented with a magnetized conductor 20, preferably with a magnetized copper conductor, for example a conductor developed by Sensortex Inc. Fig. 2 shows the structure of such a magnetized conductor. The core of the conductor is a copper wire CU coated with a pressure-sensitive magnetic coating C. The coating C can cover the copper wire CU within a certain length. As an example of the coating it is possible to mention nickel-iron alloy (Permalloy). The magnetized conductor can be formed into a loop circuit (sensor) as can be seen in Fig. 1. Loop-shaped conductor circuits are advantageously positioned on the roll 10 at least in one axial line with respect to the cross-machine direction. Fig. 3a shows an arrangement with several loop-shaped sensors at different locations in the cross-direction of the machine element of the machine. The sensors can also be positioned in other ways. A single magnetized conductor can also be positioned as a continuous wire in the roll, said wire being wound in a spiral-like manner around the roll (Fig. 3b). If such a wire circles for example 360° around the roll, a certain section of said wire is always subjected to the pressure produced by the web, the texture or the roll nip, and by means of this arrangement it is possible to attain information on the tension or nip profile during one revolution of the roll, although not simultaneously as in the situation where separate, advantageously densely placed sensors are used, said sensors being positioned in a line in the same section of the periphery of the roll.

In the rotating roll, the group formed by loop-shaped sensors can also be arranged to travel diagonally in the axial direction of the roll, i.e. in the direction of the rotating axis (Fig. 3c), wherein they are positioned at different locations in the cross-machine direction (axial direction of the roll), but also in the direction of the periphery of the roll. Thus, only

some of the sensors can be alternately subjected to pressure, i.e. can be located in a sector where the web or the texture covers the shell surface of the roll, or can be located in a roll nip formed by the roll with another roll. Thus, the measurement from different points is conducted at different times, at intervals dependent on the speed of rotation of the roll. Furthermore, it is possible to install the magnetized conductor as a mesh in the coating structure, as shown in Fig. 3d. In this context the section of the measured roll coating can be determined by means of signal positioning systems known as such, said systems utilizing signal propagation time, phase shift or another corresponding variable that correlates with the distance. It can also be considered that the entire shell surface of the roll is covered with loop-shaped sensors, wherein every section in the coating of the machine element is monitored.

Several sensor circuits make it possible to monitor the state of the roll, such as the damaging of the coating in such a manner that the degree of propagation of the damage as well as the location of the damage can be determined on the basis of the inactiveness of the circuits. Furthermore, the conductor reinforces the composite material effectively, wherein the durability of the coating is increased. It is possible to predict the durability by monitoring the changes in the electrical properties of the conductor.

The magnetized conductor of the above-described type is well suited to be integrated in a composite material, such as a composite material located in the roll. It is possible to connect various monitoring and measurement methods to the conductor. In connection with paper machines, advantageous applications include for example the act of monitoring the manufacturing processes of composite rolls or the like. Furthermore, it is possible to diagnose the state and condition of the composite rolls by monitoring the changes in the signal levels. When the roll is in use, it is possible to utilize a magnetized copper fiber to measure the force produced by the continuous planar structure travelling over the roll, such as a texture, for example a wire, intended for guiding/supporting the paper web, or the force produced by the paper web itself, which can be utilized to determine the tension or tension

profile of the texture or the web. Similarly, when the roll is in operation, it is possible to constantly measure the nip pressure produced by the counter element underneath the polymer surface or inside the composite material, especially in calenders in which the roll forms a calender nip with a heated hard-faced counter roll, the paper web that is being processed travelling through said calender nip. Furthermore, by means of a magnetized conductor it is possible to diagnose the loosening of the roll coating. When the magnetized conductor is installed for example as a mesh in the coating structure, it is possible to monitor the condition of the polymer/fiber roll surface in the area of the entire surface. Furthermore, the magnetized conductor provides the possibility to optimize the roll change intervals and maintenance. It is also possible to use the sensors of the actual roll coating (coating arranged on top of the cylindrical roll frame) in a belt-like form in machine elements forming an endless loop, for example in belts of a belt calender, which are also arranged to form a calender nip with a counter element within a certain section of its travel path. The magnetized conductor can also arranged in any machine element having a composite structure; for example in a doctor in which the conductor can be placed in the blade structure of the doctor or in the blade holder. Thus, an advantageous measurement target is for example the blade pressure of the doctor, to establish a blade pressure profile.

