

Cylinder and method for determining a position of a piston in a cylinder

5 The present invention is related to a cylinder, particularly for the use in hydraulic systems, and a method for determining a position of a piston in a cylinder, particularly for the use in hydraulic systems.

State of technology

10 For measuring a position of a piston in a cylinder, particularly in a hydraulic cylinder, different measuring methods are known. Methods based on runtime measurements of ultrasonic signals are characterised by high robustness and do not need a bore of the piston. From *US 6 119 579 A*, a measuring method is known, where ultrasonic sensors are located on the
15 outside of the cylinder, and the position of the piston is determined by the runtime of the ultrasonic measuring signal.

However, these methods depend on the wave propagation medium, i.e. hydraulic oil in case of hydraulic cylinders, as the sound velocity depends
20 on the pressure and the temperature of the hydraulic oil as well as on the type of oil. Particularly, residues in the wave propagation medium, for example metal particles or air bubbles, will result in additional inaccuracies and potential measuring errors due to cavitation effects.

25 Disclosure of the invention

The present invention refers to a cylinder, particularly for use in hydraulic systems, having the characteristics of patent claim 1 and a method for
30 determining a position of a piston in a cylinder, particularly for use in a hydraulic system with the characteristics of patent claim 6.

Hence according to a first aspect, the present invention provides a cylinder, particularly for use in hydraulic systems comprising a cylinder casing with cylindrical side wall, an axial slidable piston located in the cylinder casing, and at
35 least one signal feeding device, which is located and arranged at the cylinder casing, and at the side wall or at an outside wall in axial direction of the cylinder

casing, to send out an ultrasonic signal in such way that the ultrasonic signal propagates alongside an inner face of the side wall of the cylinder casing, at least along a receiving device being located and arranged at the cylinder casing to receive the ultrasonic signal reflected from the piston, and along an evaluation
5 device being arranged to determine a position of the piston by a runtime of the ultrasonic signal between the sending of the ultrasonic signal from the signal feeding device and the receiving of the ultrasonic signal by the receiving device. In particular, the ultrasonic signal may be reflected by a gasket of the piston.

10 Hence according to a second aspect, the present invention provides a method for determining a position of a piston in a cylinder, particularly for use in a hydraulic system. The method comprises sending of an ultrasonic signal on a cylinder casing with cylindrical side wall in such way that the ultrasonic signal propagates
15 alongside an inner face of the side wall of the cylinder casing. Moreover, the method comprises receiving of the ultrasonic signal being reflected from a piston located axial slidable in the cylinder casing, and computation of a position of the piston by a runtime of the ultrasonic signal between sending and receiving of the ultrasonic signal.

20 Preferred advancements are the subjects of the respective subclaims.

Advantages of the invention

It must be noted that the invention can be versatile in use. Thus, the term
25 ‘cylinder‘ encompasses particularly pneumatic cylinders, hydraulic cylinders or lifting cylinders, as they are used in a variety of machines. Here, the cylinder may be filled with any kind of fluid, particularly with any kind of liquids or gases. The invention is also not confined to a certain cylinder shape. Furthermore, the piston being slidable located in the cylinder casing may encompass particularly also a
30 membrane.

The propagation medium of the ultrasonic signal is the inner face of the side wall of the cylinder casing. Therefore, a wave propagation speed of the ultrasonic signal can be easily computed, as the properties of the cylinder wall are known. The sound velocity and the group velocity of the ultrasonic signal in the cylinder wall according to the present invention depend only on the wave mode and on the sound frequency in the cylinder wall.

However, the properties of the cylinder wall will remain largely unchanged during the whole operating time of the cylinder; hence, the dependencies of the ultrasonic wave propagation can be included in the computation in a deterministic and reproducible way. This dependency can be simply calibrated during the installation of the sensors, and it will remain constant during the life span of the cylinder. Thus, the cylinder according to the present invention differs from cylinders with ultrasonic sensors, where the ultrasonic signal propagates in the hydraulic oil. In particular, high measuring accuracy is possible.

