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TITLE OF THE INVENTION

INFUSION PUMP

BACKGROUND OF THE INVENTION

The present invention relates to an infusion pump and, more specifically, to a peristaltic type infusion pump capable of automatically controlling the flow rate of an infusion and having a function for detecting an air bubble with a specific length (size) which is mixed with the infusion in an infusion tube (conduct).

According to conventional peristaltic type infusion pumps, an infusion is dripped to the patient by controlling the rotational speed of a finger drive motor by determining the rotational speed of the motor from the flow rate of the infusion which has been set and input and the amount of the infusion discharged from an infusion tube by the peristaltic motion per one cycle of fingers to set the flow rate of the infusion to a specific value.

On the other hand, there are also systems arranged such that a drip probe is disposed at some midpoint in an infusion tube connected to a peristaltic type infusion pump, the number of drips is measured by the drip probe and an infusion is dripped to the patient by

controlling the rotational speed of a finger drive motor so that the number of drips is made to the specific number of drips.

Liquid medicine or the like contained in an infusion bag is dripped to the patient through a flexible infusion tube by being fed under pressure by the peristaltic motion caused by the infusion pump.

The infusion pump is provided with an ultrasonic bubble sensor for detecting a bubble larger than a permissible size which may be in the infusion tube. The ultrasonic bubble sensor is disposed at some midpoint in the infusion tube and composed of a transmitter and a receiver which confront with each other across the infusion tube.

The ultrasonic bubble sensor makes use of such a principle that if a bubble (air) exists at some midpoint in the infusion tube, ultrasonic waves are reflected by the bubble and the output from the receiver drops. More specifically, the presence of a bubble is determined based on the drop of the output and warning and the like are issued by the detection of the bubble in the infusion tube.

SUMMARY OF THE INVENTION

However, according to the open-loop type infusion

pumps arranged as described above, there is a problem that the flow rate of the infusion flowing in the flexible infusion tube is not constant because the rigidity of the flexible infusion tube is varied depending upon the temperature of the atmosphere where an infusion apparatus is used. In addition, a patent for effecting temperature correction in drip control has been filed.

A first object of the present invention made in view of the above problem is to provide a peristaltic type infusion pump capable of keeping the flow rate of an infusion substantially constant at all times without being affected by an atmospheric temperature.

According to the infusion pump for feeding the infusion under pressure through the flexible infusion tube and dripping it to the patient, since the increasing ratio of the number of revolutions of the finger drive motor is unstable just after the infusion is dripped, it is difficult to drip the infusion at the specific flow rate which has been set and input. As a result, a few minutes must elapse until the number of revolutions of the drive motor is made constant and thus there is a problem that the flow rate of the infusion is barely made to the set value after the above time elapses.

When the number of drips detected by the drip

probe is abruptly increased or decreased by a factor such as an impact force from the outside and the like, since the rotational velocity of the drive motor is abruptly changed in accordance with the degree of the increase or decrease, the amount of the infusion is abruptly changed and as a result there may be a case that a load is imposed on the patient.

A second object of the present invention made in view of the above problem is to provide an infusion pump capable of controlling the rotational velocity of a drive motor so as to promptly secure a set flow rate without imposing a load on the drive motor even if the number of drips detected by a drip probe is abruptly changed.

Since the infusion pump provided with the ultrasonic bubble sensor as described above is arranged to stop even by a slight bubble and issue warning, the pump is disadvantageous in that it forcibly stops the feed of the infusion even if a bubble smaller than a regulated size is in the infusion.

A third object of the present invention made in view of the above problem is to provide an infusion pump which previously sets and stores the size (the length in an infusion tube) of an air bubble larger than a regulated size which is to be detected to the infusion pump and can determine the presence of an air bubble

based on the set value.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an outside perspective view showing the schematic arrangement of an infusion pump 10 of an embodiment of the present invention;

FIG. 2 is a block diagram of the infusion pump 10;

FIG. 3 is a correction coefficient table of the rotational speed of a drive motor depending upon temperature;

FIG. 4 is a characteristic graph when a motor is driven;

FIG. 5 is a partially enlarged view of the portion of the infusion pump 10 where an ultrasonic sensor is mounted; and

FIG. 6 is a view showing the detection of a bubble in the infusion pump.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will be described with reference to the accompanying drawings.

FIG. 1 shows the schematic arrangement of an infusion pump 10 of the embodiment of the present invention. In the drawing, an infusion tube (coduct) 1 is composed of a flexible thermoplastic resin such as polyvinyl chloride or the like. An infusion bag 13 in which an infusion (liquid medicine) is contained is disposed to the upstream side of the infusion tube 1. Further, a needle (not shown) is connected to the downstream side of the infusion tube 1.

