FI000127477B

SUOMI – FINLAND
(FI)

PATENTTI- JA REKISTERIHALLITUS
PATENT- OCH REGISTERSTYRELSEN

(12) **PATENTTIJULKAISU**
PATENTSKRIFT

(10) **FI 127477 B**

(45) Patentti myönnetty - Patent beviljats **29.06.2018**

(51) Kv.lk. - Int.kl.

G01D 5/347 (2006.01)
G01B 11/02 (2006.01)
G06K 9/18 (2006.01)

(21) Patenttihakemus - Patentansökning **20175374**

(22) Saapumispäivä - Ankomstdag **27.04.2017**

(24) Tekemispäivä - Ingivningsdag **27.04.2017**

(41) Tullut julkiseksi - Blivit offentlig **29.06.2018**

(73) Haltija - Innehavare

1 •Mikronix Oy, Aapistie 1, 90220 OULU, SUOMI - FINLAND, (FI)

(72) Keksijä - Uppfinnare

1 •STENMAN, Edward, VAASA, SUOMI - FINLAND, (FI)

(74) Asiamies - Ombud

Berggren Oy, Isokatu 32, 90100 Oulu

(54) Keksinnön nimitys - Uppfinningens benämning

LIIKKEENMITTAUSJÄRJESTELY
ARRANGEMANG FÖR MÄTERING RÖRELSE
ARRANGEMENT FOR MEASURING MOVEMENT

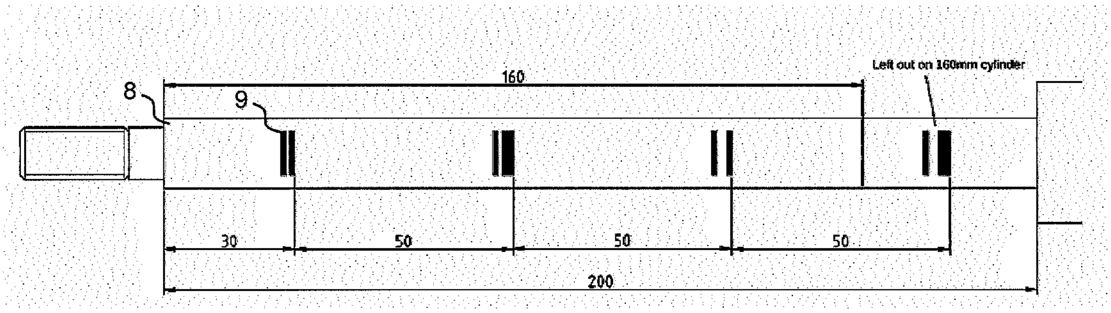
(56) Viitejulkaisut - Anförda publikationer

US 4901073 A, US 2002/0111766 A1, WO 00/77472 A1, EP 2560127 A2

(57) Tiivistelmä - Sammandrag

The present invention discloses a position determination method and arrangement for a movable element (8) in relation to a stationary element. The invention applies markings (9) on the movable element (8) which are formulated as bar codes in uniform or non-uniform intervals along a bar- or cylinder-shaped movable element (8). The coding uses at least two bars and spacings between the bars, and both the bars and spacings may have a wide or a thin width. By comparing the widths of the parts and also incorporating halving of a part into the calculations, the arrangement is able to define a bit sequence for a sensed marking (9). The markings (9) may be arranged in a rising natural number fashion. When the sensed symbols behind the markings (9), the intervals between the markings and lengths of each marking are known, accurate positioning along the movable element (8) is obtained. In one embodiment, the wider part is 2,5 times wider than the thin part. The optical sensor (3) may apply incremental tracking in determining the characteristics of the sensed image when the movable element (8) moves in view to the stationary element. Application areas comprise e.g. hydraulic and pneumatic cylinders in general, industrial machines, vehicular applications, and furthermore, health, rehabilitation and gym devices for various users and patients.