Hence, the determination of the piston position is extremely robust regarding the operation conditions of the hydraulic oil. In addition, it is easily possible to retrofit the signal feeding device, the receiving device and the evaluation device for existing cylinders.

According to an advancement, the cylinder comprises a top piece being located at one of the side walls of the cylinder casing, and a sender located on the top piece. Here, the sender is arranged for the purpose to send out the ultrasonic signal through the top piece so that an ultrasonic wave carrying the ultrasonic signal will strike the cylinder casing under an incidence angle. In addition, the incidence angle is selected so that the ultrasonic signal is refracted on an interface of top piece and cylinder casing in such way that the ultrasonic signal will propagate alongside an inner face of the side wall of the cylinder casing. The refraction of the ultrasonic signal is known by Snell's law of refraction so that it can be ensured by the appropriate selection of the top piece with known refractive index of the top piece with the setting of the incidence angle, that the ultrasonic signal will propagate parallel to the inner face of the side wall of the cylinder casing.

According to the advancement, the signal feeding device is located at the side wall of the cylinder casing, and comprises at least two electrodes being comb-like arranged, and being located to send out an ultrasonic signal. By the electrical feeding of the ultrasonic signal by means of electrodes, the signal feeding device can be kept very compact, so that the required space is little.

According to the advancement, the signal feeding device is located at an outside wall in axial direction of the cylinder casing and has at least one shear plate being slidable in the direction parallel to the outside wall of the cylinder casing, and being coupled with the cylinder casing by friction, wherein an ultrasonic signal can be transferred to the cylinder casing by periodical shifting of the shear plate at the outside wall of the cylinder casing, which will propagate alongside an inner face of the side wall of the cylinder casing. The term 'shear plate' means in this case a plate or little plate, particularly a flat metal plate, contacting planar a counter-piece, which can be flat and metallic arranged as well, and swaying alongside this counter-piece parallel to the contact surface.

A cylinder according to this advancement is characterised in that the transfer of the signal will take place at a bottom side and not at a side wall of the cylinder, which can be an advantage at certain requirements for the cylinder, as no space will be required at the side wall.

According to the advancement, the signal feeding devices and the receiving devices are located in axial direction being spaced from each other. The cylinder comprises a control device being arranged to control a sending of an ultrasonic signal by the signal feeding devices and a receiving of the reflected ultrasonic signals by the receiving devices in multiplexing technique, particularly in time-multiplexing technique or frequency-multiplexing technique. Thus, the invention can be scaled and is suitable for cylinders of any size, as the piston position can be detected at different positions of the receiving devices. Hence, the piston position can be accurately determined particularly also for long cylinders.

According to an advancement of a method, the control device is arranged to control the signal feeding devices in such way that the signal feeding devices will send out time-staggered ultrasonic signals, wherein a time difference between the sending of two ultrasonic signals by signal feeding devices is bigger than the runtime of the signals of ultrasonic signals.

According to an advancement of the method, the sending of the ultrasonic signal occurs through a top piece being located at the side wall of the cylinder casing. Hereby, the ultrasonic signal will strike the cylinder casing under an incidence angle. The incidence angle is selected so that the ultrasonic signal is refracted on an interface of top piece and cylinder casing in such way that the ultrasonic signal will propagate alongside an inner face of the side wall of the cylinder casing.

According to an advancement of the method, the sending of the ultrasonic signal occurs by means of at least two electrodes being located comb-like at the side wall of the cylinder casing.

According to an advancement of the method, the sending of the ultrasonic signal occurs by shifting a shear plate on an outside wall in radial direction, wherein the shear plate is coupled with the outside wall by friction.

According to an advancement of the method, the sending of the ultrasonic signal and the receiving of the reflected ultrasonic signal takes place at different positions of the cylinder casing in a multiplexing technique, particularly a time-multiplexing technique or frequency-multiplexing technique. By using different signal feeding devices, the accuracy of the measuring of the position of the piston can be increased. For example, each of the signal feeding devices can be responsible for a certain section of the cylinder. In doing so, a decrease of the accuracy due to limited range of the measuring section can be avoided by sound absorption alongside the propagation stretch of the ultrasonic signal. Transverse effects between the different signal feeding devices can be avoided by multiplexing strategies. Preferably, sound wave frequency sections for the ultrasonic signals can be used by the different signal feeding devices as well.

