[0004] Additional problems have also been experienced with infusion pumps. For example, certain sensing systems that detect whether an occlusion is present in an infusion line have proven to be unreliable or too complex in construction. Certain syringe plunger position detectors and syringe barrel size detectors have also proven to be unreliable. In addition, drive mechanisms for syringe plungers have also proven to be unreliable as certain components become stripped or jammed adversely affecting the mechanism.

SUMMARY

[0005] The present invention is generally directed to a syringe pump for delivering a flowable material, such as a fluid medication, to a patient through an infusion line.

[0006] Aspects of the subject matter described herein may be useful alone or in combination with one or more other aspects described herein. In an ~~exemplary aspect~~example of the present disclosure, a syringe pump includes a housing with a syringe-accepting region.

[0006a] According to an aspect, the present disclosure refers to a syringe pump comprising: a housing with a syringe accepting region; a syringe holding system configured to hold a syringe in the syringe accepting region; characterized in that the syringe pump further comprises: a drive mechanism including: a lead screw, at least one half nut, a clutch assembly, and a drive rod, wherein the clutch assembly is configured to engage and disengage the at least one half nut to and from the lead screw; and a drive head operatively coupled to the drive mechanism, the drive head configured to engage a piston of a syringe held by the syringe holding system, wherein the clutch assembly includes a magnet configured to increase a holding force of the clutch assembly and prevent ratcheting between the lead screw and the at least one half nut.

[0007] In accordance with ~~a second exemplary aspect~~an example of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe pump includes a syringe holding system configured to hold a syringe in the syringe-accepting region.

[0008] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects,

the syringe pump includes a drive mechanism.

[0009] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe pump includes a drive head operatively coupled to the drive mechanism. The drive head may be configured to engage a piston of a syringe held by the syringe holding system.

[0010] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe-accepting region includes a concave rear wall having a vertex, where the concave rear wall includes a top portion and a bottom portion that meet to form the vertex.

[0011] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the top portion is oriented at a first angle with respect to a vertical plane intersecting the vertex.

[0012] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the bottom portion is oriented at a second angle with respect to a vertical plane intersecting the vertex.

[0013] In accordance with an example ~~a second exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the first angle and the second angle are the same.

[0014] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the drive head includes first and second plunger hooks disposed on the drive head.

[0015] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the plunger hooks are configured to grasp onto a plunger thumb flange of a plunger of the syringe. Additionally, the first and second plunger hooks are configured to actuate between an open position and a closed position.

[0016] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the drive head includes a plunger lever. The plunger lever is adapted to move the plunger hooks between the open position and the closed position. Additionally, the plunger lever is configured for actuation by a user.

[0017] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the drive mechanism includes a lead screw, a split-nut, a clutch assembly, and a drive rod. The clutch assembly is configured to engage and disengage the split-nut to and from the lead screw.

[0018] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the clutch assembly includes a magnet configured to increase a holding force of the clutch assembly and prevent ratcheting.

[0019] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the

syringe holding system includes a barrel clamp, a flange plate, and first and second syringe hooks.

[0020] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the drive mechanism includes an anti-ratcheting magnetic clutch.

[0021] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe pump further includes an occlusion sensor. The occlusion sensor is configured to determine if an infusion line connected to the syringe barrel is blocked.

[0022] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the occlusion sensor determines if an infusion line connected to the syringe barrel is blocked by calculating a slope of a force curve, a slope of a pressure curve, a comparison to a baseline force measurement, a comparison to a baseline pressure measurement, or an area under the force curve.

[0023] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe pump further includes an accelerometer, wherein the accelerometer is configured to detect at least one of an occlusion or whether the syringe pump experienced an external impact.

[0024] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe pump is positioned in a rack with at least one other infusion pump or syringe pump.

[0025] Aspects of the subject matter described herein may be useful alone or in combination with one or more other aspects described herein. In an ~~exemplary aspect~~example of the present disclosure, a syringe positioning system for positioning a plurality of syringes having respective barrels and respective plungers within a syringe pump housing includes a barrel clamp, a flange plate, and first and second plunger hooks. The barrel clamp is adjustable to hold the syringe barrel against the syringe pump housing. The flange plate is configured to secure a syringe barrel flange against the syringe pump housing.

