

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

5 The present invention is related to a cylinder, particularly for use in hydraulic systems, and a method for determining a position of a piston in a cylinder, particularly for 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 drilling of the piston. From *US 6 119 579 A*, a measuring method is known, where ultrasonic sensors are located on the outside of a
15 cylinder, and the position of a piston is determined by means of the runtime of an ultrasonic measuring signal.

Summary of invention

20 The present invention refers to a cylinder, particularly for use in hydraulic systems, having the characteristics of patent claim 1 and a method for determining a position of a piston in a cylinder, particularly for use in a hydraulic system with the characteristics of patent claim 12.

25 According to a first aspect, the present invention provides a cylinder, particularly for use in hydraulic systems, comprising a cylinder housing with a cylindrical side wall, an axially slidable piston located in the cylinder housing; a plurality of transmitting devices arranged at the cylinder housing and configured to feed ultrasonic signals into the side wall of the cylinder housing, wherein a control
30 device, by which the plurality of transmitting devices is controlled in such way that the ultrasonic signals being fed into the side wall of the cylinder housing overlap in such way that a signal is at the position of the piston above a predetermined threshold value.

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 the control of a plurality of transmitting devices for feeding of ultrasonic signals in a side wall of the cylinder housing of the cylinder, wherein the fed ultrasonic signals overlap in such way that there is a signal at the position of the piston above a predetermined threshold value, as well as the control of a plurality of receiving devices for receiving the ultrasonic signal being reflected from the piston located axially slidable in the cylinder housing.

Preferred embodiments are the subjects of the respective subclaims.

The term 'cylinder' encompasses different piston-cylinder units, particularly pneumatic cylinders and/or hydraulic cylinders and/or lifting cylinders, as they are used in a variety of machines. Herein, 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 slidably located in the cylinder housing may also particularly comprise a membrane. Furthermore, in the following, the plurality of transmitting devices may be termed also as ultrasonic transmission array and/or the plurality of receiving devices as ultrasonic reception array. In particular, it is an advantage that the feeding of ultrasonic waves into the side wall of the cylinder and the propagation of ultrasonic waves in the side wall of the cylinder does not depend on the operating conditions of the hydraulic oil. Hence, the determination of the piston position is extremely robust considering the temperature-dependent and age-dependent properties of the hydraulic oil. In addition, it is easily possible to retrofit the transmitting devices, the receiving devices and the evaluation device for existing cylinders.

The ultrasonic transmission array can be controlled in such way that all transmitting devices will be synchronised, i.e. being operated without phase difference. This is very advantageous if the ultrasonic signals are heavily dampened in the propagation process, and therefore a high sound power should be implanted in the cylinder wall.

As there are further positions within the cylinder wall depending on number, position and phase of the controlled transmitting devices, where the ultrasonic signals will interfere destructively and where the interference signal will be below a predetermined threshold value, it is an advantage if the transmitting devices will be controlled depending on the expected piston position.

It is also possible that either only one transmitting device or a few transmitting devices will be controlled per measuring cycle and additional transmitting devices will be connected as well, if required. This method of control saves electricity and thus will increase the energy efficiency of the system and of the method.

Moreover, an ultrasonic transmission array is advantageous due to its intrinsic redundancy, as it will increase the measurement security of the system and of the method.

According to an embodiment, the cylinder comprises at least one receiving device, being located at the cylinder housing, and arranged to receive the ultrasonic signals being reflected by the piston. Hence, it will be ensured that the ultrasonic signals being reflected at the piston position or at the piston seal can be detected and the position of the piston can be determined by a runtime having passed between the sending and the receiving of the ultrasonic signals, and by the sound velocity.

It is also an advantage if the plurality of transmitting devices can be controlled by the control device in such way that there is a predetermined phase relationship between the ultrasonic signals being fed by the plurality of the transmitting devices into the side wall of the cylinder housing, which differs notably between 0° and 180° .

This phase relationship or this phase difference may be selected in such way that destructive interferences at the position of the piston or of the piston seal are prevented. Advantageously, the phase difference is selected in such way that the interference signal will be at the position of the piston or of the piston seal above a predetermined threshold value. Hence, it will be ensured that the signal being reflected at the piston or at the piston seal can be detected by at least one of the plurality of receiving devices, even after travelling basically the same distance as those of the fed ultrasonic signals.

