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(54) **Titre : CAPTEUR DE POSITION D'UNE TIGE CYLINDRIQUE**
(54) **Title: POSITION SENSOR FOR A CYLINDRICAL ROD**

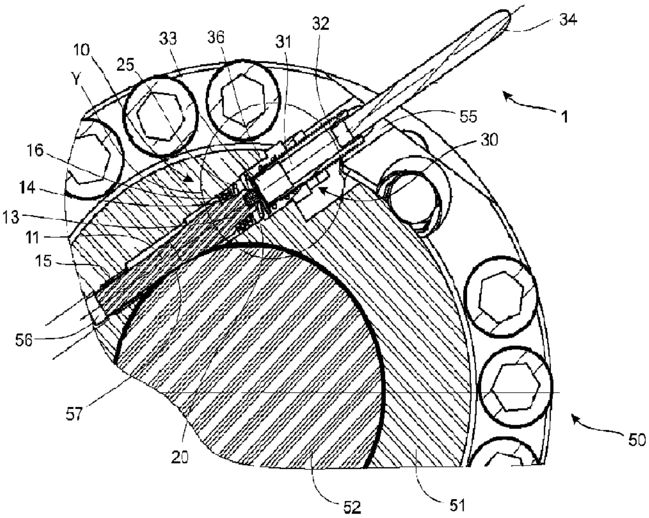

Fig. 1C

(57) **Abrégé/Abstract:**
A sensing system for determining axial position of a cylindrical rod involves: a tapered rotatable shaft having a rotation axis, the shaft positionable so that the rotation axis is perpendicular to a translation axis of a cylindrical rod, the shaft having a tapered portion that is frictionally engageable with the cylindrical rod to be rotatable by the cylindrical rod when the cylindrical rod moves axially; a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain frictional engagement of the tapered portion of the shaft with the cylindrical rod when the shaft is engaged with the cylindrical rod; and, a sensor for detecting rotation of the shaft when the shaft is rotated by the cylindrical rod, the rotation of the shaft being correlated to the axial position of the cylindrical rod.

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Abstract:

A sensing system for determining axial position of a cylindrical rod involves: a tapered rotatable shaft having a rotation axis, the shaft positionable so that the rotation axis is perpendicular to a translation axis of a cylindrical rod, the shaft having a tapered portion that is frictionally engageable with the cylindrical rod to be rotatable by the cylindrical rod when the cylindrical rod moves axially; a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain frictional engagement of the tapered portion of the shaft with the cylindrical rod when the shaft is engaged with the cylindrical rod; and, a sensor for detecting rotation of the shaft when the shaft is rotated by the cylindrical rod, the rotation of the shaft being correlated to the axial position of the cylindrical rod.

POSITION SENSOR FOR A CYLINDRICAL ROD

Cross-reference to Related Applications

This application claims the benefit of United States Provisional Patent Application USSN 63/188,144 filed May 13, 2021, the entire contents of which is herein incorporated by reference.

Field

This application relates to determining position of a moveable cylindrical rod, for example cylinder rods in rod-in-cylinder devices, for example fluid-pressure actuators (e.g., hydraulic cylinders) and linear actuators.

Background

In rod-in-cylinder devices, it is often useful to know the axial position of the cylinder rod as the cylinder rod cycles through strokes. Various attempts have been made to provide sensing systems for determining axial position of the cylinder rod. For example, United States Patent US 7,757547 and Japanese published applications JP 2006226909 and JP 2006258730 all describe arrangements in which a roller is engaged with the cylinder rod to rotate a magnet to induce a signal in an encoder. However, such arrangements invariably suffer from slippage between the roller and the cylinder rod, thereby requiring recalibration of the sensor on an on-going basis. Because the roller is biased to the cylinder rod in a direction toward the axis of rotation of the cylinder, flexion of the cylinder rod in one direction displaces the roller, and when the cylinder rod flexes in a different direction there is a momentary loss of contact between the roller and the cylinder rod causing the position sensor to skip counts leading quickly to miscalibration of the sensing system.

There remains a need for a more robust sensor arrangement for determining a position of a cylindrical rod, for example a cylinder rod during a stroke of the cylinder rod in a fluid-pressure or electrically activated rod-in-cylinder device.

Summary

A sensing system for determining axial position of a cylindrical rod comprises: a tapered rotatable shaft having a rotation axis, the shaft positionable so that the rotation axis is perpendicular to a translation axis of a cylindrical rod, the shaft having a tapered portion that is frictionally engageable with the cylindrical rod to be rotatable by the cylindrical rod when the cylindrical rod moves axially; a biasing element that biases the shaft in a direction

CA 03218896 2023-11-13

parallel to the rotation axis of the shaft to continually maintain frictional engagement of the tapered portion of the shaft with the cylindrical rod when the shaft is engaged with the cylindrical rod; and, a sensor for detecting rotation of the shaft when the shaft is rotated by the cylindrical rod, the rotation of the shaft being correlated to the axial position of the cylindrical rod.

A sensing system for determining axial position of a cylinder rod comprises: a tapered rotatable shaft insertable into a lateral bore in a head of the cylinder, the shaft having a rotation axis parallel to a tangent to a circumference of the cylinder rod when the shaft is in the lateral bore, a tapered portion of the shaft frictionally engageable with the cylinder rod to be rotatable by the cylinder rod when the cylinder rod moves axially in the cylinder; a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain frictional engagement of the tapered portion of the shaft with the cylinder rod when the shaft is inserted in the lateral bore; and, a sensor insertable into the lateral bore, the sensor detecting rotation of the shaft when the shaft is rotated by the cylinder rod, the rotation of the shaft being correlated to the axial position of the cylinder rod.

A cylinder comprises: a head; a barrel; a gland; a cylinder rod moveable through a cylinder stroke; and, a sensing system for determining axial position of the cylinder rod during the stroke, the sensing system comprising: a tapered rotatable shaft inserted into a lateral bore in the head, wherein a rotation axis of the shaft is parallel to a tangent to a circumference of the cylinder rod, wherein a tapered portion of the shaft frictionally engages the cylinder rod and wherein axial movement of the cylinder rod during the stroke causes the shaft to rotate about the rotation axis due to frictional engagement of the tapered portion of the shaft with the cylinder rod; a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain the frictional engagement of the tapered portion of the shaft with the cylinder rod; and, a sensor that detects rotation of the shaft, the rotation of the shaft being correlated to the axial position of the cylinder rod.

Further features will be described or will become apparent in the course of the following detailed description. It should be understood that each feature described herein may be utilized in any combination with any one or more of the other described features, and that each feature does not necessarily rely on the presence of another feature except where evident to one of skill in the art.

CA 03218896 2023-11-13

Brief Description of the Drawings

For clearer understanding, preferred embodiments will now be described in detail by way of example, with reference to the accompanying drawings, in which:

Fig. 1A depicts an end view of a hydraulic cylinder comprising a first embodiment of a sensing system for determining axial position of a cylinder rod during a stroke of the hydraulic cylinder.

Fig. 1B depicts a cross-sectional view through **A-A** in Fig. 1A.