Additionally, the plunger hooks are configured to grasp onto a plunger thumb flange of the plunger of the syringe. The first and second plunger hooks are also configured to actuate between an open position and a closed position.

[0026] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe positioning system is further configured to position a plurality of syringes having different sizes.

[0027] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the syringe positioning system further includes a position sensor configured to detect a rotation of the syringe barrel clamp.

[0028] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the barrel clamp includes a proximal end pivotably attached to the housing and a distal end with a barrel engagement surface.

[0029] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the barrel engagement surface is attached to the barrel clamp via a swivel and is adapted to allow the barrel engagement surface to rotate and contact syringe barrels of at least two different sizes.

[0030] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the flange plate is configured to secure a syringe barrel flange against the housing.

[0031] In accordance with ~~another~~ an example ~~exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the flange plate is biased towards the housing.

[0032] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the flange plate includes a bottom surface configured to contact the syringe barrel flange, and the flange plate has a surface profile that transitions from a flat surface to an angled surface towards the edge of the flange plate.

[0033] Aspects of the subject matter described herein may be useful alone or in combination with one or more other aspects described herein. In an ~~exemplary aspect~~example of the present disclosure, a method of detecting an occlusion includes monitoring a pressure measurement. The pressure measurement may be based on an ADC value

[0034] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the method includes, during a first interval, recording a baseline pressure measurement.

[0035] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the method includes, during a second interval, determining whether a respective current pressure measurement exceeds a first difference threshold between the current pressure measurement and the baseline pressure measurement. The first difference threshold may be based on a selected occlusion detection mode.

[0036] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the method includes, during a third interval, after the first interval and the second interval, recording a new baseline pressure measurement.

[0037] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the method includes, after determining the new baseline pressure measurement, determining whether a respective current pressure measurement exceeds a second difference threshold between the respective current pressure measurement and the new baseline pressure measurement.

[0038] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the method includes determining an occlusion exists within a tube of an infusion pump when at least one of the first difference threshold and the second difference threshold is exceeded.

[0039] In accordance with an example ~~another exemplary aspect~~ of the present disclosure, which may be used in combination with any one or more of the preceding aspects, the selected occlusion detection mode includes either a rapid occlusion detection mode or a

CLAIMS

1. A syringe pump comprising:

a housing with a syringe accepting region;

a syringe holding system configured to hold a syringe in the syringe accepting region;

characterized in that the syringe pump further comprises:

a drive mechanism including:

a lead screw,

at least one half nut,

a~~n anti-ratcheting magnetic~~ clutch assembly, and

a drive rod,~~ and~~ wherein the clutch assembly is configured to engage and disengage the at least one half nut to and from the lead screw; and

a drive head operatively coupled to the drive mechanism, the drive head configured to engage a piston of a syringe held by the syringe holding system,

wherein the clutch assembly includes a magnet configured to increase a holding force of the clutch assembly and prevent ratcheting between the lead screw and the at least one half nut.

2. The syringe pump of claim 1, wherein the syringe accepting region includes a concave rear wall having a vertex, where the concave rear wall includes a top portion and a bottom portion that meet to form the vertex, and wherein the top portion is oriented at a first angle with respect to a vertical plane intersecting the vertex.

3. The syringe pump of claim 2, wherein the bottom portion is oriented at a second angle with respect to a vertical plane intersecting the vertex.

4. The syringe pump of claim 3, wherein the first angle and the second angle are the same.

5. The syringe pump of any of claims 1 to 3, wherein the drive head includes first and second plunger hooks disposed on the drive head and configured to grasp onto a

plunger thumb flange of a plunger of the syringe, and wherein the first and second plunger hooks are configured to actuate between an open position and a closed position.

6. The syringe pump of any of claims 1 to 5, wherein the drive head includes a plunger lever, the plunger lever adapted to move the plunger hooks between the open position and the closed position, and wherein the plunger lever is configured for actuation by a user.

7. The syringe pump of any of claims 1 to 6, wherein the magnet is configured to increase the holding force of the clutch assembly to provide additional security against unintended bolus~~anti-ratcheting magnetic clutch assembly includes a magnet configured to increase a holding force of the clutch assembly and prevent ratcheting~~.

