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Method and Device for Measuring a Path Covered

The invention concerns a method and a device for measuring a path covered.

For example, a path-measuring device for measuring a path covered by a moving object capable of being deflected along a direction is known from practice. A first component of the path-measuring device is associated with the moving object and moves with it. A second component of the path-measuring device is stationary. The two components are coupled with one another in order to convert the motion and/or deflection of the moving object into an electrical signal. This electrical signal is transmitted to an evaluation arrangement of the path-measuring device and there converted into motion and/or position information.

An example of such an above-mentioned path-measuring device is a potentiometer-type sensor. The first component of this sensor is formed by a wire wound in coiled fashion and the second component is formed by a contact element capable of moving externally along this coil winding. Depending on the position of the contact element relative to the coil winding, a corresponding resistance results for a current flowing through coil winding and contact element, which is convertible into position information.

A further example of a known path-measuring device is a magnetic or inductive path measurement. In this case a coil or a part of a condenser is connected with the object moved and a further coil or the other part of the condenser is made stationary.

Further known path-measuring devices use, for example, optical sensors, the motion of a first component moving with the moving object being determined optically and converted into a corresponding motion signal by the stationary sensor. Finally, laser devices for path measurement also are known.

In the case of these previously known path-measuring devices there are the following disadvantages.

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Optical measurements are indeed very precise, but at the same time very sensitive, and only usable in the case of good visual conditions, and at the same time they are quite expensive.

Magnetic or inductive devices are sensitive to vibrations, shocks, or the like, and as a rule also are quite expensive. Potentiometer-like sensors are quite imprecise and have only a relatively short service life because of wear phenomena.

US-A-5,038,622 discloses a tension measuring device for measuring a tensile force exerted on a flexible component, such as a steel cable. The tensile measurement device is attached at two points of the cable. The device includes, among other things, a vibration wire, a spiral spring, one tube with smaller diameter and one tube with greater diameter. If excess tensile force of the cable is to be measured, a frequency change in the vibration wire in relation to the tensile force is measured by means of a coil. The coil also is used for exciting the vibration wire by means of a magnet. At the same time the wire is monitored by a reading device in order to detect possible frequency changes in the vibration wire. Such a frequency change takes place, for example, if the vibration wire experiences a change in its effective length between the securing devices.

CHR. Rohrbach: "Manual for electric measurement of mechanical values," 1967, VDI-Press, Duesseldorf, pages 48, 49 concerns a number of different path measurement devices with an elongation measurement strip or semiconductor sensors. Of course, in the case of the corresponding devices it is not force, but elongation that is measured. Furthermore, also it is not linear position along a path that is measured, but deflection of a beam that is clamped tight on one side. In this case a corresponding measurement device is mounted on both sides of the beam in the vicinity of its clamped end.

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Therefore the object of the invention is to improve processes or path measuring devices of the type named initially so that the path measurement may be used with high accuracy, without wear, insensitive to vibrations, shocks, or corrosion and economically in almost all media without special sealing and in any pressure range.

This object is achieved according to the device by having the first component be a moving object and the second component be a connecting spring and the second component be a force measurement device that emits an electric signal corresponding to a force exerted on the spring element.

According to the process, the object is achieved by having the moving object move against the resistance of an elastically expandable retaining element along an essentially linear path, having the retaining force appearing in the retaining element be measured in relation to the path covered by the moving object and a signal corresponding to the retaining element be transmitted from the force measuring device to an evaluation device, and the path covered by the moving object corresponding to the retaining element be determined there.

The path measurement device according to the invention is simply designed. The spring element is expanded in the case of motion of the moving object, the retaining force appearing in the spring element in the simplest case is directly proportional to the path covered by the moving object. The retaining force is transferred through the spring element to the force measuring device and measured there. In this case [text ends]

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a corresponding electrical signal, which corresponds to the retaining force, and thus to the path covered by the moving object, is received by an evaluation device connected with the force-measuring device. The components used for the path-measuring device according to the invention are designed simply and economically. No wear of these components takes place, since, for example, there is no friction between the components or between the components and other objects. The path-measuring device according to the invention is independent of a medium in which it is located, of the site conditions, of vibrations, shocks, or the like.