The magnetized conductor can also be applied in the texture of the paper machine (for example a wire conveying/supporting the paper web), wherein it can perform diagnostic measurements from said texture, while the data transmission takes place in a wireless manner or with a contact or at longer intervals utilizing a memory according to the above-described principles. Thus, it is possible to use the conductor at the same time as reinforcement for the texture.

It is obvious that the above-described different embodiments of the invention can be combined to provide various embodiments of the invention, which comply, as such, with the spirit of the invention. Therefore, the above-presented examples must not be interpreted as restrictive to the invention, but the embodiments of the invention can be freely

varied within the scope of the inventive features presented in the claims hereinbelow.

Claims:

1. An apparatus for monitoring the state of a machine element in a paper machine or finishing machine for paper, **characterized** in that the apparatus comprises a magnetized conductor (20) that is located in the machine element (10), which magnetized conductor (20) is arranged to measure properties affecting the state of the machine element.

2. The apparatus according to claim 1, **characterized** in that the apparatus comprises several magnetized conductors (20).

3. The apparatus according to claim 1 or 2, **characterized** in that the magnetized conductor (20) is arranged as a loop.

4. The apparatus according to claim 1 or 2, **characterized** in that the magnetized conductor (20) is arranged spirally around the machine element (10).

5. The apparatus according to any of the preceding claims, **characterized** in that the magnetized conductor (20) is a conductor coated with a magnetic material, for example a copper fiber.

6. The apparatus according to any of the preceding claims, **characterized** in that the magnetized conductor (20) is installed inside the coating material of the machine element (10).

7. The apparatus according to any of the preceding claims, **characterized** in that a continuous planar structure, such as a paper web or a texture is arranged to travel over the surface of the machine element (10) that is journalled rotatable.

8. The apparatus according to any of the preceding claims, **characterized** in that the machine element (10) that is journalled rotatable forms a nip with a counter element, such as another roll.

9. The apparatus according to any of the preceding claims, **characterized** in that the apparatus also comprises a switch unit (23) for receiving an electrical signal measured by the magnetized conductor (20) as well as a telemetry apparatus comprising a telemetry transmitter (26) and a telemetry receiver (27) outside the machine element to transfer a signal outside the machine element.

10. A method for monitoring the state of a machine element in a paper machine or finishing machine for paper, **characterized** in that the measurement is conducted by means of a magnetized conductor located in the machine element (10), said magnetized conductor (20) being arranged to measure properties affecting the state of the machine element.

11. The method according to claim 10, **characterized** in that the state of the machine element is monitored in several sections of the machine element (10).

12. The method according to claim 10 or 11, **characterized** in that the variable measured by the magnetized conductor (20) is transmitted as an electrical signal to a switch unit (23), wherein the measurement signal of the conductor is coupled to a telemetry transmitter (26) located in connection with the machine element, from which the signal is transmitted wirelessly to a telemetry receiver (27) outside said machine element.

13. The method according to claim 10 or 11, **characterized** in that the variable measured by the magnetized conductor (20) is transmitted as an electrical signal indirectly to the receiver (27) outside said machine element.

14. The method according to any of the claims 10 to 13, **characterized** in that at least the elongation of the coating of the machine element or the stress of the coating of the machine element is measured.

15. The method according to any of the claims 10 to 14, **characterized** in that the nip pressure in the nip, for example the calender nip between the machine element and the counter element, or the blade pressure of the doctor in the contact between the doctor and the rotating machine element, or the force produced by the continuous planar structure, such as texture or paper web travelling over the rotating machine element is measured.