Esillä oleva keksintö esittää menetelmän ja järjestelyn liikkuvan osan (8) paikan määrittämiseksi paikallaan olevan osan suhteen. Keksinnössä käytetään hyväksi liikkuvassa osassa (8) olevia merkintöjä (9), jotka on muodostettu viivakoodeiksi yhtenäisin tai epäyhtenäisin välein tangon tai lieriön muotoiseen liikkuvaan osaan (8). Koodauksessa käytetään ainakin kahta viivaa ja viivojen välissä olevaa tilaa, ja sekä viivat että välitilat voivat olla leveydeltään leveitä tai kapeita. Vertaamalla osien leveyksiä ja sisällyttämällä laskelmiin myös osien puolittaminen järjestelyssä voidaan määrittää havaitun merkinnän (9) bittisekvenssi. Merkinnät (9) voi olla järjestetty luonnollisten lukujen tapaan nousevasti. Kun merkintöjä (9) vastaavat havaitut symbolit, merkintöjen väliset etäisyydet ja kunkin merkinnän pituus tunnetaan, saadaan tarkka paikka liikkuvaa osaa (8) pitkin. Eräässä suoritusmuodossa leveämpi osa on 2,5 kertaa leveämpi kuin kapea osa. Optinen anturi (3) voi käyttää asteittaista seurantaa havaitun kuvan ominaisuuksien määrittämiseen, kun liikkuva osa (8) liikkuu paikallaan olevaan osaan nähden. Sovellusalueita ovat esimerkiksi hydrauli- ja paineilmasylinterit yleisesti, teolliset koneet, ajoneuvosovellukset, ja lisäksi hoito-, kuntoutus- ja kuntosalivälineet erilaisille käyttäjille ja potilaille.



Arrangement for measuring movement

Field of the invention

The present invention relates to tracking and measuring movement in a piston-type arrangement present in many applications, such as in heavy machinery, tractors, and industrial machines, for instance.

Background of the invention

There are various different ways for tracking and measuring the location of a given movable or fixed element in a single direction or to measure the movement status or speed along that direction. Accelerometers are a type of the possible device which is able to determine the speed or rotational movement based on acceleration affecting the element.

One type of measuring the presence or non-presence of an element in a given spot and thus, also the movement of an element, is to use several reflection-type transmission-reception elements. When the transmitted signal (e.g. light) reflects from an element by e.g. measuring the propagation time until the reflected signal is received, it is possible to determine whether the signal has reflected from a given surface or not (in case the surface of the element is movable in a non-parallel direction to the transmitted signal, for instance).

Optical arrangements may be used in general for tracking a location even for a more complex movement than just within a single direction. These arrangements can be called camera-based optical navigation sensors. One example of tracking the location and movement within a two-dimension flat horizontal surface is implemented in a traditional optical mouse used in connection with a regular PC. It uses a light source, such as a light emitting diode (LED), and a light detector in a form of photodetectors. Also a laser diode, which emits infrared (IR) light, can be used. The sensor system generally comprises a low resolution camera, the light source, some simple optics and a controller. The principle of the optical mouse is to take 1000 or even more images (e.g. up to 12000 frames) per second from the underlining surface and to analyze each pair of subsequent images with cross-correlation on how much offset two subsequent images have with one another in two dimensions. The speed of movement in X/Y coordinates is thus achieved, and it can be interpreted and shown as a moving cursor on a screen.

20175374 PRH 09 -02- 2018

A product called “Intellinder, an absolute position sensor” by Parker Hannifin Corp. (later called as “Parker’s Intellinder”), is a movement detector in a single direction having a single movable rod and a certain type of coding on the surface of the rod. This product is also published as a patent application publication US 2013/0319224 (“Hartzell”). The rod moves within a cylinder and a sensor is mounted to the side of the cylinder for reading the coding. It seems that the Parker’s Intellinder may use four different widths in the coding bars where the coding bars are each marked directly on the whole outer circumference of the rod. The position of the rod is communicated continually to the controller. Many applications are discussed, such as forklifts, forestry vehicles, gantry cranes, trucks or tractors (lift or tilt cylinders) or in door systems. According to the information available from the Parker’s Intellinder, it uses a camera (optical sensor “30”) and a bar where the latter is applied in “Kilpinen” (US 5,539,993) as well.