The infusion pump 10 must execute drip control to show a pump which gradually increases and decreases a velocity.

A drip probe 4 is detachably disposed at some midpoint in the infusion tube 1 to detect the number of drips. Further, the infusion pump 10 is provided with a plurality of peristaltic type fingers 2a, an infusion actuation unit (infusion feed means) 2, an occlusion detecting sensor (occlusion detecting means) 3 for detecting that the infusion tube 1 is occluded and an ultrasonic sensor 5 as bubble sensing means for detecting a bubble larger than a specific size which is in the infusion tube 1.

The infusion actuation unit 2 is arranged such that a plurality of eccentric cams are mounted on a

rotating shaft which is rotated by a drive motor (not shown) and the plurality of peristaltic type fingers 2a follow the outer peripheries of the eccentric cams, respectively so as to press the infusion tube 1. An opening/closing lid member 10a is disposed to the infusion pump 10 and the infusion tube 1 is clamped between the pressure plate 20 provided with the lid member 10a and the fingers 2a to thereby cause a peristaltic motion to the infusion tube 1.

As shown in FIG. 1, the ultrasonic sensor 5 disposed downstream of the infusion tube 1 is composed of a pair of a transmitter and a receiver and the transmitter confront the receiver across the infusion tube 1.

The ultrasonic transmitter and the ultrasonic receiver are composed of a ceramic pizoelectric element which is composed of or mainly composed of PZT (lead zirconate titanate).

When a bubble is fed under pressure while mixed in the infusion 12 and its size is larger than a preset size, the ultrasonic sensor 5 detects it as the bubble.

The occlusion detecting sensor (occlusion detecting means) 3 for detecting the closure of the infusion tube 1 is provided to detect the abnormally closed state of the infusion tube 1 and when the infusion tube 1 is in a closed state exceeding a

specific degree, the occlusion detecting sensor 3 detects the abnormally closed state and thereafter stops the feed of the infusion 12.

The automatic control of the flow rate of the infusion 12 will be described below with reference to the block diagram of the infusion pump 10 shown in FIG. 2 and the correction coefficient table of the rotational speed of the drive motor depending upon temperature shown in FIG. 3.

In FIG. 2, a CPU 6 as a controller (control means) for controlling the infusion pump 10 is supplied with specific electric power from a not shown power supply unit.

When a setting/input unit (setting/input means) 7 connected to the CPU 6 is used by the user, the user sets and inputs there through the flow rate (velocity) of the infusion, the number of drips, the information as to the infusion tube (the name of the manufacture of the tube and the like).

The CPU 6 calculates the rotational velocity (pps) required to the drive motor based on the flow rate of the infusion and the information of the infusion tube 1 input from the setting/input unit 7, the drive motor is driven based on the result of the calculation and the plurality of peristaltic motion fingers 2a cooperate with the drive motor being driven to thereby drip the

infusion to the patient at the specific flow rate.

The output from the ultrasonic sensor 5 connected to the CPU 6 is supplied to the CPU 6 which also acts as determination means and comparison means.

A display unit (display means) 8 connected to the CPU 6 displays the flow rate (ml/h) of the infusion, the added amount (ml) of the infusion, errors such as an error in operation and the like and notifies warning and the like.

In the above arrangement, when the drip of the infusion begins and the CPU 6 indicates to start the detection of a bubble, ultrasonic waves having a specific wavelength are transmitted from the ultrasonic transmitter of the ultrasonic sensor 5 and received by the ultrasonic receiver at the same time.

A ROM 9 connected to the CPU 6 acts as storing means for storing data arranged as a table showing the correction coefficients of the rotational velocity (pps) of the drive motor depending upon temperature, the length (size) of a bubble which is to be detected in the infusion tube 1 by the ultrasonic sensor 5, and the like.

A temperature sensor 14 connected to the CPU 6 is composed of a thermistor or the like, detects the temperature of the environment where the infusion pump is used and supplies it to the CPU 6.

Thereafter, the CPU 6 selects a proper correction

coefficient from the temperature correction table stored to the ROM 9 based on the temperature information from the temperature sensor 14 disposed in the vicinity of the infusion tube 1.

The CPU 6 further calculates the rotational velocity (pps) of the drive motor as a stepping motor based on the flow rate of the infusion which is input to the setting/input unit 7 and the information as to the infusion tube and drives the drive motor based on the result of the calculation.

A rotational velocity sensor (rotational velocity sensing means) 15 composed of an encoder and connected to the CPU 6 detects the rotational velocity of the drive motor. More specifically, the rotational velocity sensor (rotational velocity sensing means) 15 composed of the encoder detects the rotational velocity (pps) of the drive motor at a specific sampling cycle (at intervals of, for example, every ten milliseconds).