According to an advancement of the method, the ultrasonic signals are sent out at the different positions of the cylinder casing time-staggered, wherein a time

difference between the sending of two ultrasonic signals at different positions of the cylinder casing is bigger than the runtime of the signals of the ultrasonic signals. As the sound velocity, i.e. the propagation velocity of the ultrasonic signals is much higher than the piston velocity, a time-multiplexing technique will have no influence on the accuracy of the measuring system.

Brief description of drawings

The following is shown:

- Fig. 1 A cylinder according to a first embodiment of the present invention;
- Fig. 2 A cylinder according to a second embodiment of the present invention;
- Fig. 3 A top view on the electrode structure of a signal feeding device according to the second embodiment of the present invention;
- Fig. 4 A cylinder according to a third embodiment of the present invention;
- Fig. 5 A cylinder according to a fourth embodiment of the present invention; and
- Fig. 6 A flow chart for a method to determine a position of a piston in a cylinder.

In all Figures, the same or analogous elements and devices have the same reference signs, unless stated otherwise.

Description of Embodiments

Figure 1 shows a cylinder 100, particularly a hydraulic cylinder for use in hydraulic systems. The cylinder 100 comprises a cylinder casing 102 with cylindrical side wall 103 being axially arranged around a symmetry axis of the cylinder 100, and a first outside wall 104 in axial direction of the cylinder casing 102, which limits the cylinder 100 in axial direction. Opposite to the first outside wall 104, an opening 105 is arranged in a second outside wall 115 of the cylinder casing 102, in which a piston 101 is axial slidably inserted. A position of the piston 101 is determined by a distance x from the first outside wall 104. The cylindrical side wall 103 of the cylinder casing 102 has an inner face 103a and an exterior outer face 103b in radial direction. The piston 101 here has a gasket 101a, forming a radial outside section of the piston 101, contacting the outer face 103b of the cylinder casing and serving for the sealing of a pressure chamber 116 between the piston 101 and the first outside wall 104 of the cylinder casing 102.

At the cylindrical side wall 103, a signal feeding device 106 is located. The signal feeding device 106 comprises a top piece 106a being located at the outer face 103b of the cylindrical side wall 103 of the cylinder casing 102. The top piece 106a here consists preferably of metal with a first refractive index n_1 , whereby the first refractive index n_1 differs from a second refractive index n_2 of the cylinder casing 102.

However, the invention is not confined to that. Thus, the top piece 106a can be inserted in the cylindrical side wall 103 as well.

A sender 106b is located on the top piece 106a being arranged in such way to send out an ultrasonic signal 108 through the top piece. Herein, the ultrasonic signal 108 is typically modulated on an ultrasonic wave. The ultrasonic signal can be particularly a wave pack as well.

The top piece 106a is arranged wedge-shaped so that the ultrasonic signal 108 sent out from the sender 106b will strike the cylindrical side wall 103 under an incidence angle φ_1 related to a surface normal 109. At the interface 110 between top piece 106a and cylindrical side wall 103, the ultrasonic signal 108 and the ultrasonic wave carrying the ultrasonic signal 108 is refracted. The angle of refraction here is determined by Snell's law of refraction, namely according to the following formula:

$$n_1 \cdot \sin(\varphi_1) = n_2 \cdot \sin(\varphi_2).$$

Herein, φ_2 is the exit angle of the ultrasonic signal 108 in the cylinder casing 102. With the known refractive indices n_1 and n_2 of the top piece and of the cylinder casing 102, the incidence angle φ_1 is set in such way that the exit angle φ_2 will be primarily 90° , so that the ultrasonic signal will propagate alongside the inner face 103a of the side wall 103 of the cylinder casing 102. Hence, the ultrasonic signal 108 runs parallel to the cylindrical side wall 103. An ultrasonic wave carrying the ultrasonic signal 108, which propagates at the inner face 103a of the side wall 103 or within the side wall 103 of the cylinder casing 102, is called Rayleigh-wave or Scholte-wave.