According to an embodiment, the cylinder comprises a plurality of receiving devices, whereby the control device from the plurality of receiving devices will select at least one receiving device in such way that one receiving signal at least of one of the selected receiving devices will be above a predetermined threshold value. This has the advantage that the signal can be detected at least by the plurality of the receiving devices, and thus the position of the piston can be determined.

It is also an advantage if the plurality of receiving devices can be controlled by the control device in such way that the ultrasonic signals being reflected by the piston can be received from one predetermined direction. Hence, it will be ensured that, from various signals being reflected at the position of the piston or of the piston seal and thus coming from different directions, the signal, which has the highest intensity, can be selected.

Furthermore it is practical, if the plurality of transmitting devices at the cylinder housing are arranged in such way that the ultrasonic signals being fed into the side wall of the cylinder housing will overlap in such way that the signal will be at the position of the piston above a predetermined threshold value. Hence, it will be ensured that the individual ultrasonic signals at the position of the piston or of the piston seal will constructively overlap only by the way of the arrangement of the individual transmitting devices.

According to an embodiment of the invention, the plurality of transmitting devices is arranged along the axial direction of the side wall of the cylinder

housing and/or along a perimeter of the side wall of the cylinder housing. The variation option for the arrangement of the transmitting devices given by that is particularly an advantage if the cylinder has a large length when compared to its diameter, e.g. in a proportion of 1 to 5 or smaller, or if the cylinder when compared to its diameter has a little length, e.g. in a proportion of 5 to 1 or bigger.

It is also an advantage if adjacent transmitting devices are arranged equidistantly along an axial direction of the side wall of the cylinder housing and/or along the perimeter of the side wall of the cylinder housing. Hence, with a similar control of the transmitting devices, which is equal to a fixed phase relationship or a fixed phase difference between two adjacent transmitting devices, it will be possible, to achieve a constructive overlapping of the ultrasonic signals being sent by the individual transmitting devices at the position of the piston or of the piston seal. This will reduce the complexity of the control of the individual transmitting devices.

A cylinder according to this embodiment is characterised in that the plurality of transmitting devices are arranged on the front side of the cylinder housing; this can be an advantage for certain cylinder requirements, as no space will be required at the side wall.

Furthermore, it is practical if the plurality of receiving devices is arranged at the same positions as the plurality of transmitting devices and/or that the plurality of transmitting devices are also arranged as receiving devices, to receive the ultrasonic signals being reflected by the piston. Thus, complexity of the control will be simplified by this, and space on the cylinder surface will be saved as well. Furthermore according to the previous aspect of the embodiment, the functions of the transmitting and receiving devices may be swapped during the measurement and also adjusted to the required transmission and/or receiving power, if necessary.

According to an embodiment, the cylinder comprises at least one evaluation device, being configured to determine a piston position by means of a runtime of the ultrasonic signal between the sending of the ultrasonic signal by a plurality of transmitting devices and the receiving of the ultrasonic signals by the

plurality of receiving devices. The propagation medium of the ultrasonic signal is the inner face of the side wall of the cylinder housing. Therefore, a wave propagation velocity of the ultrasonic signal is easy to compute, 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.

According to an embodiment of the method, the following is a step of computation of the piston position by means of a runtime of the ultrasonic signal between sending and receiving of the ultrasonic signal. The advantages mentioned above apply correspondingly also for the method.

Brief description of drawings

The following is shown in the Figures:

- Fig. 1 A cross section view of a side presentation of a cylinder according to the invention;
- 5 Fig. 2 A sector of a cross section view of a side view of a cylinder according to the invention;
- Fig. 3 A top view on the front side of the cylinder according to the invention;
- 10 Fig. 4 A side view of the cylinder according to the invention;
- Fig. 5 A side view of the cylinder according to an alternative embodiment of the invention;
- 15 Fig. 6 A top view on the front side of the cylinder according to an alternative embodiment of the invention; and
- 20 Fig. 7 A flow chart for a method according to the invention to determine a position of a piston in a cylinder.