Patent publication “Kilpinen” (US 5,539,993 by Partek Cargotec Oy) discloses an optical reading sensor for reading a location scale. Kilpinen applies bar coding, where there are two different bar widths. Other vertical edge of the subsequent bars seems to locate in places with fixed distance gaps. In an embodiment, the above fixed distance gap is three units of length, the width of the thicker bar is two units of length and the narrower bar has a width of one unit of length. A disadvantage of Kilpinen is that it requires heavy processing power for the image recognition performed by the camera. This results in an expensive solution. The same applies for the Parker’s Intellinder as well where a same type of bar is used. As a further disadvantage, both Hartzell and Kilpinen require that the whole length of the rod has the markings. Also, the marking length is a fixed one. Furthermore, for longer marking lengths, the sensor needs to be a longer one as well in Kilpinen (many light receivers with different detection areas). This makes the size of the sensor hard to be fit in a regular cylinder used in industrial applications.

Patent publication “Norcross” (US 6,327,791) discusses a chain code on a rod or cylinder type of a movable member which is applicable in hydraulic cylinders, gantry cranes, drawbridges, canal locks, elevators, conveyer belt systems, systems with robotics, computer controlled painting devices and shock absorbers for cars. The bar code can be manufactured on the member by laser photo absorption, or by etching on an aluminum surface. The bar code may have four different types (bar code, line bar code, binary code, gapped binary code) and the detector detects a part of the code in one instant and possibly the whole code during the movement of the member. A signal is created based on the detected code.

20175374 PRH 09 -02- 2018

German publication “Leuze”, DE 10014194 (by Leuze Electronic GmbH) discloses a piston rod position determination arrangement where the rod surface has an alternating pattern comprising black lines. The markings are scanned with an optical transmitter beam as the piston moves, through the reflected light. The black parts are interpreted as “1” and white parts as “0”, and based on these values, a binary valued voltage signal U1 is obtained. U2 is obtained by delaying U1 by the propagation time spent along the width of the thinner line.

The prior art has the following additional problems. Reed switches do not work properly with the hydraulic cylinders because the piston would require a magnet and it would not work properly with an iron-made cylinder tube. Furthermore, reed switches output just an on/off-kind of data, suitable e.g. as a proximity switch for a burglar alarm; i.e. the position data information is obtained for a singular location only. This means that reed switches are not well suited for situations where continuous position data is required.

Summary of the invention

The present invention discloses an arrangement for measuring a position of a movable element in relation to a stationary element or surface, wherein the arrangement comprises:

– a sensor for sensing optically a section of a surface of a movable element; and

– a microcontroller configured to control the arrangement, and to save obtained measurement results, and to send forward obtained information at least partially.

The present invention is characterized in that the arrangement further comprises

– at least one optically visible marking on or in the movable element, where each marking comprises a bar code wherein each different bar code corresponds to a dedicated symbol;

– the microcontroller configured to determine the symbol from the optically sensed bar code; and

– the microcontroller is configured to determine a position of the movable element in view of the sensor by taking the determined symbol and/or incremental movement data between the markings into account.

20175374 PRH 09 -02- 2018

In an embodiment of the invention, the width of the each marking is taken into account in the position determination.

In an embodiment of the invention, a single bar code comprises thin bars, wide bars, thin spacings and/or wide spacings between the bars, as parts of the bar code.

In an embodiment of the invention, a bar code represents a 3-bit symbol where two bars and a single spacing each correspond to a bit in a consequential fashion.

In an embodiment of the invention, the wide part corresponds to bit “1” and a thin part corresponds to bit “0”.

In an embodiment of the invention, a bar code represents a 5-bit symbol where three bars and two spacings each correspond to a bit in a consequential fashion.

In an embodiment of the invention, in case all the sensed parts are of equal width, the symbol is determined to be all zeros.

In an embodiment of the invention, the markings are manufactured on the movable element by etching or laser carving.

In an embodiment of the invention, all markings are manufactured on the movable element with uniform spaces between subsequent markings.

In an embodiment of the invention, the wider part is over two times wider than the thinner part.

In an embodiment of the invention, in the microcontroller, it is configured to compare subsequent parts of the marking and if a width ratio of a first part and a second part is over 1, and a width ratio of a halved first part with a second part is also over 1, it is determined that the first part is “1” and the second part is “0”.

In an embodiment of the invention, in the microcontroller, it is configured to compare subsequent parts of the marking and if a width ratio of a first part and a second part is over 1, and a width ratio of a halved first part with a second part is less than 1, it is determined that the first part and the second part have same bit values.