In a simple embodiment the spring element can be a spiral spring, which is connected with one of its ends on the moving object and with its other end with the force-measuring device. In this case, the spiral spring can be chosen so that a retaining force exerted on the moving object, and thus a limitation of the mobility of the moving object, is relatively small, and at the same time the retaining force is great enough for the force-measuring device to obtain a sufficiently large signal. Furthermore, in the case of using such a spiral spring as a spring element it is shown that in the case of the path-measuring device according to the invention no parts actually moving together with the moving object are present. The spiral springs, respectively the spring element, can be chosen in particular so that they expand proportional to the retaining force exerted, so that the evaluation of the signal of the force-measuring device and correspondingly the determination of motion or position of the moving object is simplified.

Such a spring element can be chosen with the corresponding spring constants, from corresponding material, and the like depending on the requirements. At this point it is to be noted that in the case of the path-measuring device according to the invention or the corresponding measuring method, only a limited motion of the moving object is possible because of the connection with the spring element and via the latter with the force-measuring device. Essentially the range of motion is determined by the spring element and the maximum expansion which can be evaluated by the latter.

According to the invention it is possible for the spring element to follow a curved, for example circular, path of the moving object, and correspondingly the position of the moving

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object along this path can be determined. A simple embodiment for a path-measuring device without a curved course of the spring element and without friction which may possibly appear between a spring element and the guide may be seen when the spring element extends essentially in a straight line. Furthermore, in this case it is advantageous if the moving object also moves in a straight line.

In order to adapt the path-measuring device to different requirements in a simple way, such as, for example, longer paths to be covered by the moving object, or the like, the spring element may be replaceable. Thus, the spring elements may be chosen corresponding to their maximum expansion.

The force-measuring device may be made in different ways. According to the invention such a force-measuring device must convert the force exerted on it into a corresponding electrical signal, which then is acquired and processed by the evaluating unit.

In the case of a simple embodiment which can be produced economically, the force-measuring device has at least one electrically conducting, in particular wire-like conductor, the electric resistance of which depends on a force exerted upon it in the longitudinal direction. Such a conductor also may be made out of different materials, which are chosen, for example, with respect to the environmental conditions under which the path-measuring device is used. In this way the path-measuring device according to the invention also may be used in aggressive media, under water, under pressure, under a vacuum and the like, essentially without limitations. Because of a simple structure of the path-measuring device there is no wear and no abrasion of the individual parts, so that the service life is extraordinarily high.

Since a spring element, as a rule, has a soft damping characteristic, corresponding vibrations, shocks, or the like are transmitted without influence on the force-measuring device.

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Such an electrical conductor as a force-measuring device changes its electrical resistance in the case of exertion of a corresponding tensile force on the conductor, and such a resistance change can be detected via corresponding stress or current changes and evaluated as a signal in the evaluating device.

In order to determine a zero point for path measurement in a simple way, the spring element can be pre-stressed, and a corresponding motion or position signal is determined by the evaluating unit only in the case of further stress of the pre-stressed spring element.

In order to compensate for certain statistical irregularities of the wire, such as diameter deviations, changes in the properties of the material, and so forth, in a wire-like conductor in a simple way, the conductor can have a number of electrically conducting wires located parallel to one another. In this way, corresponding statistical deviations of the individual wires are determined and a force-measuring device measuring accurately over its entire measuring range results.

The wires may be individual wires or formed by an individual wire which is laid meandering.

In order to be able to determine changes in the resistance in such an electrical conductor in a simple way, the electrical conductor can be connected in a bridge circuit, such as a so-called Wheatstone bridge, and form at least one resistor in the bridge circuit. Highly accurate circuit measurements are possible by means of such a bridge, whereby a high accuracy for position determination of the moving object also results.

