SYRINGE INFUSION PUMP

Related applications and Priority

This patent application claims the benefit of provisional patent application number 60/934,236 entitled "Axially Centered Syringe Infusion Pump Drive Mechanism," filed June 11, 2007, incorporated herein by reference.

Field

This patent application generally relates to infusion pumps. More particularly it relates to syringe infusion pumps. More particularly it relates to a drive mechanism for syringe infusion pumps.

Background

Infusion pumps currently present in the market consist of two basic types, syringe infusion pumps and volumetric infusion pumps. Typically, syringe infusion pumps accept a range of syringe sizes, typically from 1cc to 60cc or more in volume from a variety of syringe manufacturers. Typically these devices use a motor under control of a microprocessor. A motor such as is available from Maxon Precision Motors, Inc., Fall River, MA, can be used. The motor is connected to a lead screw which advances a pushing element that pushes against the plunger of the syringe, driving it into the barrel of the syringe, thus dispensing fluid or other material. The devices have used sensors for determining the size of syringe loaded, the position of the plunger within its travel, whether the plunger is captured by the pushing element, and the driving force needed to push the plunger. The devices have also included encoders or other means for determining the motor speed.

The syringe drives have fixed the barrel of the syringe against a fixture, such as a V-block. A spring loaded clamp mechanism has been used to capture the barrel of the syringe against the V-block. Because the barrel diameter of a 1cc syringe is significantly smaller than the barrel diameter of a 60cc syringe, the pushing element has not always pushed along the center line of the syringe, and the variance between pushing element and syringe center line can be as much as 1 inch or more. The variance in the syringe center line with respect to the pushing surface has caused difficulties in measuring the force applied to the syringe which is used to estimate fluid pressure within the syringe. The variance has also caused inaccuracy in the resultant flow rate because the syringe plunger has not been driven into the syringe barrel squarely. Thus better schemes for mounting a syringe and driving its plunger are needed to eliminate these problems, and these schemes are provided by this patent application.

Summary

One aspect of the present patent application is a syringe infusion pump that includes a syringe, a syringe barrel holder, and a force sensor. The syringe includes a barrel and a plunger. The plunger has a plunger axis. The barrel has a barrel axis and a barrel diameter. The syringe is one of a plurality of syringes, each having a different barrel diameter. The syringe barrel holder provides the barrel axis automatically aligned with the force sensor for each syringe of the plurality of syringes.

Another aspect is a syringe infusion pump that includes a syringe, a syringe plunger holder, and a force sensor. The syringe includes a barrel and a plunger. The plunger has a plunger axis and the barrel has a barrel diameter. The syringe is one of a plurality of syringes, each having a different barrel diameter. The syringe holder includes a plunger holder. The syringe plunger holder maintains a constant plunger axis independent of the barrel diameter.

Another aspect is a syringe infusion pump that includes a syringe, a syringe plunger holder, and a force sensor. The syringe includes a barrel and a plunger. The plunger has a plunger axis. The barrel has a barrel axis and a barrel diameter. The syringe is one of a plurality of syringes, each having a different barrel diameter. The syringe plunger holder provides the plunger axis approximately aligned with the barrel axis independent of the barrel diameter.

Another aspect is a syringe infusion pump that includes a syringe, a syringe barrel holder, and a force sensor. The syringe includes a barrel and a plunger. The barrel has a barrel axis and a barrel diameter. The syringe is one of a plurality of syringes, each having a different barrel diameter. The plurality of syringes includes a syringe having a smallest barrel diameter. The syringe barrel holder provides the barrel axis approximately aligned with the force sensor for a syringe having a barrel diameter that is less than or equal to two times the smallest barrel diameter.

A syringe infusion pump, comprising a syringe, a motor, a drive head, and a drive head position sensing mechanism. The motor is connected to move the drive head to facilitate operating the syringe. The drive head position sensing mechanism includes a guide rod, a pin, and a guide rod sensor. The guide rod has a helical groove. The pin extends from the drive head and fits in the helical groove. The guide rod rotates as the drive head moves, and the guide rod sensor senses rotation of the guide rod for use in determining drive head position.