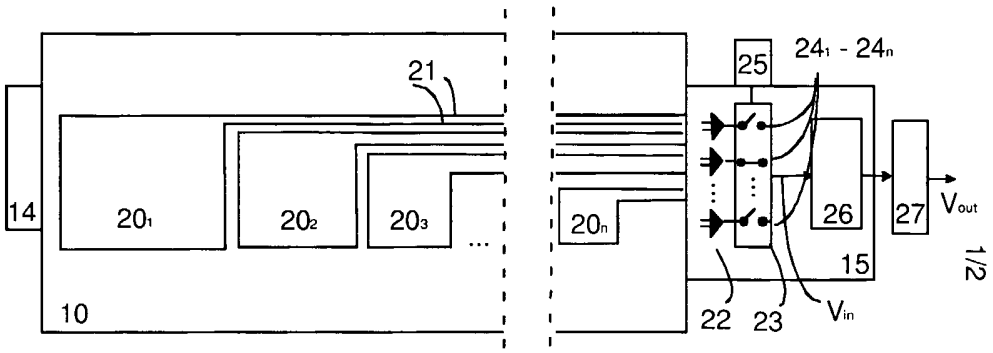

Fig. 1

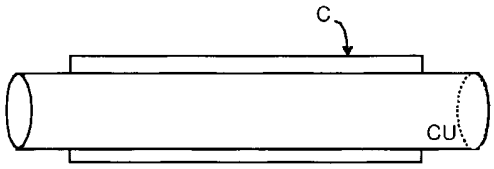

Fig. 2

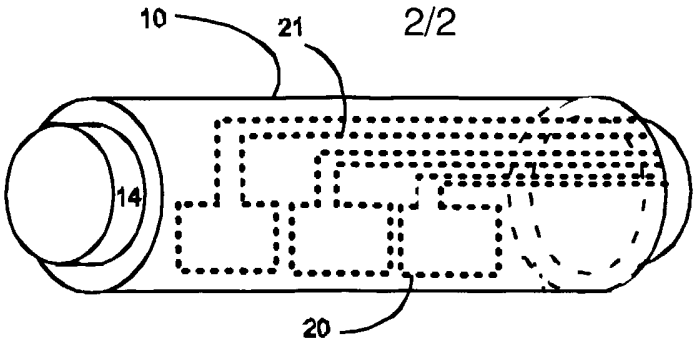

Fig. 3a

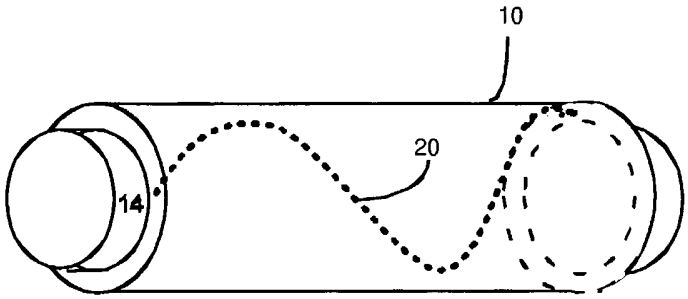

Fig. 3b

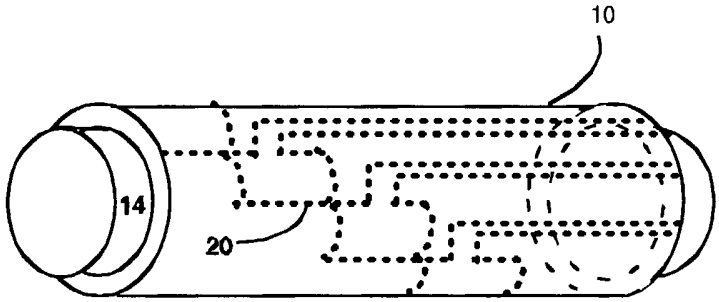

Fig. 3c

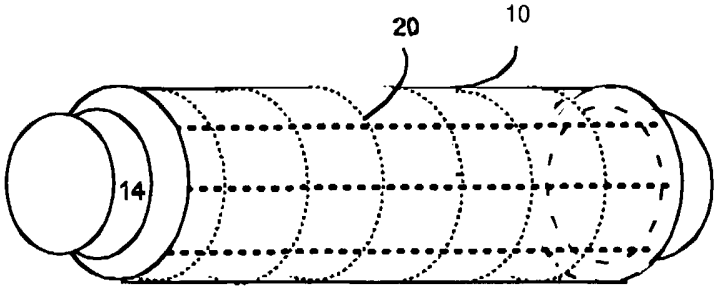

Fig. 3d