In order to compensate for changes in the resistance of the conductor, on the basis of temperature changes, so that the latter do not lead to an erroneous determination of the position of the moving object, the bridge circuit can have a further resistor analogous to the resistor formed by the force-measuring device. For example, if the force-measuring device is made up of a number of wires, this further resistor is made in a similar way. Of course, as opposed

to the force-measuring device, it is not exposed to a corresponding tensile force from the spring element.

According to the invention a simple electrical structure, which also requires simple means in the case of the evaluating unit, results from the use of the bridge circuit and the electrically conducting wires as a force-measuring device. For example, an amplifier and/or a differentiator and/or an evaluating device, connected with a microprocessor or the like, are the only electronic components which are necessary. The differentiator may be omitted if, for example, a determination of the speed or acceleration of the moving object during this motion is omitted. In addition, arrangements of other evaluating devices are used if the latter are supported by software.

Because of the simple, strong, and reliable construction of the path-measuring device according to the invention, the latter is particularly suited for applications in remote and inaccessible areas. For example, one area of application is the use of the measuring device described above, for a linearly moving object of the device from oil and/or gas production. Corresponding devices are so-called actuators, BOP's (blowout preventors), valves and the like, as are necessary in the case of oil and gas production. In this case, the area of application of the path-measuring device according to the invention is not limited to uses on land, but because of the insensitivity to pressure or other unfavorable environmental influences, in particular the use under water is also possible. This obtains analogously for underground use.

It is to be noted that the path-measuring device according to the invention naturally is not limited to devices for oil and/or gas production, but is usable in other machines, in manufacturing, in the case of earth-working devices and the like. Essentially the path-measuring device according to the invention may be used everywhere where a moving object moves over a limited area, in particular linearly back and forth.

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In the case of oil and gas recovery, in particular, a number of linear control devices are used, one of which is described, for example, in German patent 20 008 415. Such a linear control device is used, in particular, for operating valves, throttles or the like, in the case of oil and/or gas recovery, and has at least one control element mounted movable linearly within a housing and a drive device associated with the latter. The control element may be a ball spindle, which is mounted capable of turning in a corresponding nut. The nut is connected moving with the corresponding drive device and converts rotation of the nut induced thereby into a longitudinal motion of the ball spindle. Again express reference is made here to German Patent 20 008 415 for a further description of this linear control device.

In order to determine the position of the control element relative to the housing in a simple way, in the case of such a linear control device relative to the housing, according to the invention one end of the control element is connected with a spring element, which with its end turned away from the control element is connected with a force-measuring device, which transmits an electrical signal corresponding to a force transmitted from the spring element to the force-measuring device, to an evaluating device. This means that the linear control device according to the invention is distinguished by the fact that the path-measuring device described above is incorporated in the latter.

Correspondingly the path-measuring device in the linear control device can have the same features as the path-measuring device described above. There are some further refinements which are described below as a result of the incorporation of the path-measuring device into the linear control device.

For example, in order to protect the spring element from damage resulting from moving parts of the linear control device, the spring element can be located and guided in a pipe.

In order to be able to fasten the ends of the spring element both to the control element and to the force-measuring device in a simple way, the spring element can have corresponding connecting pieces on its ends. The spring

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element can be suspended on the latter with one end and then the connecting piece is to be fastened detachably by screwing or the like on the control element, respectively on the force-measuring device.

In the case of a linear control device which has a control element moving linearly forward by a screw motion, it is advantageous if the corresponding turning of the control element is not transferred to the spring element and thus leads to a stress or force in the spring element, which is not caused by the linear motion of the control element. For this, for example, at least the connecting piece between spring element and control element can have a rotation decoupling device. Only the linear motion of the control element is transferred to the spring element by means of this rotation decoupling element, and the rotation is received by the rotation coupling device.

The force-measuring device can be made correspondingly in order to convert the tensile force exerted by the spring element into an electrical signal. A simple example of such a force-measuring device can be seen if the latter has at least one electrical measuring conductor, the electrical resistance of which changes depending on a force exerted on the measuring conductor.

In order to be able to detect corresponding resistance changes easily via associated stress changes, the electric measuring conductor can be connected as a resistor in a bridge circuit, as a so-called Wheatstone bridge.