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

25 **Description of the embodiments**

Figure 1 shows a cylinder 100, in particular a hydraulic cylinder for use in a hydraulic system. The cylinder 100 comprises a cylinder housing 102 with cylindrical side wall 103, being axially arranged around a symmetrical axis of the cylinder 100, and an outer wall 104 in an axial direction of the cylinder housing 102, limiting the cylinder 100 in the axial direction. Opposite to the first outer wall 104, an opening 105 is arranged in a second outer wall 115 of the

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cylinder housing 102, in which a piston 101 is axially slidable inserted. A position of the piston 101 is determined by a distance x from the first outer wall 104. The cylindrical side wall 103 of the cylinder housing 102 has an inner face 103a and an exterior outer face 103b in radial direction. The piston 101 here has a seal 101a, forming a radial outer section of the piston 101, contacting the outer face 103b of the cylinder housing and serving for the sealing of a pressure chamber 116 between the piston 101 and the first outer wall 104 of the cylinder housing 102.

At the cylindrical side wall 103, a plurality of transmitting devices 1061, 1062, 1063 are located. The transmitting devices 1061, 1062, 1063 comprises one top piece 1061a, 1062a, 1063a each, being located at the outer face 103b of the cylindrical side wall 103 of the cylinder housing 102. The top pieces 1061a, 1062a, 1063a herein consist 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 housing 102.

However, the invention is not confined to that. Thus, the top pieces 1061a, 1062a, 1063a can be inserted in the cylindrical side wall 103 as well.

One transmitting device 1061b, 1062b, 1063b, each located on the top pieces 1061a, 1062a, 1063a, is being arranged in such way to send out an ultrasonic signal 108 through the top pieces 1061a, 1062a, 1063a. Herein, the ultrasonic signal 108 is typically modulated on an ultrasonic wave. The ultrasonic signal can be particularly a wave package as well.

The top pieces 1061a, 1062a, 1063a are configured as wedge-shaped so that the ultrasonic signal 108 sent out from the transmitting device 1061b, 1062b, 1063b will strike the cylindrical side wall 103 under an incidence angle φ_1 with respect to a surface normal 109. For reasons of clarity, this is shown in the following only for one of the transmitting devices 1063.

At the interface 110 between a top piece 106a and a 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 that is 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 housing 102. With the known refractive indices n_1 and n_2 of the top piece and of the cylinder housing 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 housing 102.

Hence, the ultrasonic signals 108 of the transmitting devices 1061, 1062, 1063 run parallel to the cylindrical side wall 103. Such ultrasonic signals 108, which propagate at the inner face 103a of the side wall 103 or within the side wall 103 of the cylinder housing 102, are called Rayleigh-wave or Scholte-waves.

As the ultrasonic signals 108 of the plurality of transmitting devices 1061, 1062, and 1063 will propagate not only along the cylindrical axis but also over the entire side wall 103 of the cylinder housing 102, the ultrasonic signals 108 of the plurality of transmitting devices 1061, 1062, and 1063 will interfere. Within the side wall 103, there will be spots where the ultrasonic signals 108 will constructively overlap and there will be spots where the ultrasonic signals 108 will destructively overlap. At spots where the ultrasonic signals 108 will destructively interfere, none or only one little reflection will occur, for instance, at the piston 101 or at the piston seal 101a. Only at spots where the ultrasonic signals 108 will constructively interfere, the ultrasonic signal 108 can be reflected at the piston 101 or at the piston seal 101a.

The reflected ultrasonic signal 108 will subsequently propagate in the opposite direction and will be received by at least one of the receiving devices 1071. Herein, the receiving devices 1071 are preferably similarly arranged like the transmitting devices 1061, 1062, 1063 that is the receiving devices 1071 have a top piece 1071a each and a receiving device 1071b each located on it as well.

It is also possible that the transmitting devices 1061, 1062, 1063 and the receiving devices 1071 are identical, i.e. that the devices can receive and send ultrasonic signals 108, or that they are arranged at or on the cylindrical side wall 103 in such way that a distance x_1 or x_2 from the first outer wall 104 to the transmitting devices 1061, 1062, 1063 and to the receiving devices 1071 is the same. For instance, this is the case if one of the transmitting devices 1061, 1062, 1063 and one of the receiving devices 1071 are installed side by side on the same perimeter of the cylinder 100. For reasons of clarity, it is assumed in the following that on the cylinder 100 along the cylindrical axis, several transmitting devices 1061, 1062, 1063 and one receiving device 1071 are installed. Herein, the transmitting device 1061 and the receiving device 1071 are to be considered as one device.