Another aspect is a method of providing a fluid. The method includes providing a syringe, wherein the syringe includes a barrel and a plunger. The plunger has a plunger axis. The barrel has a barrel axis and a barrel diameter. The syringe is one of a plurality of syringes, each having a different barrel diameter. The method also includes providing a syringe infusion pump that includes a syringe barrel holder and a force sensor. The barrel syringe holder provides the barrel axis automatically aligned with the force sensor for each syringe of the plurality of syringes. The method also includes using the syringe

infusion pump to provide the fluid.

Brief Description of the Drawings

The foregoing will be apparent from the following detailed description as illustrated in the accompanying drawings, for clarity not drawn to scale, in which:

FIG. 1 is a three dimensional view of one embodiment of a syringe infusion pump of the present patent application;

FIG. 2 is a three dimensional view of a drive head, motor, and position sensing mechanism of the syringe infusion pump of FIG. 1;

FIGS. 3a-3c are a three dimensional cutaway views of a portion of the drive head of FIG. 2 showing a plunger in position in front of a force sensor, and showing plunger clamp elements maintaining the plunger axis in front of the center of the force sensor;

FIG. 4 is another three dimensional view of the drive head of FIG. 2;

FIG. 5 is a block diagram of electronic components for the syringe infusion pump;

FIGS. 6a-6d are three dimensional views of the barrel holder portion of the syringe holder of FIG. 1 showing how the axis of the barrel is maintained in the same position regardless of the diameter of the barrel; and

FIG. 7 is another three dimensional view of the barrel holder portion of the syringe holder of FIGS. 6a-6d.

Detailed Description

One embodiment of the present patent application provides a syringe infusion pump with a force sensor and a syringe holder. In this embodiment the syringe holder includes a syringe plunger holder and a syringe barrel holder. The syringe holder can include mechanisms that provide the syringe plunger axis and the syringe barrel axis automatically aligned with the force sensor for all sized syringes.

Syringe infusion pump 20 includes drive head 22, syringe barrel holder 24, motor 26, lead screw 28, and position sensing device 30, as shown in FIGS. 1 and 2.

Motor 26 turns lead screw 28 clockwise or counterclockwise to move drive head 22 toward or away from syringe barrel holder 24. Drive head 22 includes force sensor 32 against which plunger 36 of syringe 38 is positioned, as shown in FIGS. 3a-3c. Force sensor 32 can be one available from Strain Measurement Devices, Meriden, CT. Plunger 36 is held in position against force sensor 32 by syringe plunger holder and syringe plunger flange holder 40 that includes front plunger clamp element 42a and rear plunger clamp element 42b. Plunger clamp elements 42a, 42b have V-grooves 44a, 44b that both hold plunger 36 and capture plunger flange 46. Thus, plunger axis 54 extends directly into center 56 of force sensor 32, as shown in FIGS. 3a-3c and FIG. 4.

Plunger clamp elements 42a, 42b are connected to gear 48 through racks 50a, 50b so that plunger clamp elements 42a, 42b are constrained to move equal distances in opposite directions to each other, maintaining plunger flange 46 centered before force sensor 32 and maintaining plunger axis 54 of plunger 36 extending directly into center 56 of force sensor 32, regardless of the diameter of plunger 36. Gear 48, racks 50a, 50b are included in drive head housing 58.

Post 60 holds spring 62 for providing pressure for restoring plunger clamp elements 42a, 42b toward each other, as shown in FIG. 4.

Force sensor 32 senses the force being applied to plunger 36 by drive head 22. Force sensor 32 is connected to motor processor 64 on electronic circuit board 66. Motor 26, barrel sensor 76, and position sensor 78 are also connected to motor processor 64 on electronic circuit board 66. Motor processor 64 can be one available from Microchip Technology Inc., Chandler, AZ. Barrel sensor 76 and position sensor 78 can be ones available from US Digital, Inc., Vancouver, Washington. Electronic circuit board 66 also includes main microprocessor 68. Keypad 70, display 72, and battery 74 are connected to main microprocessor 68. Main processor 68 and display 72 can be ones available from Sharp Electronics Corporation, Romeoville, IL.