The electric measuring conductor can be made as a conducting wire or by a number of conducting wires arranged in parallel. In the case of using several conducting lines corresponding statistical deviations of individual wires are compensated.

In order to be able to compensate temperature drifts of the electrical measuring conductor, a further electrical measuring conductor can be connected without action of force in the bridge circuit for temperature compensation.

Advantageous embodiments of the invention are explained in greater detail below by means of the appended figures in the drawing.

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Here:

Fig. 1 shows a top view of a basic representation of an embodiment of path-measuring device;

Fig. 2 shows a partially cut top view of a second embodiment;

Fig. 3 shows a partially cut top view of a third embodiment;

Fig. 4 shows a partially cut top view of a fourth embodiment;

Fig. 5 shows a circuit representation analogous to Fig. 4;

Fig. 6 shows a longitudinal section through a linear control device with incorporated path-measuring device in a partial representation;

Fig. 7 shows an enlarged representation of a detail "X", and

Fig. 8 shows an enlarged representation of a detail "Y".

Fig. 1 shows a top view of a basic embodiment of a path-measuring device 1 according to the invention. It has a spring element 6 as a first component and a force-measuring device 7 as a second component 4. First component 3 is connected with a moving object 2 on one end 8. In the case of motion of moving object 2 in direction 37, spring element 6 is stretched and a corresponding force is exerted over end 9 of spring element 6 onto second component 4, that is, force-measuring device 7. The force exerted is converted by means of force-measuring device 7 into an electrical signal from which a corresponding position of moving object 2 is determined by connecting evaluation unit 5.

Moving object 2 moves linearly in direction of motion 37 and in the longitudinal direction 12 of spring element 6 or force-measuring device 7.

Force-measuring device 7 is formed by an electrical conductor 10, which can include a number of electrical conducting wires 13. The latter change their resistance depending on the force exerted on them. This means, a resistance change of electrical conducting wires 13 corresponds to a force transferred by spring element 6, and the force is proportional to a deflection of spring element 6 and thus to a position of moving object 2.

Wires 13 are located parallel to another and can be switched electrically also parallel or even in series. Wires 13 form a resistor, which is part of a bridge circuit, see Fig. 5. A further resistor 15 of this bridge circuit also is formed by a number of electric conducting wires and this further electrical resistor 15 corresponds to the resistance formed by electric conducting wires 13 and is used for temperature compensation.

An offset device 31, 32, and amplifier 16 are connected with the resistors formed by the wires. Corresponding signals from the amplifier may be output on an output unit of evaluating unit 5, in which case this evaluating unit 5 also can have a differentiator 17, by which the corresponding position values of moving object 2 changing in time can be differentiated and thus a speed and, in a given case, acceleration, of the moving object can be determined.

A zero point of the deflection of the spring element 6 can be adjusted by offset device 31, 32. For example the springs can be pre-stressed 2% to 5%, in order to create such a measurable zero point for the motion of the moving object 2. A stress value associated with this pre-stress is set to zero by means of the offset device 31, 32.

A voltage supply 36 is connected with the wires and the evaluating unit for the voltage supply of the wires and evaluating device 5.

Fig. 2 shows a further embodiment of a path-measuring device according to the invention analogous to Fig. 1. Moving object 2 is formed by a stamp mounted capable of moving in a housing in the direction of motion 37. The back of the

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stamp is connected with spring element 6. An electrical conductor 10 is connected in series to spring element 6 as a force-measuring device 7 with resistor 11, which is fastened to the housing on its end opposite spring element 6. Resistor 11 is connected with a corresponding bridge circuit via two connecting lines 38, 39, see Fig. 5.

Fig. 3 shows a further embodiment analogous to Fig. 2. This embodiment corresponds to the embodiment according to Fig. 1, a further resistor 15 analogous to resistor 11 and part of the bridge circuit according to Fig. 5. For example a temperature compensation of the path measurement is possible by further resistor 15 in the direct vicinity of resistor 11.