Fig. 1C depicts a cross-sectional view through **B-B** in Fig. 1B.

Fig. 1D depicts a magnified view of region **Y** in Fig. 1C.

Fig. 1E depicts a magnified view of region **X** in Fig. 1B.

Fig. 2A depicts an end view of a hydraulic cylinder comprising a second embodiment of a sensing system for determining axial position of a cylinder rod during a stroke of the hydraulic cylinder.

Fig. 2B depicts a cross-sectional view through **C-C** in Fig. 2A.

Fig. 2C depicts a cross-sectional view through **D-D** in Fig. 2B.

Detailed Description

Herein is described a sensing system for determining axial position of a cylindrical rod, preferably a cylinder rod of a cylinder. Preferably the cylinder is a rod-in-cylinder device, for example a hydraulic cylinder, a pneumatic cylinder, a linear actuator or the like. The sensing system can be used for determining a stroke position of the cylinder rod in the rod-in-cylinder device. The sensing system comprises a biased tapered rotatable shaft so that the tapered shaft tangentially contacts the cylindrical rod. Axial movement of the cylindrical rod, for example during a stroke of a cylinder-in-rod device causes the tapered shaft to rotate.

The tapered rotatable shaft is biased into frictional engagement with the cylindrical rod by a biasing element. In some embodiments, the biasing element comprises spring, for example a leaf spring, a coiled spring or the like. Preferably, the biasing element comprises a coiled extension spring.

CA 03218896 2023-11-13

The tapered portion of the shaft tapers between a thicker end and a thinner end. A radial angle of the tapered portion of the shaft is preferably from 3-10 degrees, more preferably 3-7 degrees, yet more preferably 4-6 degrees, for example about 5 degrees. Preferably, the biasing element engages the tapered shaft to continually bias the tapered shaft in a direction of the thinner end so that as the tapered shaft and/or cylindrical rod wears due to the frictional engagement of the shaft with the cylindrical rod, the biasing element advances the tapered shaft to compensate for the wear and continues to maintain the frictional engagement of the tapered portion of the tapered shaft with the cylindrical rod. Once wear causes the biasing element to translate the tapered shaft to an end of the tapered portion or to another predetermined point, the tapered shaft needs to be replaced. However, unlike the devices of US 7,757547, JP 2006226909 and JP 2006258730, where slippage between the roller and the cylinder rod is a common and recurring problem, the tapered shaft in the present device is strongly frictionally engaged with the cylindrical rod at all times as a result of the tapered shaft being tapered and the biasing element urging the tapered portion of the tapered shaft against the cylindrical rod in a direction tangential to the surface of the cylindrical rod, and/or in a direction perpendicular to the translation axis of the cylindrical rod. Further, when the tapered shaft is used in the head of a cylinder of a cylinder-in-rod device, the cylinder rod at the location of the tapered shaft is constrained from flexing laterally during the stroke, which reduces or prevents slippage of the tapered shaft relative to the cylinder rod. Also, by judicious choice of material for the tapered shaft and providing sufficient length to the tapered portion of the tapered shaft, the sensing system can be used for a much longer period of time before requiring any maintenance or replacement.

The sensing system is provided with a sensor that detects rotation of the tapered shaft. The rotation of the tapered shaft is correlated to the axial position of the cylindrical rod. In some embodiments, the sensor detects rotational position of the shaft and counts a number of rotations of the shaft, the rotational position and the number of rotations of the shaft correlated to the axial position of the cylindrical rod.

In some embodiments, the sensor comprises a magnet mounted to the shaft, the magnet rotating with rotation of the shaft, and a linear encoder in proximity to the magnet so that rotation of the magnet induces a changing electrical signal in the linear encoder. In some embodiments, the linear encoder comprises at least one Hall effect sensing element in which the changing electrical signal is induced by the rotating magnet. The rotational angle of the tapered shaft is thereby correlated to the axial position of the translating cylinder rod to determine the axial position of the cylinder rod. In some embodiments, the

CA 03218896 2023-11-13

at least one Hall effect sensing element comprises a first Hall effect sensing element stacked orthogonally to a second Hall effect sensing element, the first Hall effect sensing element used to determine absolute position of the cylindrical rod and the second Hall effect sensing element used to determine an incremental position of the cylindrical rod. In some embodiments, the magnet has a face that faces the linear encoder. The face preferably has a north pole at first side of the face and a south pole at a second side of the face opposite the first side. In this way, as the magnet rotates with the tapered shaft, the magnet will induce the changing electrical signal in the linear encoder. In some embodiments, the magnet is embedded into an end of the tapered shaft. The magnet is preferably a permanent magnet, although it is possible to use an electromagnet in some embodiments.

In some embodiments, the sensing system is preferably inserted into a lateral bore in a head of a cylinder so that the tapered shaft tangentially and frictionally engages the cylinder rod while the sensor has a portion that protrudes from the lateral bore so that the sensor can be readily coupled to electronic monitoring equipment through an electronic communication element (e.g., an electrical wire or an antenna). The rotation axis of the tapered shaft and a longitudinal axis of the sensor are preferably parallel and more preferably colinear so that a single substantially linear lateral bore can be machined into the head of the cylinder. Such an arrangement facilitates insertion and removal of the components of the sensing system and facilitates servicing the sensing system from outside the cylinder.

The lateral bore in the head intersects partially with the axial cylinder bore that passes through the head of the cylinder so that the outer surface of the cylinder rod partially protrudes into the lateral bore to engage the tapered portion of the tapered rotatable shaft. Further, the tapered shaft has a maximum diameter that is almost as large as a minimum diameter of the lateral bore in the region of the lateral bore in which the tapered shaft is situated without inhibiting rotation of the tapered shaft. Therefore, the tapered shaft is unable to translate laterally past the cylinder rod and the outer surface of the tapered shaft must frictionally engage the outer surface of the cylinder rod as the biasing element urges the thicker end of the tapered shaft toward the cylinder rod.

The tapered rotatable shaft can be inserted into the lateral bore with a thicker end of the tapered shaft closer to or farther from the sensor. When the thicker end of the tapered shaft is closer to the sensor, the lateral bore may be a closed bore having a single opening in the head and a closed distal end because the cylinder rod does not prevent the tapered shaft from being removed out of the single opening when maintenance or replacement is desired. When the thicker end of the tapered shaft is farther the sensor, the lateral bore is preferably a through-bore having openings in the head at both ends of the lateral bore. When the thicker end of the tapered shaft is farther the sensor, having only a single opening in the head would trap the tapered shaft on the distal side of the cylinder rod because the tapered rod could not be moved through the lateral bore past the cylinder rod, thereby requiring opening the entire cylinder to access the tapered rod. Opening the cylinder is often impossible without destroying the cylinder, and would nevertheless be harmful.

The lateral bore is preferably located between a rod seal and a rod wiper in the head of the cylinder because that is generally the cleanest part of the cylinder.