The receiving device 1071 and the transmitting devices 1061, 1062 and 1063 are connected with a control device 111. The control device 111 controls the transmitting devices 1061, 1062, 1063. The control device 111 comprises an evaluation device 112 being arranged to determine the position of the piston 101 by means of a runtime Δt of the ultrasonic signal 108 between the sending of the ultrasonic signal 108 by the transmitting device 106 and receiving of the reflected ultrasonic signal 108 by the receiving device 1071 that is the distance x between the first outer wall 104 and piston 101. For this, the evaluation device 112 will measure a first point in time t_1 of the sending of the ultrasonic signal 108 by the transmitting devices 1061, 1062, 1063 and a second point in time t_2 of the receiving of the reflected ultrasonic signal 108 by the receiving device 1071. 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

will consider a known distance x_2 of the transmitting device 1061 and a known distance x_1 of the receiving devices 1071 from the first outer wall 104 of the cylinder housing 102.

5 A total run distance Δy of the ultrasonic signal 108 between sending and receiving is computed according to the following formula:

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

10 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 transmitting devices 106 from the piston 101. The size of the cylindrical side wall 103 is neglected, as it is small as compared to the distance y_1 of the transmitting devices 106 from the piston 101, as well as a distance x_2
15 $- x_1$ of the transmitting devices 106 and the receiving devices 107. As the transmitting device 1061 and the receiving device 1071 have the same distance from the side wall 103, it is $x_2 - x_1$.

20 Thus, the distance x of the piston from the first outer 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
25 distance x of the piston 101 from the first outer 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 to 1,500 m/s and if the
30 distance x_2 of the transmitting device 106 from the first outer wall 104 of the cylinder housing 102 equals to 10 cm and the distance x_1 of the receiving device 107 from the first outer wall 104 of the cylinder housing 102 also equals to 10 cm, and if the runtime Δt of the ultrasonic signal 108 equals to 1 ms, the distance x of the piston from the first outer wall 104 is:

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$$x = (v \cdot \Delta t + x_1 + x_2) / 2 = (150 \text{ cm} + 10 \text{ cm} + 10 \text{ cm}) / 2 = 85 \text{ cm}.$$

5 The evaluation device 112 can be aligned to consider a reflection of the ultrasonic signal 108 at the second outer wall 115, whereby this reflection comes from a part of the ultrasonic signal, which is not yet reflected at the front point 114 of the seal 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 transmitting devices 1061b, 1062b and 1063b and of the receiving device 107b of the cylindrical side wall 103.

10 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.

15 The invention is not confined to that. Thus, the evaluation device 112 may be identical to the transmitting device 106.

20 Figure 2 shows a section from Figure 1 where the side wall 103 of the cylinder housing 102 is shown enlarged. Each of the transmitting devices 1061, 1062, 1063 sends out ultrasonic signals 1081, 1082, 1083, which propagate along the inner face of the side wall 103. The wave length of the ultrasonic signals 1081, 1082 and 1083 can be selected in such way
25 that the amplitude of an ultrasonic signal 1080, which results from the overlapping of the ultrasonic signals 1081, 1082, 1083 will be as large as possible at the front point 114 of the seal 101a of the piston 101.

Preferably, it is possible that the control device 111 (not shown) will control the transmitting devices 1061, 1062, 1063 by phase shifting in such way that the amplitude of the ultrasonic signal 1080, which results from the overlapping of the ultrasonic signals 1081, 1082, 1083, will be as large as possible at the front point 114 of the seal 101a of the piston 101.

Figure 3 shows a cylinder 200 according to a second embodiment of the present invention. Herein, the transmitting devices 1061, 2061, 3061, 4061, 5061 are identical with the receiving devices 1071, 2071, 3071, 4071, 5071 and located along the perimeter of the cylinder housing 102. Each of the transmitting devices 1061, 2061, 3061, 4061, 5061 is arranged to send out coherent ultrasonic signals 108. The spots along the side wall 103 of the cylinder housing 102 where the ultrasonic signals 108 will interfere constructively and destructively vary depending on the plurality of transmitting devices 1061, 2061, 3061, 4061, 5061 sending the ultrasonic signals 108 and also on the positions of the transmitting devices 1061, 2061, 3061, 4061, 5061. Therefore, depending on the expected piston position, which can be estimated by empirical data, advantageously, some of the transmitting devices 1061, 2061, 3061, 4061 and 5061 may be switched off or connected. Accordingly, it can be intended that not all receiving devices 1071, 2071, 3071, 4071, 5071 will be used, but depending on the expected piston position and thus depending on the expected position, where the ultrasonic signal 108 being reflected at the piston seal 101a can be received by one or some of the receiving devices 1071, 2071, 3071, 4071, 5071.