In an embodiment of the invention, the sensor is configured to optically take a first image of an area on the surface of the movable element, then to take a second

20175374 PRH 09 -02- 2018

image after a given period of time and after a possible movement of the movable element in relation to the sensor, then to compare locations of the components visible in both taken images, and the microcontroller is configured to obtain a movement speed for the movable element based on the obtained change of the location of the components.

In an embodiment of the invention, the microcontroller is configured to calculate a reference location point at the start or end of each sensed marking, and to calculate a position of the movable element in relation to the previously calculated reference location point.

In an embodiment of the invention, the arrangement is configured to automatically change the shutter speed after every sampled image has been taken, in order to compensate different lighting conditions, and shiny and black areas on the surface of the movable element.

In an embodiment of the invention, in case where accurate positioning is required in a given range of the movable or stationary element, the markings are configured to be manufactured in relatively thick intervals along the given range of the movable or stationary element.

The inventive idea also comprises a use of an arrangement for measuring a position of a movable element in relation to a stationary element or surface, corresponding to the above arrangement. The use is characterized in that the arrangement is applied in hydraulic or pneumatic cylinders, industrial machines, vehicles, robotic arms, training devices, in medical or rehabilitation testing devices or in academic testing devices.

The inventive idea also comprises a corresponding method for measuring a position of a movable element in relation to a stationary element or surface, wherein the method comprises the steps of

– sensing optically a section of a surface of a movable element by a sensor; and

– controlling the measurement steps and saving obtained measurement results and sending forward obtained information at least partially by a microcontroller.

The method is characterized in that

– at least one optically visible marking has been manufactured on or in the movable element, where each marking comprises a bar code wherein each different bar code corresponds to a dedicated symbol;

wherein the method further comprises the steps of

– determining the symbol from the optically sensed bar code by the microcontroller; and

– determining a position of the movable element in view of the sensor by the microcontroller by taking the determined symbol and/or incremental movement data between the markings into account.

Brief description of the drawings

Figure 1a illustrates the sensor mounted on a cylinder with etched markings, as a photograph showing an embodiment of the product,

Figure 1b illustrates a close-up of the etched markings shown in Figure 1a,

Figure 2 illustrates an example illustrating certain bar code markings and their dimensions along a cylinder,

Figure 3 illustrates a coding system example represented with two vertical bars (left column), and another coding system example represented with three vertical bars (two right-most columns),

Figure 4a illustrates an example of the possible dimensions applicable in the bar codes, in this example for the symbol representing “4”,

Figure 4b illustrates an example of a mark, which is a two-bar marking representing “1”, showing also some characteristics of the marking used in the determination logic of the symbol, and

Figure 5 illustrates a cylinder integrated sensor in an embodiment of the arrangement.

Detailed description of the invention

The present invention introduces a position tracking sensor for various different applications, uses and devices. For instance, such a sensor can be applied in hydraulic or pneumatic cylinders usable in strength training devices, gym devices or

20175374 PRH 09 -02- 2018

medical testing devices, or in academic testing environments. The sensor can also be applied in industrial manufacturing environments, or in vehicles or working tools, such as in robotic arms, in tractors, or in pneumatic lifts, for instance. Basically the position tracking sensor is applicable in any environment where a physical member is movable in a single direction in reference to another member or fixed structure.

The present invention applies markings which are visible on the movable element. The markings can be manufactured with many various methods and examples of these are the laser engraved markings and markings made with etching. One physical aspect of the markings is that the marking itself should not increase the gasket wear or make any audible sounds in the situation where the rod slides against the gasket. An embodiment showing an etched cylinder is illustrated in Figure 1a and a close-up of the marking is illustrated in Figure 1b. Laser marking is a highly useful way to perform the markings on the cylinder because the surface smoothness will not suffer after the laser marking has been added. Laser carving will make a deep color change in the metal surface, and therefore it will not wear off in regular use situations of the moving cylinder.

As a single parameter selection option, the laser carvings can be made with a fiber laser source having a wavelength of 1062 nm, power selection of 70 % of the available maximum, the input power of the laser source is 1 kW at its maximum and the marking speed obtained with this device is about 3000 mm/s. It is emphasized that this is merely a single example, and also many other parameter values of the laser source can be found useful in the context of the present application.