With reference to Fig. 1A to Fig. 1E, a first embodiment of a sensing system **1** for a hydraulic cylinder **50** is illustrated. The hydraulic cylinder **50** comprises a head **51**, a gland **54** and a barrel **60** between the head **51** and the gland **54**, with a cylindrical cylinder rod **52** disposed in the cylinder **50**. The cylinder rod **52** is axially moveable within the cylinder **50** between a rod end and a gland end of the hydraulic cylinder **50** under the influence of hydraulic fluid pressure, the cylinder rod **52** cycling through forward and backward strokes along a longitudinal axis of the cylinder **50**. Through a cycle of through forward and backward strokes, the cylinder rod **52** passes through the head **51** and the barrel **60** and into the gland **54**. The construction and operation of a hydraulic cylinder, and other rod-in-cylinder devices, is generally known.

The head **51** is provided with a lateral bore **55** extending into the head **51** from an outer surface of the head **51** past the cylinder rod **52** to terminate within the head **51** at a closed end **56**. An open portion **57** of the lateral bore **55** is open to the cylinder rod **52**, the lateral bore **55** being tangentially oriented with respect to an outer surface of the cylinder rod **52**. As best seen in Fig. 1B and Fig. 1E, the lateral bore **55** is located in the head **51** at a rod end of the hydraulic cylinder **50** between an annular rod wiper **58** and an annular rod seal **59**. The sensing system **1** is inserted into the lateral bore **55** and comprises two parts, a shaft assembly **10** and a linear encoder assembly **30**.

The shaft assembly **10** comprises a tapered shaft **11** made from a suitable material such as stainless steel, the tapered shaft **11** having a tapered portion **12**, an outer surface of the tapered portion **12** frictionally engaged with the outer surface of the cylinder rod **52**, the outer surface of the tapered portion **12** of the tapered shaft **11** being tangentially oriented to the surface of the cylinder rod **52**. The tapered shaft **11** has a longitudinal axis **TS-TS** (see Fig. 1D) parallel to, and preferably colinear with, a longitudinal axis of the lateral bore **55**, the longitudinal axis of the tapered shaft **11** being a rotation axis about which the tapered shaft **11** can rotate. The tapered shaft **11** has a thicker portion closer to an opening of the lateral bore **55** and a thinner portion closer to the closed end **56** of the lateral bore **55**.

The tapered shaft **11** is rotationally supported in the lateral bore **55** by a bushing or bearing **15** at a distal end of the tapered shaft **11** proximate the closed end **56** of the lateral bore **55**. The tapered shaft **11** is also supported in the lateral bore **55** by a support bearing **16** at a proximal end of the tapered shaft **11** closer to the opening of the lateral bore **55**. The tapered shaft **11** is able to rotate on the bushing or bearing **15** and the support bearing **16**. The support bearing **16** is seated against a shoulder **14** of the tapered shaft **11**, the shoulder **14** being a wider portion of the tapered shaft **11** than a proximal tip portion **13** of the tapered shaft **11**. A block magnet **20** is housed in a pocket in an end face of the proximal tip portion **13** of the tapered shaft **11**, the magnet **20** crimped in the pocket so that the magnet **20** is retained therein. The magnet **20** has an exposed face **21** facing the opening of the lateral bore **55**, with a north pole **N** and a south pole **S** being on opposite sides of the face **21** so that a portion of the north pole **N** and a portion of the south pole **S** face out toward the opening in the lateral bore **55**.

The linear encoder assembly **30** comprises a linear encoder **31** and a retainer coupler **32** and a plug **36** for immovably retaining the linear encoder **31** in the lateral bore **55**. The linear encoder **31** is friction fitted in the retainer coupler **32**, which is threaded onto the plug **36**, the plug **36** and the lateral bore **55** being designed to render the linear encoder assembly **30** immobile once the linear encoder assembly **30** is inserted into the lateral bore **55**. The linear encoder **31** comprises a head **33** that houses a pair of Hall effect sensing elements (not shown) stacked orthogonally with respect to each other. The linear encoder **31** is inserted into the lateral bore **55** to provide a small gap **49** between a distal face **35** of the head **33** and the exposed face **21** of the magnet **20**. The gap **49** is small enough that the rotating magnet **20** can induce electrical currents in the Hall effect sensing elements in the head **33** of the linear encoder **31**. A proximal end of the linear encoder **31** protrudes from the lateral bore **55**, the proximal end having an electronic communication element **34** extending therefrom for electronic communication with monitoring equipment.

A coiled extension spring **25** surrounds the proximal tip portion **13** of the tapered shaft **11**. A distal end of the coiled extension spring **25** is seated against the support bearing **16** on a proximal end of the support bearing **16** opposite from the shoulder **14** of the tapered shaft **11**. A proximal end of the coiled extension spring **25** is seated in the plug **36**. The coiled extension spring **25** is under compression when seated between the support bearing **16** and the plug **36**. Because the linear encoder assembly **30** is immovably secured in the lateral bore **55**, and the support bearing **16** is seated on the shoulder **14** of the tapered shaft **11**, the coiled extension spring **25** continually urges the support bearing **16** and therefore the tapered shaft **11** toward the closed end **56** of the lateral bore **55**. Continually urging the tapered shaft **11** toward the closed end **56** of the lateral bore **55** continually urges the outer surface of the tapered portion **12** of the tapered shaft **11** toward the outer surface of the cylinder rod **52** so that the tapered portion **12** of the tapered shaft **11** maintains tangential contact with the cylinder rod **52** under sufficient force to increase frictional engagement between the tapered shaft **11** and the cylinder rod **52** to reduce or prevent slippage between the tapered shaft **11** and the cylinder rod **52** during operation of the hydraulic cylinder **50**. Further, as the tapered portion **12** wears during use, the tapered shaft **11** is never out of contact with the cylinder rod **52** because the coiled extension spring **25** continually urges the tapered shaft **11** in a tangential direction with respect to the outer surface of the cylinder rod **52**, which ensures that a thicker and thicker portion of the tapered portion **12** remains in contact with the cylinder rod **52**.

In operation, when the cylinder rod **52** translates axially back and forth between the rod end and a gland end of the hydraulic cylinder **50**, the frictional engagement of the cylinder rod **52** with the tapered portion **12** of the tapered shaft **11** causes the tapered shaft **11** to rotate about the rotation axis **TS-TS**, thereby causing the magnet **20** to rotate about the rotation axis **TS-TS**. Because the north pole **N** and the south pole **S** of the magnet **20** straddle the rotation **TS-TS**, the relative positions of the north pole **N** and the south pole **S** change with respect to the stationary Hall sensing elements in the stationary linear encoder **31**, thereby inducing electrical signals in the Hall sensing elements, which are correlated to the axial position of the cylinder rod **52** in a known manner.

With reference to Fig. 2A to Fig. 2C, a second embodiment of a sensing system **100** for a hydraulic cylinder **150** is illustrated. The hydraulic cylinder **150** comprises a head **151**, a gland **154** and a barrel **160** between the head **151** and the gland **154**, with a cylindrical cylinder rod **152** disposed in the cylinder **150**. The cylinder rod **152** is axially moveable within the cylinder **50** between a rod end and a gland end of the hydraulic cylinder **150** under the influence of hydraulic fluid pressure, the cylinder rod **152** cycling through forward and backward strokes along a longitudinal axis of the cylinder **150**. Through a cycle of through forward and backward strokes, the cylinder rod **152** passes through the head **151** and the barrel **160** and into the gland **154**. The construction and operation of a hydraulic cylinder, and other rod-in-cylinder devices, is generally known.