In an alternative embodiment, it is possible that not all transmitting devices 1061, 2061, 3061, 4061, 5061 or receiving devices 1071, 2071, 3071, 4071 and 5071 are used or controlled per measuring cycle.

It may be intended that in case of undershooting of the receiving ultrasonic signal 108 under a predetermined threshold value by one or some of the receiving devices 1071, 2071, 3071, 4071, 5071, other receiving devices and/or transmitting devices will be connected until the predetermined threshold will be surpassed.

Figure 4 shows a side view of an embodiment of the cylinder 200 according to the invention from Figure 2. Herein, the transmitting devices 1061, 1062, 1063 and the receiving devices 1071, 1072, 1073 are shown, each being located at the same place on the cylinder housing 202. Furthermore, the transmitting devices 1061, 1062, 1063 and the receiving devices 1071, 1072, 1073 on the cylinder housing 202 are located along the cylindrical axis with a predetermined distance to each other. Moreover, the transmitting devices 2061, 3061, 4061, 5061 and receiving devices 2071, 3071, 4071, 5071 are mounted on the cylinder housing 202, which are located along a perimeter of the cylinder 200, where the transmitting device 1061 and the receiving device 1071 are mounted as well. Moreover, the transmitting devices 2062, 3062, 4062, 5062 and receiving devices 2072, 3072, 4072, 5072 are mounted on the cylinder housing 202, which are located along a perimeter of the cylinder 200, where the transmitting device 1062 and the receiving device 1072 are mounted as well. Moreover, the transmitting devices 2063, 3063, 4063, 5063 and receiving devices 2073, 3073, 4073, 5073 are mounted on the cylinder housing 202, which are located along a perimeter of the cylinder 200, where the transmitting device 1063 and the receiving device 1073 are mounted as well. The array structure as a result may be extended or reduced along the cylindrical axis. Furthermore, it is possible that the number at the transmitting and receiving devices along a perimeter of the cylinder housing 202 will be increased or decreased. The control device 111 (not shown) being connected with all transmitting and receiving devices may operate now in analogy to the embodiment being described in Figure 3 a certain number of transmitting devices 1061 – 5061, 1062 – 5062, 1063 – 5063 and/or of receiving devices 1071 – 5071, 1072 – 5072, 1073 – 5073 in such way that there will be a predetermined phase relationship between the ultrasonic signals 108 being fed by the individual transmitting devices 1061 – 5061, 1062 – 5062, 1063 – 5063. By this, it

can be ensured that at the front point 214 of the piston seal 201a, the interference signal of all transmitted ultrasonic signals will be above a predetermined threshold value and that the direction of the reflected ultrasonic signal can be determined. By this, the number of controlled and/or operated receiving devices 1071 – 5071, 1072 – 5072, 1073 – 5073 can be reduced.

In Figure 5, a side view, and in Figure 6, a top view of a cylinder 300 of an alternative embodiment according to the invention, are shown. Herein, the transmitting devices 1061 - 8061 and the receiving devices 1071 - 8071 are mounted along the edge of the first outer wall 304 of the cylinder 300. It is useful if the transmitting devices 1061 - 8061 and the receiving devices 1071 – 8071 are each located at the same position.

In Figure 7, a flow chart for a method 700 according to the invention for determining a position of a piston 101, 201 in a cylinder 100, 200, 300 is shown. The method 700 comprises a first step 701 of the controlling of the plurality of transmitting devices 1061 – 5061, 1062 – 5062, 1063 – 5063 for sending or feeding of ultrasonic signals 108 in a side wall 103, 203 of the cylinder housing 102, 202. Herein, the transmitting devices 1061 – 5061, 1062 – 5062, 1063 – 5063 are operated by a control device 111 in such way that the ultrasonic signal 108 will constructively overlap at a front point 114, 214 of a piston seal 101a, 201a of a piston 101, 201 and hence have maximum sound intensity, which will be above a predetermined threshold value. The control may happen in such way that the ultrasonic signals 108 sent out by the transmitting devices 1061 – 5061, 1062 – 5062, 1063 – 5063 will have a predetermined phase difference.