The position tracking sensor applies certain kinds of coding in the preferred embodiment of the present invention. For detecting multiple positions along a rod or cylinder, a specific barcode is applied in these multiple positions along the rod or cylinder in an embodiment of the invention.

An example illustrating certain bar code markings along a cylinder is shown in Figure 2. The markings 9 can be manufactured on the cylinder or rod 8 with uniform spaces between one another. In the illustrated example, the distance between markings 9 is 50 mm but it is notable that all values in Figure 2 show just a single embodiment of the invention. The example shows a total cylinder 8 length of 200 mm with four different bar code markings 9 along this length, and an option of having a shorter cylinder length of 160 mm with first three markings 9. Still, even a non-uniform space profile is possible between the applied markings 9. For instance in situations, where an end of the range of the movement needs to be more accurately sensed, it would be useful to have markings 9 with thicker spaces in another end of the cylinder 8, than near the opposite end of the cylinder 8. As a summary, Figure 2 applies a certain pattern of bar codes where the markings 9 represent numbers “0, 1, 2, 3” in their running order, in this example.

Furthermore, Figure 3 illustrates an example of a possible bar code system which may apply either two bars or three bars. A single bar code corresponds to a single marking 9. Thus, eighteen markings 9 are shown in Figure 3 illustrating the logic behind the coding in this embodiment of the invention. The two-bar system is shown in the column on the left, while the three-bar system is shown in the two rightmost columns of Figure 3. The two-bar coding system can define seven different symbols which can be named as natural numbers in their running order, as [0, 1, 2, 3, 4, 5, 6], for instance. The bar widths are here constructed so that the maximum width of a single symbol (“6”) is six units of length in this embodiment of the bar code system.

In the three-bar coding system example on the right-hand side of Figure 3, there are 31 possible symbols which can be used in the coding along the cylinder or rod. In Figure 3, these are marked as symbols [0, 1, 2, ..., 9, ..., 30]. In this embodiment, the largest space required for a single symbol is for the last symbol “30”, whose width is selected to be eleven units of length.

An example of the possible dimensions applicable in the bar codes is shown in Figure 4a. This illustration shows a two-bar marking 9 and some selected widths and other dimensions in one embodiment of the coding used in the present invention. This corresponds to the symbol “4” in the two-bar coding example above in Figure 3. The wider bar may have a width of 2,5 units of length and the narrower bar has a width of 1 (one) unit of length. The spacing within a single marking 9, between the two bars is also 1 (one) unit of length. The space from the left edge of the marking 9 to a previous marking (the right edge of the previous marking) is 2,5 units of length.

In an embodiment of the invention, the above factor 2,5 can be replaced with some other value which is larger than 2,5.

When detecting a symbol along the surface of the cylinder, the width of the bar can be measured by measuring the movement from when the shutter value has passed a predefined threshold until it returns to normal. If there are two or more

20175374 PRH 09 -02- 2018

bars within the same symbol, the gap width between the bars can be measured in the same way.

In an embodiment of the present invention, only the ratio between wide and thin bars is fixed, and absolute width values can be selected based on the usual movement speeds present in the used application. This means that in case the cylinder moves in a rapid speed, the markings 9 have to be longer, i.e. wider, in order to detect them properly. The sensor can be used with different resolutions and with different surfaces, in addition to different movement speeds of the moving element.

In an embodiment, both bars and spacings are used to represent an odd-bit binary number for the different positions on the rod (or cylinder). Possible numbers of different codes in relation to the number of bars can be theoretically expressed with equation (1) and the maximal code length can be expressed with equation (2):

$$N_{codes} = 2^{N_{bar}*2-1} - 1 \qquad (1)$$

$$L_{max} = (N_{bar} * 2 - 2) * Ew_{thick} + Ew_{thin} \qquad (2)$$

where Ew_{thick} equals the width of the wider bar and Ew_{thin} equals the width of the thinner bar.

In the above disclosed embodiment discussing possible widths used in the markings, Ew_{thick} = 2,5 units and Ew_{thin} = 1 unit (of length).

Figure 4b shows an example of a marking 9, which is a two-bar marking representing “1”, as in Figure 3 (second marking from the top). The decoding of the marking 9 is now explained. In this embodiment, the code is supposed to move from right to left under the sensor, and the controller of the sensing system is aware that each code has only two bars and the direction of movement.