The head **151** is provided with a lateral through-bore **155** extending through the head **151** from a first opening in an outer surface of the head **151** past the cylinder rod **152** to terminate at a second opening in the outer surface of the head **151** opposite the first

CA 03218896 2023-11-13

opening. An open portion **157** of the lateral through-bore **155** is open to the cylinder rod **152**, the lateral through-bore **155** being tangentially oriented with respect to an outer surface of the cylinder rod **152**. As best seen in Fig. 2B, the lateral through-bore **155** is located in the head **151** at a rod end of the hydraulic cylinder **150** between an annular rod wiper **158** and an annular rod seal **159**. The sensing system **100** is inserted into the lateral through-bore **155** and comprises two parts, a shaft assembly **110** and a linear encoder assembly **130**.

The shaft assembly **110** comprises a tapered shaft **111** made from a suitable material such as stainless steel, the tapered shaft **111** having a tapered portion **112**, an outer surface of the tapered portion **112** frictionally engaged with the outer surface of the cylinder rod **152**, the outer surface of the tapered portion **112** of the tapered shaft **111** being tangentially oriented to the surface of the cylinder rod **152**. The tapered shaft **111** has a longitudinal axis parallel to, and preferably colinear with, a longitudinal axis of the lateral through-bore **155**, the longitudinal axis of the tapered shaft **111** being a rotation axis about which the tapered shaft **111** can rotate. The tapered shaft **111** has a thicker portion more distant from the linear encoder assembly **130** and a thinner portion closer to the linear encoder assembly **130**.

The tapered shaft **111** is rotationally supported in the lateral through-bore **155** by a first support bearing **116** at the thinner portion of the tapered shaft **111** and by a second support bearing **117** at the thicker portion of the tapered shaft **111**. The tapered shaft **111** is able to rotate on the support bearings **116**, **117**.

The second support bearing **117** is seated against a shoulder **114** of the tapered shaft **111**, the shoulder **114** being a wider portion of the tapered shaft **111** than a distal end portion **119** of the tapered shaft **111**. A block magnet **120** is housed in a pocket in an end face of a proximal tip portion **113** of the tapered shaft **111**, the magnet **120** crimped in the pocket so that the magnet **120** is retained therein. The magnet **120** has an exposed face facing the linear encoder assembly **130**, with a north pole and a south pole being on opposite sides of the face so that a portion of the north pole and a portion of the south pole face out toward the linear encoder assembly **130**.

The linear encoder assembly **130** comprises a linear encoder **131** and a retainer coupler **132** and a plug **136** for immovably retaining the linear encoder **131** in the lateral through-bore **155**. The linear encoder **131** is friction fitted in the retainer coupler **132**, which is threaded onto the plug **136**, the plug **136** and the lateral through-bore **155** being designed to render the linear encoder assembly **130** immobile once the linear encoder assembly **130** is inserted into the lateral through-bore **155**. The linear encoder **131** comprises a head **133** that houses a pair of Hall effect sensing elements (not shown) stacked orthogonally with respect to each other. The linear encoder **131** is inserted into the lateral through-bore **155** to provide a small gap **149** between a distal face of the head **133** and the exposed face of the magnet **120**. The gap **149** is small enough that the rotating magnet **120** can induce electrical currents in the Hall effect sensing elements in the head **133** of the linear encoder **131**. A proximal end of the linear encoder **131** protrudes from the lateral through-bore **155**, the proximal end having an electronic communication element **134** extending therefrom for electronic communication with monitoring equipment.

A coiled extension spring **125** surrounds a ram **118** in the through-bore **155**, the ram **118** engaging the distal end portion **119** of the tapered shaft **111**. A distal end of the coiled extension spring **125** is seated against a rim of an insert **115** inserted into the through-bore **155**, the insert **115** housing the ram **118**. A proximal end of the coiled extension spring **125** is against a rim of the ram **118**. The coiled extension spring **125** is under compression when seated between the rim of the insert **115** and the rim of the ram **118**. Because the insert **115** is immovably secured in the lateral through-bore **155**, and the distal end portion **119** of the tapered shaft **111** and the second support bearing **117** are engaged with the ram **118**, the coiled extension spring **125** continually urges the tapered shaft **111** toward the linear encoder **130**. Continually urging the tapered shaft **111** toward the linear encoder **130** continually urges the outer surface of the tapered portion **112** of the tapered shaft **111** toward the outer surface of the cylinder rod **152** so that the tapered portion **112** of the tapered shaft **111** maintains tangential contact with the cylinder rod **152** under sufficient force to increase frictional engagement between the tapered shaft **11** and the cylinder rod **152** to reduce or prevent slippage between the tapered shaft **111** and the cylinder rod **152** during operation of the hydraulic cylinder **150**. Further, as the tapered portion **112** wears during use, the tapered shaft **111** is never out of contact with the cylinder rod **152** because the coiled extension spring **125** continually urges the tapered shaft **111** in a tangential direction with respect to the outer surface of the cylinder rod **152**, which ensures that a thicker and thicker portion of the tapered portion **112** remains in contact with the cylinder rod **152**.

In operation, when the cylinder rod **152** translates axially back and forth between the rod end and a gland end of the hydraulic cylinder **150**, the frictional engagement of the cylinder rod **152** with the tapered portion **112** of the tapered shaft **111** causes the tapered shaft **111** to rotate about the rotation axis, thereby causing the magnet **120** to rotate about the rotation axis. Because the north pole and the south pole of the magnet **120** straddle the rotation, the relative positions of the north pole and the south pole change with respect to the stationary Hall sensing elements in the stationary linear encoder **131**, thereby inducing electrical signals in the Hall sensing elements, which are correlated to the axial position of the cylinder rod **152** in a known manner.

The novel features will become apparent to those of skill in the art upon examination of the description. It should be understood, however, that the scope of the claims should not be limited by the embodiments, but should be given the broadest interpretation consistent with the wording of the claims and the specification as a whole.

Claims:

1. A sensing system for determining axial position of a cylindrical rod comprises:

a tapered rotatable shaft having a rotation axis, the shaft positionable so that the rotation axis is perpendicular to a translation axis of a cylindrical rod, the shaft having a tapered portion that is frictionally engageable with the cylindrical rod to be rotatable by the cylindrical rod when the cylindrical rod moves axially;

a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain frictional engagement of the tapered portion of the shaft with the cylindrical rod when the shaft is engaged with the cylindrical rod; and,

a sensor for detecting rotation of the shaft when the shaft is rotated by the cylindrical rod, the rotation of the shaft being correlated to the axial position of the cylindrical rod.

2. The sensing system of claim 1, wherein:

the cylindrical rod is a cylinder rod of a cylinder;

the tapered rotatable shaft is insertable into a lateral bore in a head of the cylinder, the shaft having a rotation axis parallel to a tangent to a circumference of the cylinder rod when the shaft is in the lateral bore;

the biasing element biases the shaft when the shaft is inserted in the lateral bore; and,

the sensor is insertable into the lateral bore.