When temperature correction control is described with reference to FIG. 3, the embodiment shows the previously stored correction coefficients as ratios to 1.0 as a reference value.

For example, when a rotational velocity at 20℃ is set to 100 pps (pulses/second) and input, the rotational velocity is not corrected within the temperature range of from 15 - 30℃. When the temperature is within the

range of 10 - 15℃, the rotational velocity of the drive motor is controlled to 105 pps based on a selected correction coefficient 1.05. When the temperature is within the range of 0 - 10℃, the rotational velocity of the drive motor is controlled to 110 pps based on a selected correction coefficient 1.1, whereas when the temperature is within the range of 30 - 40 ℃, the rotational velocity of the drive motor is controlled to 95 pps.

More specifically, the rotational velocity of the drive motor at the temperature of 15 - 30℃ is used as a reference rotational velocity and the drive motor is driven at the rotational velocity of 1.05 times the reference rotational velocity at 10 - 15℃, 1.1 times the reference rotational velocity at 0 - 10℃ and 0.95 times the reference rotational velocity at 30 - 40℃.

The temperature range of the reference rotational velocity can be suitably when necessary. The above control is executed only when open loop control is carried out to control a closed loop in which the drip probe is used.

As described above in detail, since there are provided the infusion actuation means, the setting/input means for setting and inputting the flow rate of the

infusion, the temperature sensor disposed in the vicinity of the infusion tube and the control means for controlling the rotational velocity of the motor of the infusion actuation means by the stored correction coefficients based on the temperature detected by the temperature sensor and the flow rate of the infusion input through the setting/input means, an approximately similar flow rate of the infusion can be obtained at all times without depending upon the atmospheric temperature. The above temperature control is described as to the closed loop-controlled condition communicated with the drip probe. The temperature control may also be applied to an open-loop type infusion pump or the open-loop condition of the infusion pump with the drip probe.

When the drip of the infusion begins in the closed-loop type infusion pump, the rotational velocity of the drive motor is controlled by the CPU 6 so that a next rotational velocity (pps) is made nearer to the range of a specific ratio (for example, within the range of ±10%) than the present rotational velocity even if the rotational velocity of the drive motor obtained by the drip probe (drip detection) 4 based on the intervals of the drip is changed to a rotational velocity larger or smaller than a target rotational velocity (set value) by any factor as shown in the characteristic graph of the motor drive shown in FIG. 4. Note, FIG. 4 shows a

case that the target rotational velocity A (pps) is set to 200 pps.

When the number of drips is made larger than the specific number of drips by any factor halfway while the drive motor is driven at the specific rotational velocity (A = 200 pps), the rotational velocity of the drive motor is decreased by an amount corresponding to a specific ratio for a specific period of time (ta). More specifically, it is decreased by an amount of 10% of the specific ratio for the specific period of time of 10 seconds so that the drive motor is set to the state of Aa in which it is driven at the rotational velocity of 180 pps.

Thereafter, when it is determined that the number of drips is still too large, the rotational velocity of the drive motor is further decreased by the amount of 10% of the specific ratio during the specific period of time (ta) so that the drive motor is set to the state of Ab where it is driven at 162 pps.

Thereafter, even if it is detected that the number of drips has reached the specific number of drips, the rotational velocity of the drive motor is increased by the amount corresponding to the specific ratio for the specific period of time (ta) without suddenly changing the rotational velocity from the state Ab of 162 pps to the state A where it is rotated at the target rotational

velocity of 200 pps. In FIG. 4, the rotational velocity is increased by 10% for 10 seconds so that it is changed from the state of 162 pps to the state Ac of 178 pps. Thereafter, the rotational velocity is increased by 10% to thereby set the rotational velocity to 200 pps (A as the target rotational velocity).

As described above, when the specific rotational velocity is not reached even if the rotational velocity is controlled, the control is further repeated until the previous rotational velocity and the present rotational velocity are within the range of the specific ratio (for example, ±10%).

The rotational velocity of the drive motor is controlled to the specific rotational speed without being suddenly changed by the above arrangement. As described above in detail, there can be obtained the peristaltic type infusion pump for feeding the infusion by successively pressing the infusion tube, the infusion pump comprising the infusion actuation means, the setting/input means for setting and inputting the flow rate of the infusion, the control means for controlling the number of revolutions of the drive motor of the infusion actuation means and the drip probe unit, wherein since the control means controls the drive motor by increasing or decreasing the rotational velocity thereof at the specific ratio based on the intervals of

the drip measured by the drip probe unit, the rotational velocity of the drive motor can be controlled so as to promptly obtain the set flow rate without imposing a load on the patient.