Motor processor 64 controls speed of motor 26 in a software closed control loop by monitoring two quadrature signals emitted by a motor encoder that is part of motor 26. Motor processor 64 monitors output of force sensor 32 and provides an alarm signal to alarm 79 if a preset force above a threshold is detected. This force translates to a resultant fluid pressure based upon the cross sectional area of syringe barrel 96. Motor processor 64 also monitors barrel sensor 76 and determines its outer diameter and thence its volume based upon a software look up table that cross references barrel diameter to syringe barrel volume. Motor processer 64 also monitors position sensor 78 and from this position determines the state of fill of syringe barrel 96 installed.

Main processor 68 sends the display information to display 72 to be visually communicated to the user. Main processor 68 also monitors keypad 70 to enable the user to control the device via key press.

Battery 74 supplies power to all the electronics and motor 26.

Position of drive head 22 along lead screw 28 is measured with position sensing device 30, as shown in FIGS. 1 and 2. Position sensing device 30 includes guide rod 80 and position sensor 78. Guide rod 80 has helical groove 84. Pin 86 extends from drive head 22 into helical groove 84 and causes guide rod 80 to rotate as drive head 22 moves

under control of lead screw 28 and motor 26. Because helical groove 84 extends only once around guide rod 80, rotation of guide rod 80 can be used to accurately determine position of drive head 22 along lead screw 28. Rotation of guide rod 80 is measured with position sensor 78, and data from position sensor 78 is fed to motor processor 64 on circuit board 66.

Syringe barrel holder 24 includes front barrel clamp element 90a and rear barrel clamp element 90b, as shown in FIGS. 6a-6d. Front barrel clamp element 90a has a curved portion 94 to hold syringe barrel 96 in position within groove 98 in rear barrel clamp element 90b. Groove 98 of rear barrel clamp element 90b may have different flat regions 100a, 100b to facilitate accommodating barrels having different diameters. Flat regions 100c can be used to facilitate accommodating barrels having collars.

Syringe barrel holder 24 also includes barrel flange clamp 102 on the side facing drive head 22, as shown in FIGS. 6a-6d and 7. Barrel flange clamp 102 is for capturing barrel flange 104 in a fixed position, as shown in FIGS. 6a-6d and FIG. 7 so that position of drive head 22 alone determines the amount of penetration of plunger into syringe barrel 96. Syringe holder 106 includes syringe plunger holder and syringe plunger flange holder 40 and syringe barrel holder 24.

Syringe barrel holder 24 also includes barrel centering mechanism 108 for automatically centering barrel axis 110 of barrel 96 along plunger axis 54 and along center 56 of force sensor 32. Barrel centering mechanism 108 provides that both front barrel clamp element 90a and rear barrel clamp element 90b move equal distances in opposite directions when syringe barrel 96 is inserted, maintaining barrel axis 110 in fixed position regardless of the size of barrel 96, as shown in FIGS. 6a-6d.

Barrel centering mechanism 108 includes barrel racks 112a, 112b, as shown in FIGS. 6a-6d. Barrel rack 112a is connected to front barrel clamp element 90a and to barrel clamp sensor gear 114 located in base 116, as shown in FIG. 1. Barrel rack 112b is

connected to rear barrel clamp element 90b and to barrel clamp sensor gear 114. Barrel sensor 76 is also connected to barrel clamp sensor gear 114, and from the magnitude of rotation it measures of barrel clamp sensor gear 114 barrel sensor 76 determines the size of syringe barrel 96.

Spring shaft 124 carries spring 126 that provides a force against base 116 pulling front barrel clamp element 90a toward rear barrel clamp element 90b to apply pressure to and hold syringe barrel 96. Guide shaft 128 extends from front barrel clamp element 90a through rear barrel clamp element 90b and into base 116.