The ultrasonic signal 108 and the ultrasonic wave carrying the ultrasonic signal 108 is reflected at a front position 114 of the gasket 101a of the piston 101 facing the signal feeding device 106 and will subsequently propagate in the opposite direction. The reflected ultrasonic signal 108 is received by a receiving device 107. Here, the receiving device 107 is preferably similarly arranged as the signal feeding device 106, that is the receiving device 107 has a top piece 107a and a receiver 107b located on it as well.

The receiving device 107 and the signal feeding device 106 are connected with a control device 111. The control device 111 controls the signal feeding device 106. The control device 111 comprises an evaluation device 112 being arranged in such way to determine the position of the piston 101 by a runtime Δt of the ultrasonic signal 108 between the sending of the ultrasonic signal 108 by the signal feeding device 106 and the receiving of the reflected ultrasonic signal 108 by the receiving device 107, i.e. the

distance x between the first outside wall 104 and piston 101. For that, the evaluation device 112 will measure a first point in time t_1 of the sending out of the ultrasonic signal 108 by the signal feeding device 106 and a second point in time t_2 of the receiving of the reflected ultrasonic signal 108 by the receiving device 107. Thus, the runtime Δt of the ultrasonic signal 108 is given as $\Delta t = t_2 - t_1$. In determining a position of the piston 101, the evaluation device 112 considers a known distance x_2 of the signal feeding device 106 and a known distance x_1 of the receiving device 107 from the first outside wall 104 of the cylinder casing 102. A total run distance Δy of the ultrasonic signal 108 between sending and receiving is computed according to the following formula:

$$\Delta y = v \cdot \Delta t,$$

whereby v is the propagation velocity of the ultrasonic signal 108 in the material of the cylindrical side wall 103. The total run distance Δy of the ultrasonic signal 108 equals $2y_1 + x_2 - x_1$, whereby y_1 is the distance of the signal feeding device 106 from the piston 101, and whereby the distances d_1 and d_2 of the sender 106b and of the receiver 107b from of the cylindrical side wall 103, each measured under the incidence angle φ_1 , are neglected, as they are small as compared to the distance y_1 of the signal feeding device 106 from the piston 101, as well as a distance $x_2 - x_1$ from signal feeding device 106 and receiving device 107.

Thus, the distance x of the piston from the first outside wall 104 is:

$$x = x_2 + y_1 = x_2 + (v \cdot \Delta t + x_1 - x_2) / 2,$$

The evaluation device 112 is arranged in such way to measure the distance x of the piston from the first outside wall 104 with the above formula.

For example, if the propagation velocity of the ultrasonic signal 108 in the material of the cylindrical side wall 103 equals 1,500 m/s and if the distance x_2 of the signal feeding device 106 from the first outside wall 104 of the cylinder casing 102 equals 10 cm and the distance x_1 of the receiving device 107 from the first outside wall 104 of the cylinder casing 102 equals 12 cm,

and if the runtime Δt of the ultrasonic signal 108 equals 1 ms, the distance x of the piston from the first outside wall 104 is:

$$x = (v \cdot \Delta t + x_1 + x_2) / 2 = (150 \text{ cm} + 10 \text{ cm} + 12 \text{ cm}) / 2 = 86 \text{ cm}.$$

The evaluation device 112 can be aligned to consider a reflection of the ultrasonic signal 108 at the second outside wall 115, whereby this reflection comes from a part of the ultrasonic signal, which was not yet reflected at the front point 114 of the gasket 101a of the piston 101. In addition, the evaluation device 112 can be arranged to consider the distances d_1 and d_2 of the sender 106b and of the receiver 107b of the cylindrical side wall 103.