3. The system of claim 1 or claim 2, wherein the sensor detects rotational position of the shaft and counts a number of rotations of the shaft, the rotational position and the number of rotations of the shaft correlated to the axial position of the cylindrical rod.

4. The system of any one of claims 1 to 3, wherein the sensor comprises:

a magnet mounted to the shaft, the magnet rotating with rotation of the shaft; and,

a linear encoder in proximity to the magnet so that rotation of the magnet induces a changing electrical signal in the linear encoder.

5. The system of claim 4, wherein the linear encoder comprises at least one Hall effect sensing element in which the changing electrical signal is induced by the rotating magnet.

CA 03218896 2023-11-13

6. The system of claim 5, wherein the at least one Hall effect sensing element comprises a first Hall effect sensing element stacked orthogonally to a second Hall effect sensing element.

7. The system of any one of claims 4 to 6, wherein the magnet is a permanent magnet.

8. The system of any one of claims 4 to 7, wherein the magnet is embedded into an end of the shaft.

9. The system of any one of claims 4 to 8, wherein the magnet has a face that faces the linear encoder, the face having a north pole at first side of the face and a south pole at a second side of the face opposite the first side.

10. The system of any one of claims 1 to 9, wherein the biasing element comprises a spring.

11. The system of claim 10, wherein the spring is a coiled extension spring.

12. The system of claim 10 or claim 11, wherein the tapered portion of the shaft tapers between a thicker end and a thinner end, and the spring engages the shaft to continually bias the shaft in a direction of the thinner end so that as the shaft and/or cylindrical rod wears due to frictional engagement of the shaft with the cylindrical rod, the spring continues to maintain the frictional engagement of the tapered portion of the shaft with the cylindrical rod when the shaft is inserted into the lateral bore.

13. A cylinder comprises:

a head;

a barrel;

a gland;

a cylinder rod moveable through a cylinder stroke; and,

a sensing system for determining axial position of the cylinder rod during the stroke, the sensing system comprising:

a tapered rotatable shaft inserted into a lateral bore in the head, wherein a rotation axis of the shaft is parallel to a tangent to a circumference of the cylinder rod, wherein a tapered portion of the shaft frictionally engages the cylinder rod and wherein axial movement of the cylinder rod during the stroke causes the shaft to rotate about the rotation axis due to frictional engagement of the tapered portion of the shaft with the cylinder rod;

a biasing element that biases the shaft in a direction parallel to the rotation axis of the shaft to continually maintain the frictional engagement of the tapered portion of the shaft with the cylinder rod; and,

a sensor that detects rotation of the shaft, the rotation of the shaft being correlated to the axial position of the cylinder rod.

14. The cylinder of claim 13, wherein the sensor detects rotational position of the shaft and counts a number of rotations of the shaft, the rotational position and the number of rotations of the shaft correlated to the axial position of the cylinder rod.

15. The cylinder of claim 13 or claim 14, wherein the sensor comprises:

a magnet mounted to the shaft, the magnet rotating with rotation of the shaft; and,

a linear encoder in proximity to the magnet so that rotation of the magnet induces a changing electrical signal in the linear encoder.

16. The cylinder of claim 15, wherein the linear encoder comprises at least one Hall effect sensing element in which the changing electrical signal is induced by the rotating magnet.

17. The cylinder of claim 16, wherein the at least one Hall effect sensing element comprises a first Hall effect sensing element stacked orthogonally to a second Hall effect sensing element, the first Hall effect sensing element used to determine absolute position of the cylinder rod and the second Hall effect sensing element used to determine an incremental position of the cylinder rod.

18. The cylinder of any one of claims 15 to 17, wherein the magnet is a permanent magnet.

19. The cylinder of any one of claims 15 to 18, wherein the magnet is embedded into an end of the shaft.

20. The cylinder of any one of claims 15 to 19, wherein the magnet has a face that faces the linear encoder, the face having a north pole at first side of the face and a south pole at a second side of the face opposite the first side.

CA 03218896 2023-11-13

21. The cylinder of any one of claims 13 to 20, wherein the biasing element comprises a spring.

22. The cylinder of claim 21, wherein the spring is a coiled extension spring.

23. The cylinder of claim 21 or claim 22, wherein the tapered portion of the shaft tapers between a thicker end and a thinner end, and the spring engages the shaft to continually bias the shaft in a direction of the thinner end so that as the shaft and/or cylinder rod wears due to the frictional engagement of the shaft with the cylinder rod, the spring continues to maintain the frictional engagement of the tapered portion of the shaft with the cylinder rod.

24. The cylinder of any one of claims 13 to 23, wherein the lateral bore is located between a rod seal and a rod wiper in the head of the cylinder.