While the disclosed methods and systems have been shown and described in connection with illustrated embodiments, various changes may be made therein without departing from the spirit and scope of the invention as defined in the appended claims.

Claims

1. A syringe infusion pump, comprising a syringe, a syringe barrel holder, and a force sensor, wherein said syringe includes a barrel and a plunger, wherein said plunger has a plunger axis, wherein said barrel has a barrel axis and a barrel diameter, wherein said syringe is one of a plurality of syringes, each having a different barrel diameter, wherein said force sensor is positioned for detecting a force along said barrel axis, wherein said syringe barrel holder provides said barrel axis automatically aligned with said force sensor for each syringe of said plurality of syringes.

2. A syringe infusion pump as recited in claim 1, further comprising a syringe plunger holder, wherein said syringe plunger holder provides said plunger axis automatically aligned with said force sensor for each syringe of said plurality of syringes and wherein said syringe plunger holder provides said plunger axis automatically aligned with said barrel axis for each syringe of said plurality of syringes.

3. A syringe infusion pump as recited in claim 1 or 2, further comprising a drive head, wherein said drive head is positioned to push said plunger into said barrel, wherein said force sensor is positioned to detect force exerted by said drive head on said plunger.

4. A syringe infusion pump as recited in claim 3, wherein position of said force sensor is fixed in said drive head.

5. A syringe infusion pump as recited in claim 4, wherein position of said barrel axis is fixed with respect to position of said force sensor and wherein position of said barrel axis is independent of size of said barrel.

6. A syringe infusion pump as recited in claim 5, wherein said syringe barrel holder includes a barrel clamp having a first element and a second element, wherein said first element and said second element both move to provide said axis in a fixed position independent of size of said barrel.

7. A syringe infusion pump as recited in claim 6, wherein said barrel holder includes a mechanism having a gear, a first drive shaft and a second drive shaft, wherein said first drive shaft is connected to said first element and said second drive shaft is connected to said second element to provide said movement of said first element and said second element.

8. A syringe infusion pump as recited in claim 7, wherein said first drive shaft includes a first rack for mating with said gear and wherein said second drive shaft includes a second rack for mating with said gear.

9. A syringe infusion pump as recited in claim 7, wherein said barrel holder includes a barrel diameter sensor for detecting magnitude of separation between said first element and said second element.

10. A syringe infusion pump as recited in claim 9, wherein said barrel diameter sensor includes an absolute encoder for detecting angular movement of said gear.

11. A syringe infusion pump as recited in claim 2, wherein said syringe plunger holder automatically maintains a constant plunger axis independent of size of said barrel.

12. A syringe infusion pump as recited in claim 2, wherein said syringe plunger holder automatically maintains said plunger axis approximately aligned with said barrel axis independent of size of said barrel.

13. A syringe infusion pump as recited in claim 1, further comprising a processor and an alarm, wherein said force sensor is connected to provide force data to said processor, wherein said processor is programmed to activate said alarm if said force exceeds a specified value.

14. A syringe infusion pump as recited in claim 1, further comprising a drive head position sensing mechanism.

15. A syringe infusion pump as recited in claim 14, wherein said drive head position sensing mechanism includes a guide rod, a guide rod driver, and a guide rod sensor.

16. A syringe infusion pump as recited in claim 15, wherein said guide rod has a helical groove and wherein said guide rod driver includes a pin that fits in said helical groove, wherein said guide rod sensor senses rotation of said guide rod.

17. A syringe infusion pump as recited in claim 16, wherein said helical groove extends once around said guide rod.

18. A syringe infusion pump as recited in claim 16, wherein said a guide rod sensor includes an absolute encoder for detecting angular movement of said guide rod.

19. A syringe infusion pump as recited in claim 1, wherein said barrel includes a barrel flange, wherein said syringe barrel holder includes a barrel clamp having a first element and a second element, wherein said first element has a barrel flange clamp.