8. The syringe pump of any of claims 1 to 7, wherein the syringe holding system includes a barrel clamp, a flange plate, and first and second syringe hooks.

9. The syringe pump of claim 8, wherein the barrel clamp includes a proximal end pivotably attached to the housing and a distal end with a barrel engagement surface, wherein the barrel engagement surface is attached to the barrel clamp via a swivel and is adapted to allow the barrel engagement surface to rotate and contact syringe barrels of at least two different sizes.

10. The syringe pump of claim 8, wherein the flange plate is configured to secure a syringe barrel flange against the housing, the flange plate is biased towards the housing, and the flange plate includes a bottom surface configured to contact the syringe barrel flange, and the flange plate has a surface profile that transitions from a flat surface to an angled surface towards the edge of the flange plate.

11. The syringe pump of any of claims 1 to 10, wherein the clutch assembly includes two magnets~~drive mechanism includes an anti-ratcheting magnetic clutch~~.

12. The syringe pump of any of claims 1 to 11, further comprising an occlusion sensor, wherein the occlusion sensor is configured to determine if an infusion line connected to the syringe barrel is blocked.

13. The syringe pump of claim 12, wherein the occlusion sensor determines if an infusion line connected to the syringe barrel is blocked by calculating one of a slope of a force curve, a slope of a pressure curve, a comparison to a baseline force measurement, a comparison to a baseline pressure measurement, or an area under the force curve.

14. The syringe pump of any of claims 1 to 13, further comprising an accelerometer, wherein the accelerometer is configured to detect at least one of an occlusion or whether the syringe pump experienced an external impact.

15. The syringe pump of any of claims 1 to 14, wherein the syringe pump is positioned in a rack with at least one other infusion pump or syringe pump.

~~16. A syringe positioning system for positioning a plurality of syringes having respective barrels and respective plungers within a syringe pump housing, the positioning system comprising:~~

~~a barrel clamp, wherein the barrel clamp is adjustable to hold a respective syringe barrel against the syringe pump housing, and wherein the barrel clamp includes a proximal end pivotably attached to the housing and a distal end with a barrel engagement surface, wherein the barrel engagement surface is attached to the barrel clamp via a swivel and is adapted to allow the barrel engagement surface to rotate and contact syringe barrels of at least two different sizes;~~

~~a flange plate configured to secure a syringe barrel flange against the syringe pump housing; and~~

~~first and second plunger hooks configured to grasp onto a plunger thumb flange of the plunger of the syringe, wherein the first and second plunger hooks are configured to actuate between an open position and a closed position.~~

~~17. The syringe positioning system of claim 16 further comprising a position sensor configured to detect a rotation of the syringe barrel clamp.~~

~~18. The syringe positioning system of claim 16, wherein the flange plate is configured to secure a syringe barrel flange against the housing, the flange plate is biased towards the housing, and the flange plate includes a bottom surface configured to contact the syringe barrel flange, and the flange plate has a surface profile that transitions from a flat surface to an angled surface towards the edge of the flange plate.~~

~~19. A method of detecting an occlusion, the method comprising:~~

~~monitoring a pressure measurement, wherein the pressure measurement is based on an ADC value;~~

~~during a first interval, recording a baseline pressure measurement;~~

~~during a second interval, determining whether a respective current pressure measurement exceeds a first difference threshold between the current pressure measurement and the baseline pressure measurement, wherein the first difference threshold is based on a selected occlusion detection mode;~~

~~during a third interval, after the first interval and the second interval, recording a new baseline pressure measurement;~~

~~after determining the new baseline pressure measurement, determining whether a respective current pressure measurement exceeds a second difference threshold between the respective current pressure measurement and the new baseline pressure measurement; and~~

~~determining an occlusion exists within a tube of an infusion pump when at least one of the first difference threshold and the second difference threshold is exceeded.~~

~~20. The method of claim 19, wherein the selected occlusion detection mode includes one of a rapid occlusion detection mode and a non-rapid occlusion detection mode, and wherein the threshold is lower for the rapid occlusion detection mode than the non-rapid occlusion detection mode.~~