CA 03218896 2023-11-13

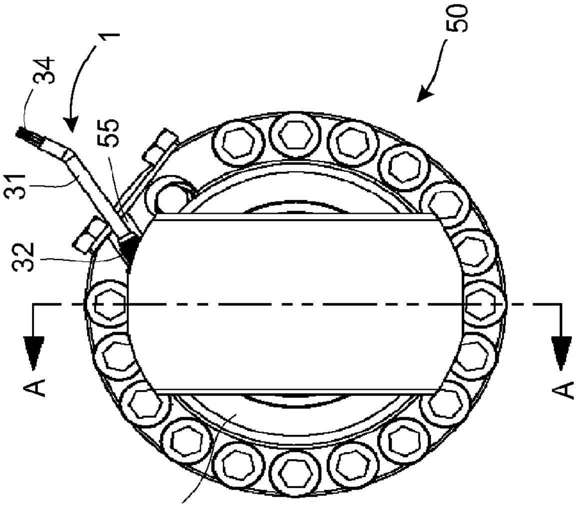

Fig. 1A

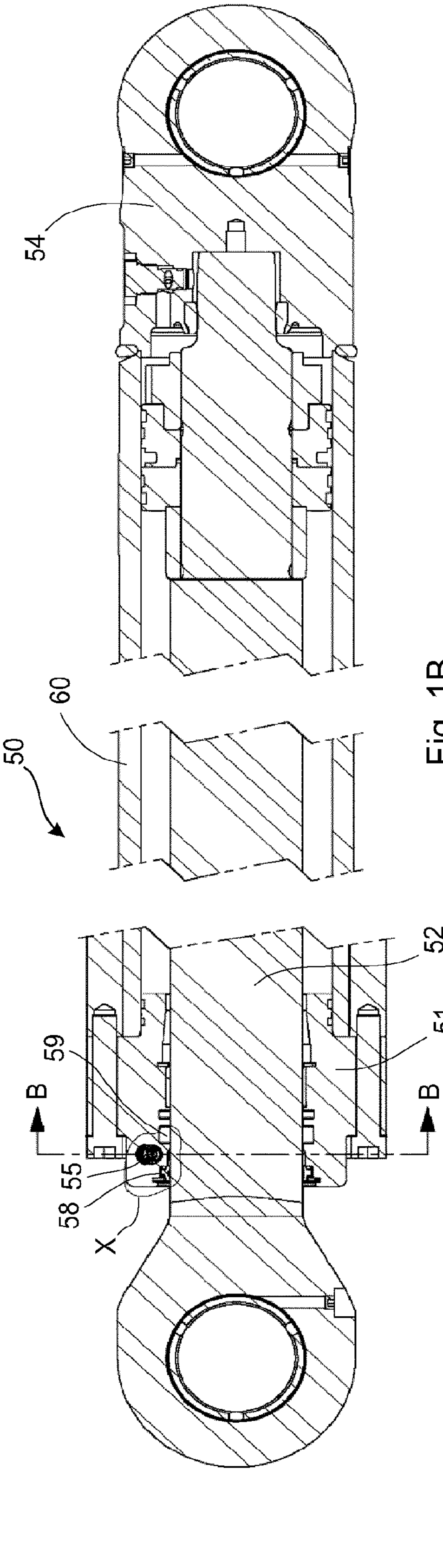

Fig. 1B

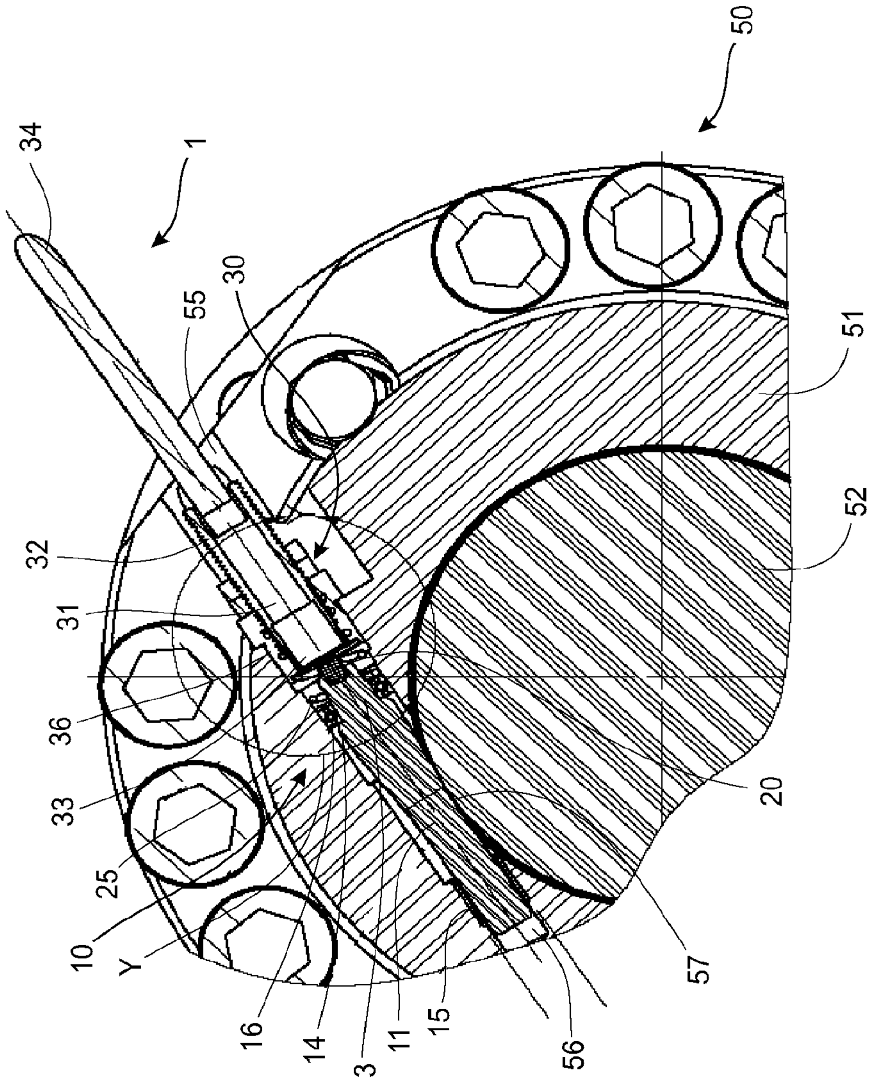

Fig. 1C