In addition, the evaluation device 112 is arranged to consider a sound energy emission of the ultrasonic signal 108 in hydraulic oil within the cylinder. Particularly, the intensity of the ultrasonic signal 108 is selected in such way that a sufficient signal-to-noise ratio will be ensured in the signal evaluation.

The invention is not confined to that. Thus, the evaluation device 112 may be identical with the signal feeding device 106.

Figure 2 shows a cylinder 200 according to a second embodiment of the present invention. Here, the signal feeding device 201 is identical with the receiving device 201 and consists of electrodes 201a. The electrodes 201a comprise a first electrode 201a-1 and a second electrode 201a-2 being comb-like arranged, whereby the first electrode 201a-1 is interlocked with the second electrode 201a-2, as illustrated in Figure 3. By connecting with current, an ultrasonic signal can be directly transferred on the side wall 103 of the cylinder casing 102, whereby the ultrasonic signal will propagate in an axial direction alongside the inner face 103a of the side wall 103 and within the side wall 103 respectively. The signal feeding device 201 serves as receiving device 201 of the ultrasonic signal as well. The evaluation device 112 being connected with the signal feeding device and the receiving device 201, is arranged in such way to determine a position of the piston 101 by the runtime Δt of the ultrasonic signal. Here, the evaluation device 112 considers a known distance x_3 of the receiving device and signal

feeding device 201 from the first outside wall 104 of the cylinder. The evaluation device 112 is arranged in such way to compute the distance x of the piston 101 from the first outside wall 104 according to the following formula:

5

$$x = x_3 + v \cdot \Delta t / 2.$$

10

Herein, a distance d of the teeth of the comb-like electrodes 201a-1 and 201a-2 is equivalent to a wave length λ of the ultrasonic signal, whereby the wave length λ is preferably between 2 and 7 mm and preferably equals 5 mm.

15

The invention is not confined to that. Thus, the receiving device may differ from the signal feeding device 201 as well. Particularly, a receiving device being similarly structured as the signal feeding device 201, may be located next to the signal feeding device 201 at the cylindrical side wall 103.

20

25

Figure 4 shows a cylinder 400 according to a third embodiment of the present invention. In this case, a signal feeding device 401 is located at the first outside wall 104. Here, the signal feeding device 401 comprises a preferably metallic shear plate 403 being slidable in a radial direction 404, i.e. in a direction 404 parallel to the first outside wall 104 of the cylinder casing 102. Here, the shear plate 403 is mechanically coupled with the cylinder casing 102, i.e. by friction. By periodical shifting of the shear plate 403 in the direction 404 parallel to the first outside wall 104 of the cylinder casing, the signal feeding device 401 is arranged in such way to transfer an ultrasonic signal to the cylinder casing 102. The ultrasonic signal 108 will propagate alongside the inner face 103a of the side wall 103.

Here, the signal feeding device 401 serves at the same time as receiving device, which receives the ultrasonic signal 108 being reflected from the gasket 101a of the piston 101. Here, the evaluation device 112 of the control device 111 being coupled with the signal feeding device 401 is arranged in such way to compute a position of the piston 101, namely a distance x of the piston 101 from the first outside wall 104 by the runtime Δt of the ultrasonic signal 108 according to the following formula:

$$x = v \cdot \Delta t / 2.$$

However, the receiving device can differ from the signal feeding device 401 as well and, for example, can be located next to the signal feeding device 401 at the first outside wall 104.

Figure 5 shows a cylinder 500 according to a fourth embodiment of the present invention. According to this embodiment, four ultrasonic devices 502a to 502d are located in distances x_a to x_d from the second first outside wall 115 in axial direction being spaced at the cylindrical side wall 103 of the cylinder casing 102. Here, the ultrasonic devices 502a to 502d comprise one signal feeding device and one receiving device each according to one of the embodiments described above. The ultrasonic devices 502a to 502d are each coupled with the control device 111. In addition, the control device 111 comprises a multiplexing device 501, which controls the ultrasonic devices 502a to 502d. The multiplexing device 501 is particularly aligned in such way to control the ultrasonic devices 502a to 502d in a time-multiplexing technique or in a frequency-multiplexing technique. For example this means that the signal feeding devices of the respective ultrasonic devices 502a to 502d will send out time-staggered an ultrasonic signal 108 in certain predefined intervals. The time difference between the sending of the ultrasonic signals by the different ultrasonic devices 502a to 502d is here preferably bigger than the runtime of the ultrasonic signal 108 between the sending and the receiving. According to the frequency-multiplexing technique, the ultrasonic signals of the ultrasonic devices 502a to 502d may be send out at the same time as well, whereby the frequency ranges of the sent-out ultrasonic signals are different.