20. A syringe infusion pump as recited in claim 1, wherein said plunger includes a plunger flange, wherein said drive head includes a plunger flange holder, wherein said plunger flange holder is automatically centered on said barrel axis when said syringe barrel holder is holding a barrel having each of said diameters.

21. A syringe infusion pump as recited in claim 20, wherein said plunger flange holder has a first plunger flange holder element and a second plunger flange holder element, wherein said first plunger flange holder element and said second plunger flange holder element both move to provide said plunger centered on said barrel axis independent of size of said barrel.

22. A syringe infusion pump as recited in claim 21, wherein said plunger flange holder includes a plunger flange holder gear, a first plunger flange holder drive shaft and a second plunger flange holder drive shaft, wherein said first plunger flange holder drive shaft is connected to said first plunger flange holder element and said second plunger flange holder drive shaft is connected to said second plunger flange holder element to provide said movement of said first element and said second element.

23. A syringe infusion pump as recited in claim 22, wherein said first plunger flange holder drive shaft includes a first rack for mating with said plunger flange holder gear and wherein said second plunger flange holder drive shaft includes a second rack for mating with said plunger flange holder gear.

24. A syringe infusion pump, comprising a syringe, a syringe plunger holder, and a force sensor, wherein said syringe includes a barrel and a plunger, wherein said plunger has a plunger axis, wherein said barrel has a barrel diameter, wherein said syringe is one of a plurality of syringes, each having a different barrel diameter, wherein said syringe plunger holder maintains a constant plunger axis independent of said barrel diameter.

25. A syringe infusion pump as recited in claim 24, wherein said force sensor is positioned to measure force along said plunger axis.

26. A syringe infusion pump, comprising a syringe, a syringe plunger holder, and a force sensor, wherein said syringe includes a barrel and a plunger, wherein said plunger has a plunger axis, wherein said barrel has a barrel axis and a barrel diameter, wherein said syringe is one of a plurality of syringes, each having a different barrel diameter, wherein said syringe plunger holder provides said plunger axis approximately aligned with said barrel axis independent of said barrel diameter.

27. A syringe infusion pump as recited in claim 26, wherein said force sensor is positioned to measure force along said plunger axis.

28. A syringe infusion pump, comprising a syringe, a syringe barrel holder, and a force sensor, wherein said syringe includes a barrel and a plunger, wherein said barrel has a barrel axis and a barrel diameter, wherein said syringe is one of a plurality of syringes, each having a different barrel diameter, wherein said plurality of syringes includes a syringe having a smallest barrel diameter, wherein said force sensor has a center, wherein said syringe barrel holder provides said barrel axis aligned with said center of said force sensor for each said syringe regardless of barrel diameter.

29. A syringe infusion pump, comprising a syringe, a motor, a drive head, and a drive head position sensing mechanism, wherein said motor is connected to move said drive head to facilitate operating said syringe, wherein said drive head position sensing mechanism includes a guide rod, a pin, and a guide rod sensor, wherein said guide rod has a helical groove, wherein said pin extends from said drive head and fits in said helical groove, wherein said guide rod rotates as said drive head moves, and wherein said guide rod sensor senses rotation of said guide rod for use in determining drive head position.

30. A syringe infusion pump as recited in claim 29, wherein said helical groove extends once around said guide rod.

31. A syringe infusion pump as recited in claim 29, wherein said a guide rod sensor includes an absolute encoder for detecting angular movement of said guide rod.

32. A method of providing a fluid comprising:

a. providing a syringe, wherein said syringe includes a barrel and a plunger, wherein said plunger has a plunger axis, wherein said barrel has a barrel axis and a barrel diameter, wherein said syringe is one of a plurality of syringes, each having a different barrel diameter;

b. providing syringe infusion pump, including a syringe barrel holder and a force sensor, wherein said force sensor is positioned for detecting a force along said barrel axis, wherein said syringe barrel holder provides said barrel axis automatically aligned with said force sensor for each syringe of said plurality of syringes; and

c. using said syringe infusion pump to provide the fluid.