The method 700 comprises also a second step 702 of the controlling of the plurality of receiving devices 1071 – 5071, 1072 – 5072, 1073 – 5073 for the receiving of the ultrasonic signal 108 being reflected at the front point 114, 214 of the piston seal 101a, 201a of the piston 101, 201.

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Furthermore, the method 700 comprises a third step 703 of the computation of a position of the piston 101, 201 that is of a distance x of the piston 101, 201 from a first outer wall 104, 304 of the cylinder 100, 200, 300. The computation of the position is done with the runtime Δt of the ultrasonic signal 108 between the sending and the receiving of the ultrasonic signal 108.

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Claims

1. A cylinder, in particular for use in a hydraulic system, comprising a cylinder housing with a cylindrical side wall; a piston arranged axially
5 slidable in the cylinder housing; a plurality of transmitting devices
arranged at the cylinder housing and configured to feed ultrasonic signals
into the side wall of the cylinder housing; characterised by a control
device by means of which the plurality of transmitting devices is
controllable in such way that the ultrasonic signals fed into the side wall of
10 the cylinder housing overlap in such way that a signal at a position of the
piston lies above a predetermined threshold value.
2. The cylinder according to claim 1, characterised in that the cylinder has at
least one receiving device being arranged on the cylinder housing and
15 configured to receive ultrasonic signals reflected by the piston.
3. The cylinder according to claim 1 or 2, characterised in that the plurality of
the transmitting devices can be controlled by the control device in such
way that a predetermined phase relationship exists between the ultrasonic
20 signals fed into the side wall of the cylinder housing by the plurality of the
transmitting devices.
4. The cylinder according to one of the preceding claims, characterised in
that the cylinder has a plurality of receiving devices, wherein the control
25 device selects from a plurality of the receiving devices at least one
receiving device in such way that one receiving signal of at least one
selected receiving device is above a predetermined threshold value.
5. The cylinder according to one of the preceding claims, characterised in
30 that a plurality of receiving devices is controlled by the control device in
such way that the ultrasonic signals reflected by the piston are received
from a predetermined direction.
6. The cylinder according to one of the preceding claims, characterised in
35 that the plurality of the transmitting devices are arranged at the cylinder
housing in such way that the ultrasonic signals being fed into the side wall

of the cylinder housing overlap in such way that the signal at the position of the piston is above a predetermined threshold value.

- 5 7. The cylinder according to claim 6, characterised in that the plurality of the transmitting devices are located along an axial direction of the side wall of the cylinder housing and/or along a perimeter of the side wall of the cylinder housing.
- 10 8. The cylinder according to claim 6 or 7, characterised in that adjacent transmitting devices are arranged equidistantly along the axial direction of the side wall of the cylinder housing and/or along the perimeter of the side wall of the cylinder housing.
- 15 9. The cylinder according to claim 6, characterised in that the plurality of the transmitting devices are located on a front side of the cylinder housing.
- 20 10. The cylinder according to one of the preceding claims, characterised in that a plurality of receiving devices are located at the same positions as the plurality of the transmitting devices and/or that the plurality of the transmitting devices are also configured as receiving devices for receiving the ultrasonic signals reflected by the piston.
- 25 11. The cylinder according to one of the preceding claims characterised by at least one evaluation device being configured to determine a position of the piston by means of a runtime of the ultrasonic signals between sending of the ultrasonic signals by the plurality of the transmitting devices and receiving of the ultrasonic signals by the plurality of the receiving devices.
- 30 12. A method for determining a position of a piston in a cylinder, in particular in a cylinder according to one of the preceding claims, comprising the steps: controlling a plurality of transmitting devices for feeding ultrasonic signals into a side wall of a cylinder housing of the cylinder, wherein the fed ultrasonic signals overlap in such way that a signal at the position of the piston is above a predetermined threshold value; and
35 controlling a plurality of receiving devices for receiving the ultrasonic signals reflected by the piston arranged axially slidable in the cylinder housing.

13. The method according to claim 12 comprising a step of computation of a piston position by means of a runtime of the ultrasonic signal between sending and receiving of the ultrasonic signal.