The output obtained by the ultrasonic sensor 5 is supplied to the CPU 6 having the function as the determination means and the comparison means. Further, when the setting/input unit (setting/input means) 7 is used by the user, the user sets and inputs the velocity of the infusion (the flow rate of the infusion), the number of drips, the information as to the infusion tube being used (for example, the name of the manufacture of the tube, the outside diameter of it and the inside diameter thereof) through the setting/input unit (setting/input means) 7.

The ROM 9 stores a size 5.0 mm as the lower limit value of the length of a bubble to be detected in accordance with Japanese Industrial Standards (T1653) as to an infusion apparatus. When the drip of the infusion begins and the CPU 6 indicates to start the detection of a bubble, the ultrasonic waves having the specific wavelength are transmitted from the ultrasonic wave transmitter 5a of the ultrasonic sensor 5 and received by the ultrasonic wave receiver 5b at the same time and an output value (output signal level) is output based on the received ultrasonic waves.

When no bubble exists in the infusion tube 1 in the view of FIG. 5 describing operation, the ultrasonic waves are not reflected and the output value (output signal level) L is made to a high level based on the ultrasonic waves received by the ultrasonic wave receiver 5b, whereas when there exits a bubble, the output value is lowered to a level La.

The CPU 6 as the determination means samples the output signal level at specific intervals t (for example, every two seconds) while comparing it with a reference value (threshold value) Lb. When the output signal level is continuously lower than the reference value (Lb) longer than the specific period of time (ta), for example, when it is continuously lower than the reference value Lb longer than 100 milliseconds, it is determined that there exists a bubble having a length to be detected in the infusion tube 1.

Warning, display and the like are carried out based on the result of the determination to notify that there exits the bubble having the length to be detected in the infusion tube 1 through the display unit 8.

The specific period of time (ta) is calculated and determined by calculation means based on the velocity of the infusion (the flow rate of the infusion), the number of drips, the information as to the infusion tube being used (for example, the name of the manufacture) and the

like which have been set and input by the user when the user uses the setting/input unit 7.

As described above in detail, the infusion pump according to the present invention for feeding the infusion by successively pressing the infusion tube as well as detecting a bubble existing in the infusion comprises the infusion actuation means, the setting/input means for setting and inputting the flow rate of the infusion and the information as to the infusion tube, the pair of ultrasonic sensors disposed at midpoint in the infusion tube in confrontation with each other across the infusion tube and determination means for comparing the output value from the ultrasonic sensor with the reference value and determining that a bubble to be detected exists when the output value is continuously smaller than the reference value longer than the specific period of time. Accordingly, the infusion pump can accurately detect a bubble larger the specific length (size) to be detected which exists in the infusion in the infusion tube and notify the existence of the bubble by the warning, display and the like.

The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present

invention. Therefore to apprise the public of the scope of the present invention, the following claims are made.

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WHAT IS CLAIMED IS:

1. An infusion pump for feeding an infusion by a peristaltic motion by successively pressing an infusion tube, comprising:

infusion actuation means driven by a drive motor for generating the peristaltic motion;

setting/input means for setting and inputting the flow rate of the infusion;

temperature measuring means disposed in the vicinity of the infusion tube for measuring the temperature of the infusion tube; and

control means for selecting a previously stored correction coefficient based on the temperature detected by said temperature measuring means and the flow rate of the infusion input through said setting/input means and increasing or decreasing the rotational velocity of the drive motor depending upon the selected correction coefficient.

2. An infusion pump for feeding an infusion by a peristaltic motion by successively pressing an infusion tube, comprising:

infusion actuation means driven by a drive motor for generating the peristaltic motion;

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setting/input means for setting and inputting the flow rate of the infusion;

motor control means for controlling the number of revolutions of the drive motor;

a drip probe unit disposed at midpoint in the infusion tube for measuring the number of drips; and

control means for reducing the rotational velocity of the drive motor at a specific ratio when the number of drips measured by said drip probe unit abruptly changes and thereafter returning the rotational velocity to the normal number of revolutions.

3. An infusion pump for feeding an infusion by a peristaltic motion by successively pressing an infusion tube as well as detecting a bubble existing in the infusion, comprising:

infusion actuation means driven by a drive motor for generating the peristaltic motion;

setting/input means for setting and inputting the flow rate of the infusion and information including the inside diameter of the infusion tube;

a pair of ultrasonic sensors disposed at midpoint in the infusion tube in confrontation with each other across the infusion tube; and

determination means for comparing the output value

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from said ultrasonic sensor with a reference value and determining that a bubble exists when the output value is continuously smaller than the reference longer than a specific period of time.

4. An infusion pump according to claim 3, wherein the specific period of time is calculated based on the value of the length of a bubble to be detected which is previously set and stored to memory means, the value of the flow rate of the infusion input to said setting/input means and the information as to the infusion tube.

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