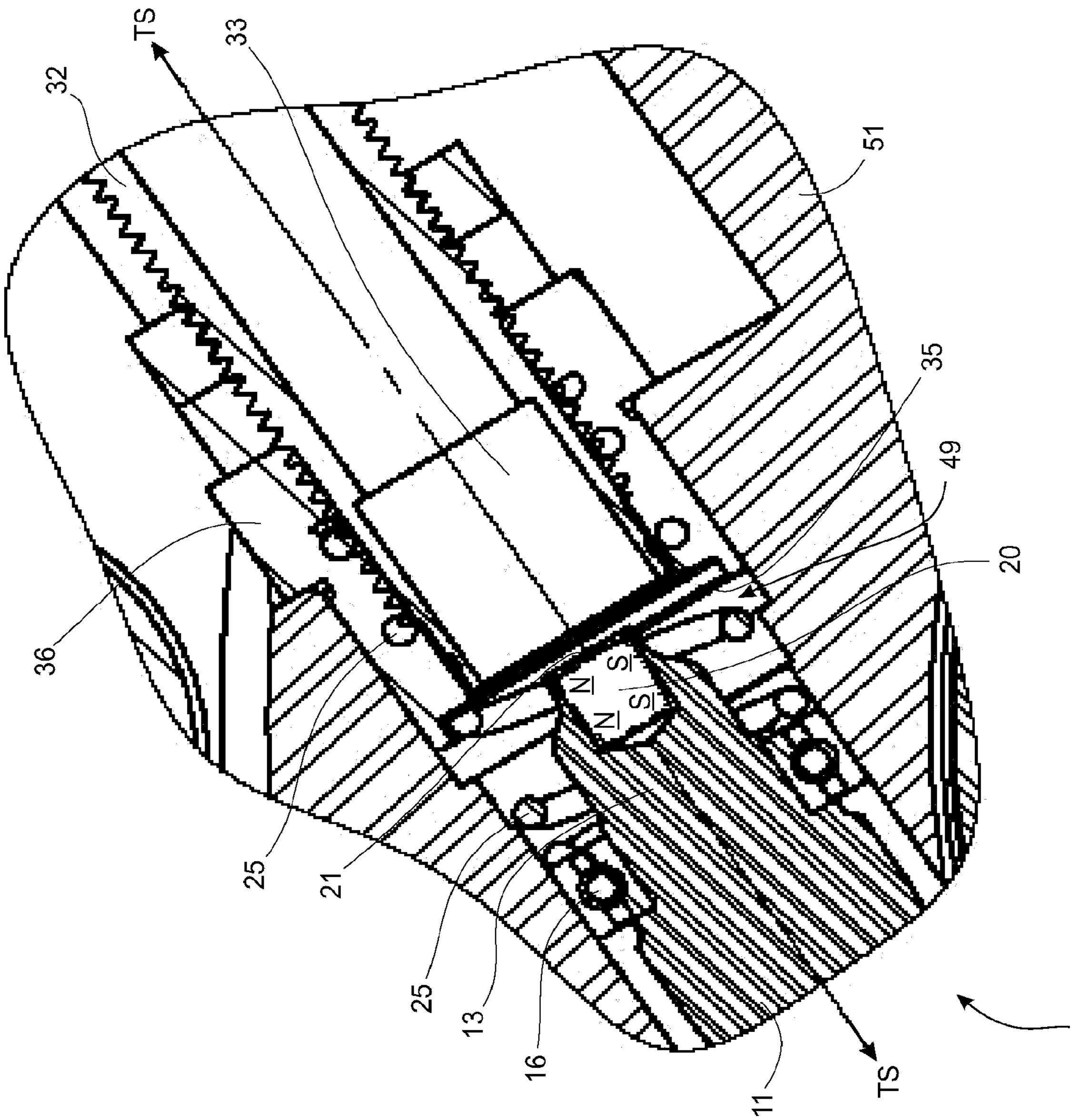

Fig. 1D

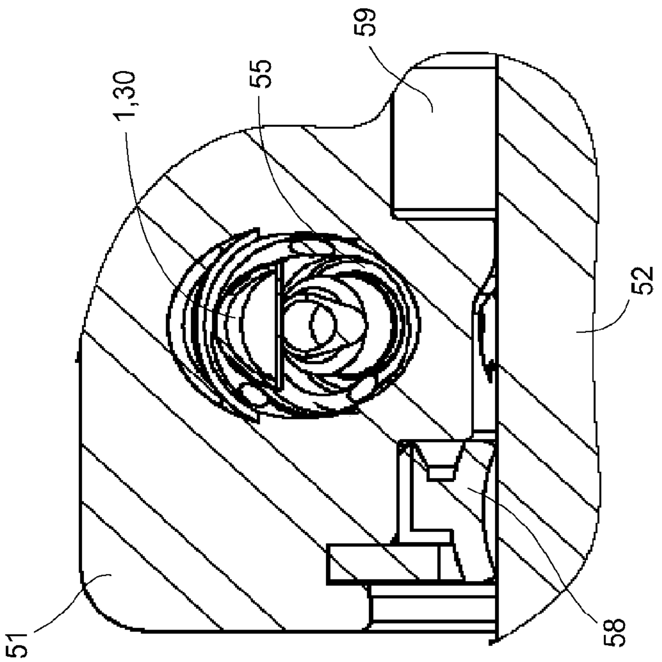

Fig. 1E

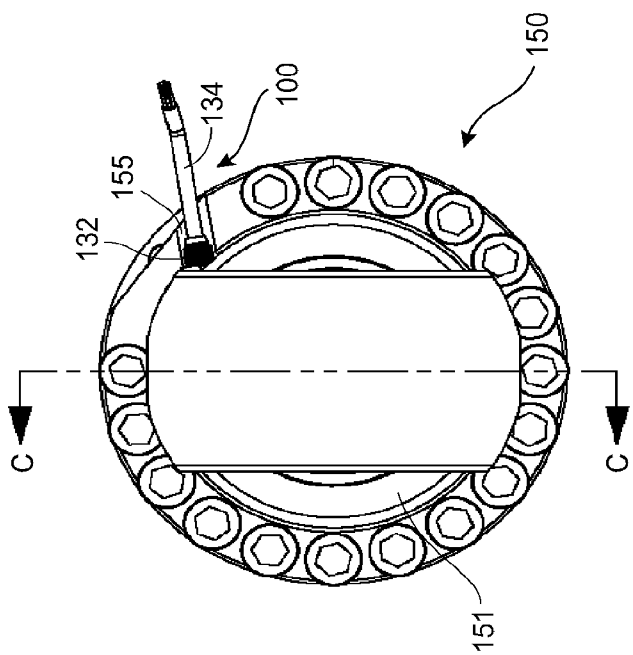

Fig. 2A

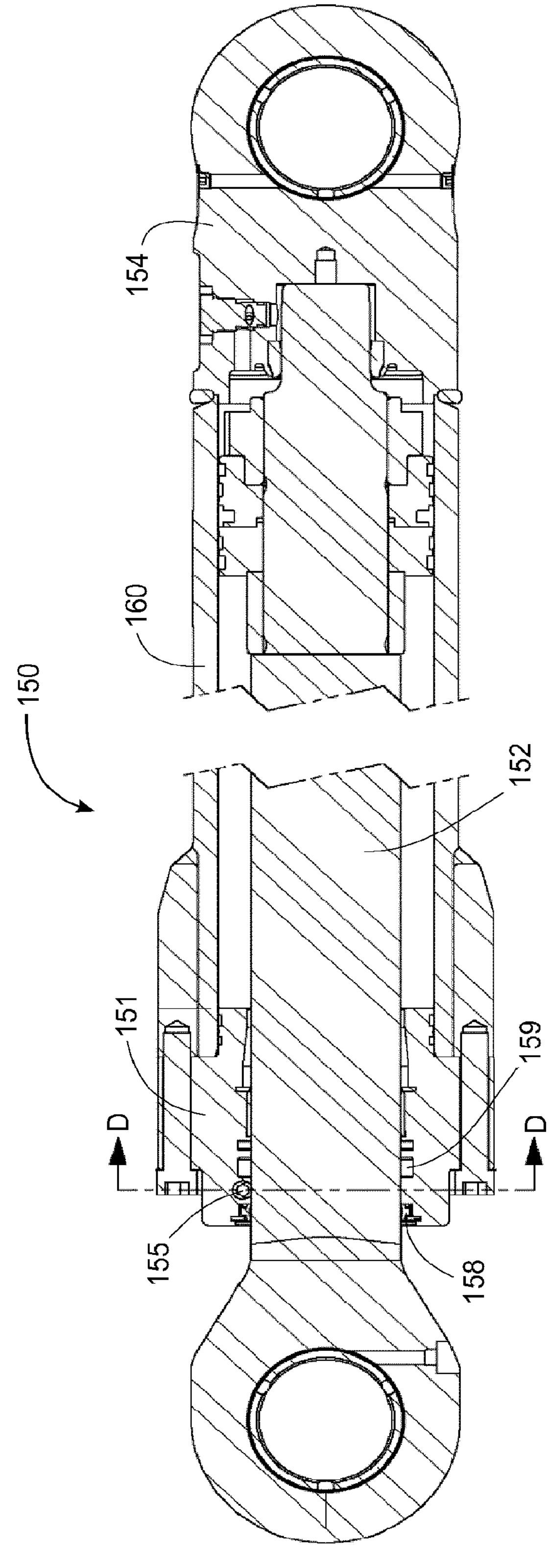