By means of the received runtimes, the evaluation device 112 may determine a position of the piston 101, namely a distance x of the piston from the first outside wall 104. If different distances x of the piston 101 are determined by the runtimes of the different ultrasonic devices 502a to 502d, e.g. a mean value may be computed. However, primarily that measuring result is preferred, which comes from the ultrasonic device, which is nearest to the piston 101 based on the measuring; by means of this measuring result, the position of the piston 101 can be determined.

Figure 6 shows a flow chart to explain a method to determine a position of piston 101 in a cylinder. The method comprises a first step S1 of the sending-out of an ultrasonic signal 108 on a cylinder casing 102 with cylindrical side wall 103. Here, the ultrasonic signal is sent out in such way that it will propagate alongside an inner face 103a of the side wall 103 of the cylinder casing 102, i.e. in an axial direction. Herein, the sending may take place particularly by one of the signal feeding devices being described in the embodiments above.

The method comprises a second step S2 of the receiving of the ultrasonic signal 108 reflected by a gasket 101a of a piston 101 within the cylinder casing 102. Hereby, preferably one of the receiving devices described above is used.

Finally, the method comprises a third step of the computation of a position of the piston 101, i.e. of a distance x of the piston 101 from a first outside wall 104 of the cylinder 103. Here, the position is computed by a runtime Δt of the ultrasonic signal 108 between the sending and the receiving of the ultrasonic signal.

Claims

1. Cylinder (100; 200; 400; 500), particularly for use in hydraulic system, comprising
 - 5 a cylinder casing (102) with a cylindrical side wall (103);
 - an axial slidable piston (101) located in the cylinder casing (102);
 - at least one signal feeding device (106; 201; 401) being located in the cylinder casing (103) and arranged to send out an ultrasonic signal (108) in such way that the ultrasonic signal (108) will propagate along
 - 10 an inner face (103a) of the side wall (103) of the cylinder casing (102);
 - at least one receiving device (107; 201; 401) being located in the cylinder casing (102) and arranged in such way to receive an ultrasonic signal (108) being reflected from the piston (101); and
 - one evaluation device (112) being arranged in such way to determine
 - 15 a position (x) of the piston (101) by a runtime (Δt) of the ultrasonic signal (108) between the sending of the ultrasonic signal (108) by the signal feeding device (106; 201; 401) and the receiving of the ultrasonic signal (108) by the receiving device (107; 201; 401).
- 20 2. Cylinder (100; 200; 400; 500) according to claim 1, wherein the signal feeding device (106; 201; 401) comprising:
 - one top piece (106a) being located at the side wall (103) of the cylinder casing (102); and
 - one sender (106b) located on the top piece (106a), wherein the
 - 25 sender (106b) is arranged in such way to send out the ultrasonic signal (108) through the top piece so that the ultrasonic signal (108) will strike the cylinder casing (102) under an incidence angle (ϕ_1),
 - wherein the incidence angle (ϕ_1) is selected so that an ultrasonic wave carrying the ultrasonic signal (108) will be refracted on an
 - 30 interface (110) of the top piece (106a) and the cylinder casing (102) in such way that the ultrasonic signal (108) will propagate alongside an inner face (103a) of the side wall (103) of the cylinder casing (102).