Fig. 4 shows a fourth embodiment analogous to the preceding Figs. 2 and 3. In the case of this embodiment a force measurement is made via all resistors of the bridge circuit according to Fig. 5. Spring element 6 correspondingly acts on all conductors, which can be formed at least partially by separate spring elements. Depending on the deflection of a connecting plate 40 connected in the middle with spring element 6, the corresponding individual spring elements 41 also are stretched or jolted, and corresponding resistance changes are induced.

A circuit for a bridge circuit for determining a resistance change and thus a corresponding stress change is shown in Fig. 5 in the form of a so-called Wheatstone bridge. A circuit of this kind is known per se. The circuit is formed by at least four resistors, of which resistors 29 and 30 are made with the same resistance value. At least one resistor of the bridge circuit is formed by resistor 11 of electrical conductor 10, see Fig. 2. Also resistors 15, 28 can be formed by a resistor independent with respect to the path measurement. Of course, as a rule the latter resistor is variable, in order to equalize the bridge circuit to zero initially before deflection of the moving object.

In the case of the embodiment according to Fig. 5, resistor 15, see Fig. 3, also is formed by a number of electrical wires, see also Fig. 1. In this case resistor 15 is used for temperature compensation of resistor 11.

An offset adjustment, that is, the adjustment of a zero point is possible in the case of slightly pre-stressed spring elements 6, by means of resistor 31 in connection with resistor 32.

The signals detected are transferred to evaluating device 5 from the bridge circuit 14 via an amplifier 16, see also Fig. 1, for further processing.

One branch of the bridge circuit is grounded; see "O" and the other branch lies on the plus pole of a voltage source.

Fig. 6 shows an example of application for an embodiment of path-measuring device 1 according to the invention. In this case path-measuring device 1 is located in a linear drive device 21, as is described, for example, in German patent 20 008 415 of the same applicant. Such a linear drive device 21 has at least one operating element 20, which is movable back and forth in the longitudinal direction. As a rule control element 20 is a ball spindle, which is mounted capable of rotating in a ball rotation nut. At the time of the rotation of the ball rotation nut by means of a drive device 21, shown only partially in Fig. 6, there is a corresponding rotation of the control element 20 and a motion of the control element 20 in the longitudinal direction takes place as a result of the rotation relative to the ball rotation nut in the longitudinal direction.

Control element 20 is connected on one end 22, see also Fig. 8, with spring element 6 of path-measuring device 1. The spring element is guided in a tube 23 by drive device 21 and connected with its end opposite the control element 20 with a corresponding force-measuring device 7 in the form of an electrical measuring conductor 27. The conversion of the force exerted by the control element 20 onto spring element 6 by means of the force-measuring device 7 or the corresponding electrical measuring conductor 27 into a corresponding voltage takes place analogous to the embodiments of the path-measuring device 1 described above.

The spring element 6 according to Figs. 6 to 8 is connected via connecting pieces 24 and 26 with control element 20, respectively with electrical measuring conductor 27. At

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least connecting piece 24 has a rotation decoupling device 26. The latter prevents a transfer of the rotation of the control element 20 made as a ball spindle to spring element 6. Rotation decoupling device 26 can be made, for example, by a screw which is screwed into control element 20 at its end 22, and which is mounted fixed capable of rotating in connecting piece 24, but in the longitudinal element the spring element 6.

Fig. 7 corresponds to a magnified representation of section "X" from Fig. 6 and Fig. 8 is a magnified representation of section "Y" from Fig. 6.

The connection of spring element 6 with connecting piece 25 in particular is shown in Fig. 7. This is connected to electrical measuring conductor 27, which is fastened on its end opposite spring element 6 at a fixed point 25 of housing 19 of linear control device 18. Corresponding connecting wires are connected to the electrical measuring conductor 27 via soldering points 33 and 34, which lead to a bridge circuit 14, see Fig. 5.