Fig. 2B

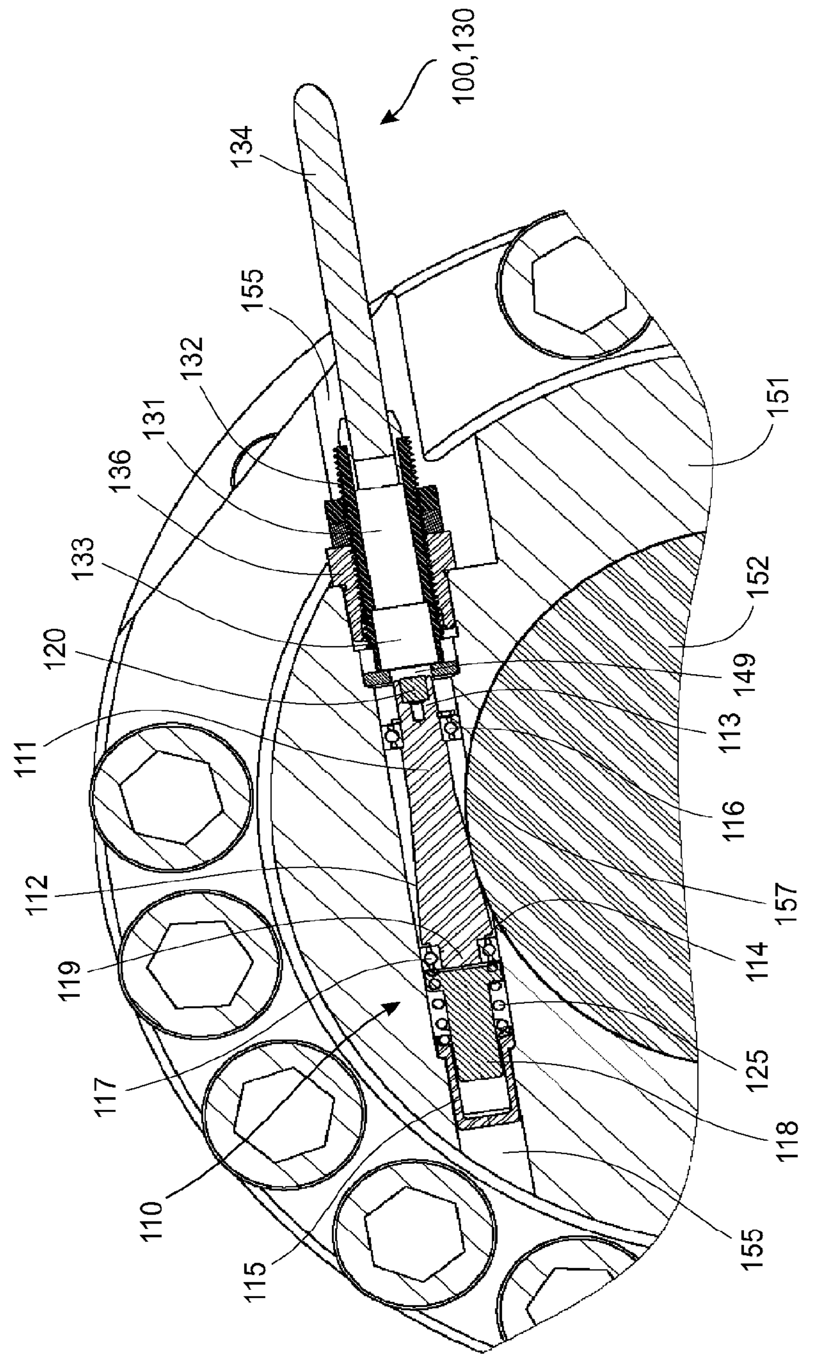
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Fig. 2C

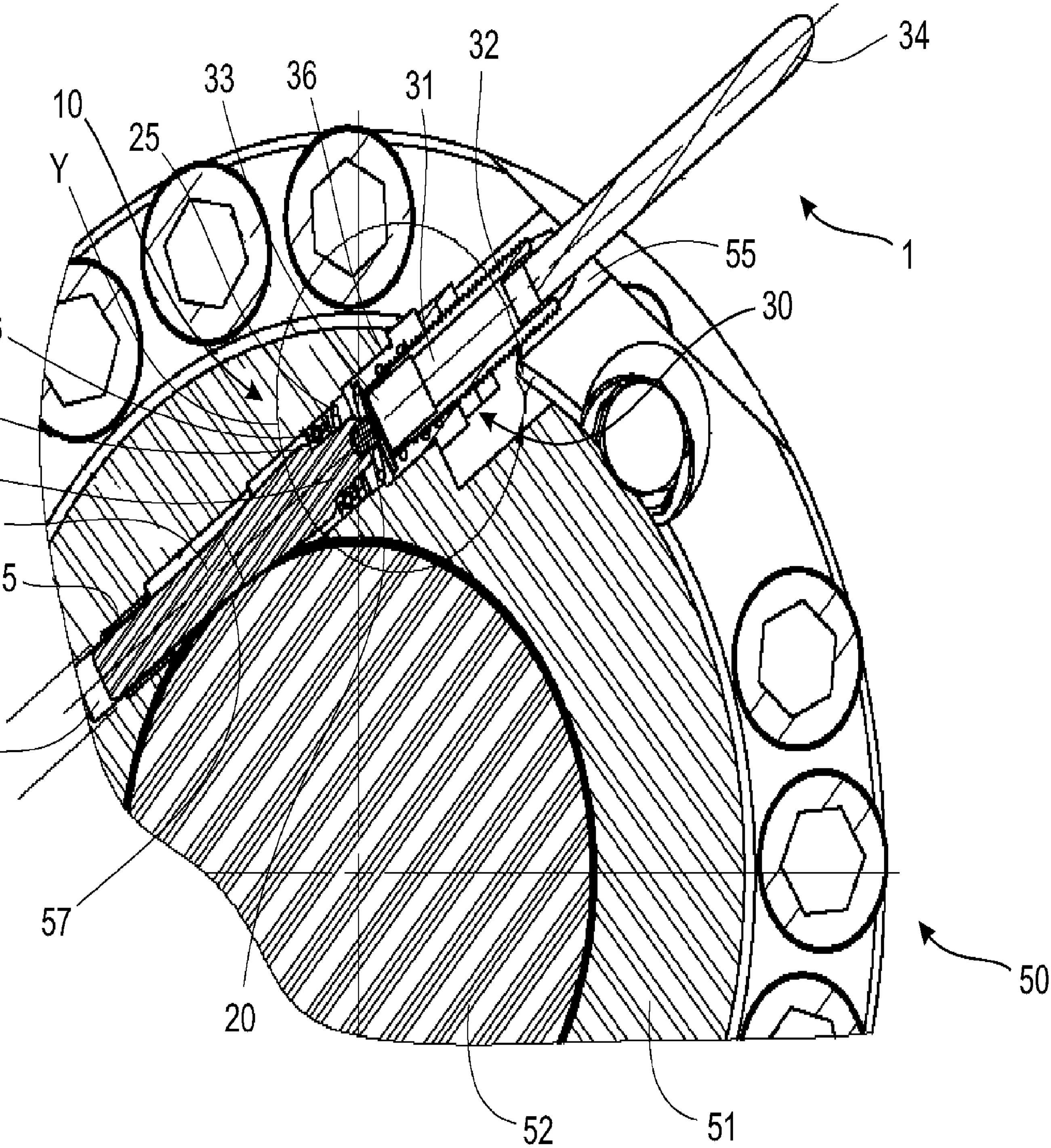

Fig. 1C