3. Cylinder (100; 200; 400; 500) according to claim 1, wherein the signal feeding device (106; 201; 401) is located at the side wall (103) of the cylinder casing (102), and comprises at least two electrodes (201a-1, 201a-2) being located comb-like and arranged in such way to send out an ultrasonic signal (108).
4. Cylinder (100; 200; 400; 500) according to claim 1, wherein the signal feeding device (106; 201; 401) is located at an outside wall (104) in axial direction of the cylinder casing (102), and has at least one shear plate (403) being slidable in a direction (404) parallel to the outside wall (104) of the cylinder casing (102) and is coupled with the cylinder casing (102) by friction,
wherein an ultrasonic signal (108) can be transferred to the cylinder casing (102) by periodical shifting of the shear plate (403) at the outside wall (104) of the cylinder casing (102), which will propagate alongside an inner face (103a) of the side wall (103) of the cylinder casing (102).
5. Cylinder (500) according to one of the claims 1 to 4,
wherein the signal feeding devices (502a to 502d) and the receiving devices (502a to 502d) are located in axial direction being spaced from each other, and
wherein the cylinder (500) comprises a control device (111) being arranged in such way to control sending of an ultrasonic signal (108) by the signal feeding devices (502a to 502d) and receiving of the ultrasonic signal (108) reflected by the receiving devices (502a to 502d) in a multiplexing technique, particularly in a time-multiplexing technique or in a frequency-multiplexing technique.
6. Cylinder (500) according to claim 5,
wherein the control device (111) is arranged to control the signal feeding devices (502a to 502d) in such way that the signal feeding devices (502a to 502d) will send out time-staggered ultrasonic signals (105),

wherein a time difference between the sending of two ultrasonic signals (108) by different signal feeding devices (502a to 502d) is bigger than the runtime (Δt) of the signals of ultrasonic signals (108).

- 5 7. Method to determine a position (x) of a piston (101) in a cylinder (100; 200; 400; 500), particularly for use in a hydraulic system with steps:
- sending out (S1) of an ultrasonic signal (108) in a cylinder casing (102) of the cylinder (100; 200; 400; 500) with cylindrical side wall (103) in such way that the ultrasonic signal (108) will propagate
10 alongside an inner face (103a) of the side wall (103) of the cylinder casing (102),
- receiving (S2) of the ultrasonic signal (108) reflected from the piston (101) located axial slidable in the cylinder casing (102),
- computing (S3) a position (x) of the piston (101) by a runtime (Δt)
15 of the ultrasonic signal (108) between sending and receiving of the ultrasonic signal (108).
8. Method according to claim 7,
- wherein the sending of the ultrasonic signal (108) takes place
20 through a top piece (106a) being located at the side wall (103) of the cylinder casing (102),
- wherein the ultrasonic signal (108) will strike the cylinder casing (102) under an incidence angle (ϕ_1), and
- wherein the incidence angle (ϕ_1) is selected so that the ultrasonic
25 signal (108) will be refracted at an interface of the top piece (106a) and the cylinder casing (102) in such way that the ultrasonic signal (108) will propagate alongside an inner face (103a) of the side wall (103) of the cylinder casing (102).
9. Method according to claim 7, wherein the sending of the ultrasonic signal (108) takes place by means of at least two electrodes (201a-1, 201a-2) being located comb-like at the side wall (103) of the cylinder casing (102).
30

10. Method according to claim 7, wherein the sending of the ultrasonic signal (108) takes place by shifting a shear plate (401) on an outside wall (104) in a radial direction (403), wherein the shear plate (401) is coupled with the outside wall (102) by friction.
- 5
11. Method according to one of the claims 7 to 10, wherein the sending of the ultrasonic signal (108) and the receiving of the reflected ultrasonic signals (108) take place at different positions of the cylinder casing (102) in a multiplexing technique, particularly in a time-multiplexing technique or in a frequency-multiplexing technique.
- 10
12. Method according to claim 11,
- wherein the ultrasonic signals (105) are sent out time-staggered at the different positions of the cylinder casing (102), and
- 15
- wherein a time difference between the sending of two ultrasonic signals (108) at different positions of the cylinder casing is larger than the runtime (Δt) of the signals of ultrasonic signals (108).