According to the equation, in particular, it is possible to measure a linear motion of a moving object 2 in a simple and economic way. The measurement takes place as a result of the fact that a retaining force is exerted by a spring element 6 during motion of moving object 2. Of course this is so small that it does not hinder, or only slightly hinders the desired motion of moving object 2. The retaining force exerted by spring element 6 is transferred to an electrical conductor as a force-measuring device 7. The electrical conductor, for example, has a number of wires, the resistance value of which varies in the case of exertion of a tensile force in a longitudinal direction of the wires. The change of the resistance value is determined by a corresponding change of a voltage decreasing on the resistor, this resistance change and thus also the associative voltage change depending on the force exerted. If the force which is exerted by the spring element onto moving object 2 is determined from the resistance changes by corresponding calculations, the deflection of the spring and thus the position of moving object 2 may be determined simply from the force if the corresponding parameter (spring constant) of spring element 6 is known.

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What is claimed is:

1. A linear control device, in particular for controlling valves, throttles, or the like, in oil and/or gas production, comprising:

a control element capable of moving linearly within a housing and a linear drive device associated with the housing, wherein the control element is connected on one end with a spring element, which is connected with an end turned away from the control element with a force-measuring device, which transmits an electrical signal corresponding to a force transmitted from the spring element to the force-measuring device to an evaluating unit which determines the motion and/or position of the control element with respect to the housing.
2. The linear control devices according to claim 1, wherein the spring element is guided in a tube and expanded as the control element moves linearly within the housing.
3. The linear control devices according to claim 1, wherein the spring element is attached at first and second ends via connecting pieces to the control element and the force-measuring device.
4. A linear control device, in particular for controlling valves, throttles, or the like, in oil and/or gas production, comprising:

a control element capable of moving linearly within a housing and a linear drive device associated with the housing, wherein the control element is connected on one end with a spring element, which is connected with an end turned away from the control element with a force-measuring device, which transmits an electrical signal corresponding to a force transmitted from the spring element to the force-measuring device to an evaluating unit, wherein at least the connecting piece has a rotation decoupling device to an evaluation unit, wherein at least the connecting piece has a rotation decoupling device between the spring element and the control element.
5. The linear control device according to claim 1 wherein the force-measuring device has at least one electrical conductor with electrical resistance which is dependent on a force exerted onto a conductor.
6. The linear control device according to claim 1 wherein the electrical conductor is connected as a resistor in a bridge circuit.
7. The linear control device according to claim 1 wherein the electrical conductor has a number of conductor wires arranged in parallel.

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8. A linear control devices, in particular for controlling valves, throttles, or the like, in oil and/or gas production, comprising:

a control element capable of moving linearly within a housing and a linear drive device associated with the housing, wherein the control element is connected on one end with a spring element, which is connected with an end turned away from the control element with a force-measuring device, which transmits an electrical signal corresponding to a force transmitted from the spring element to the force-measuring device to an evaluating unit, and wherein an electrical conductor is connected without the action of force in bridge circuit at least for temperature compensation.
9. An apparatus for actuator-controlled valve operation comprising:

a linear drive device selectively moving an operating element;

a path-measuring device connected to the operating element;

the path-measuring device including a spring and a force-measuring device;

the spring having one end connected to the operating element and another end connected to the force-measuring device; and

the force-measuring device measuring the force placed on the spring by the operating element as the linear drive device moves the operating element.
10. The apparatus of claim 9 wherein the linear drive device includes a tube housing the spring.
11. The apparatus of claim 9 wherein the force-measuring device includes an electrical measuring conductor.
12. The apparatus of claim 9 wherein the force-measuring device converts the force on the spring to a corresponding voltage.
13. The apparatus of claim 12 wherein the electrical measuring conductor includes one or more wires having a resistance value which varies with the exertion of a tensile force by the operating element on the spring.
14. The apparatus of claim 13 wherein the change of the resistance value is determined by a corresponding change of a voltage decreasing on the resistor, the resistance change and also the voltage change depending on the force exerted.

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15. The apparatus of claim 9 wherein the spring is connected to the operating element by a rotation decoupling device.
16. The apparatus of claim 9 wherein the operating element exerts a retaining force on the spring.