At first, when the sensor encounters the start of the thin black bar (“e2” in Figure 4b), the sensor measures how long distance it has to travel until the thin bar ends. Secondly, the length of the following spacing (“e1”) will be measured. Finally, when the wide bar (“e0”) is encountered after the spacing, its length is measured as well. By length in the movement direction, we mean the horizontally directed width of the bar.

In other words, the start of the first bar is detected. The sensor measures the length along the bar until the bar ends. Then the bar width is obtained and it can be right away stored in a memory. The following spacing is measured until a start for the second bar is detected. Then, the spacing width is obtained and it can be stored in the memory. Furthermore, along the movement across the second bar, when its end (the rightmost edge) is reached, the system obtains the width of the second bar and this value is stored to the memory as well. Now the system knows the widths of all three parts of a single marking 9.

The logic in the determination of the widths of different bars and spacings is performed in one embodiment as follows. It is notable that in this embodiment, applying a similar logic as in Figure 4a, the width of “e0” is 2,5 times more than the width of “e2”. The width of “e1” is equal to the width of “e2”. The measured lengths of the first two parts “e2” and “e1” are picked, and the longer value (= wider bar or spacing) is halved. After such a division by “2”, the width of e2/2 is less than the width of e1, resulting in the decision that the width of e2 must be equal of the width of e1. The same logic applies for the parts “e1” and “e0”. The wider part of this pair of parts is e0, and this width is divided by two (i.e. halved). The width of e0/2 is bigger than the width of e1. This calculation results in the decision that e0 has to be a wide part, and the two parts before e0 (= e2 and e1) have to be thin and equally wide parts. This calculation logic is also in line with the embodiment showing the dimensions in Figure 4a. Still, some other values for the widths and spacings can still be used so that the above calculation logic still obtains the correct results.

Based on the information of obtained part widths together with the direction of movement, the system can decode the binary sequence to be “0 0 1” in this case, which in decimal system means number “1”. In other words, the thin bar or spacing represents a binary value “0” and the wide bar or spacing represents a binary value “1”. This is formulated as plain data without any preamble or checksum.

In case the above comparison logic results in the fact that all three widths are the same, the system determines that they are all zeros (“0 0 0”) because “1 1 1” is determined as not allowed in the coding system according to this embodiment. Thus, two bars and a single spacing allow a three bit representation, which further allows seven different positions (2^3–1).

In one embodiment, the width sum of the all the parts present within a single marking 9 or symbol can be used to compensate the marking width in the determination of the correct and accurate position. This means that across moving the whole rod or cylinder, the system uses a complete marking 9 as a new reference point, and when determining the travelled distance by the sensor, it takes the travelled distance between the markings 9 in the account and also the width of a single marking 9 from its left edge to its right edge. This way the correct and accurate positioning information is obtained.

The present invention can be implemented even so that the number of bits used in the coding is freely selectable; meaning that more than just two- or three-bar coding schemes can be applied in situations where a vast number of different markings 9 along a long rod is required. Alternatively, the rod does not need to be very long but the required accuracy of the movement lengths requires the markings 9 to locate very close to one another. The coding scheme may thus have N bars (either thin or wide) and “N–1” spacings (either thin or wide) between these bars. The position tracking system and its controller need to be aware of the coding scheme applied in the used application.

Figure 5 illustrates a sensor integrated within a cylinder acting with compressed air. The cylinder can be manufactured from e.g. metal or hard plastic. The same principle can alternatively be implemented with a hydraulic cylinder as well, as one possible embodiment. Figure 5 shows a vertical cross-section through the arrangement. A piston assembly 1 is shown in the left-hand side of the figure as a vertically placed object within a barrel 11, and where the piston assembly 1 is placed and fixed in an orthogonal direction with a piston rod 8. The fixing can be made with a selected fixing means such as by screw-type fastening means (as indicated in the figure). The piston rod 8 is depicted as a horizontal cylinder-shaped element which has laser engraved markings 9 (with two symbols shown) on its surface with given intervals along the piston rod 8. The optical sensor 3 locates inside the front cover 6, and it faces the surface of the piston rod 8. The optical sensor 3 is secured to the front cover 6 of the housing or frame by a lock ring 4 and by an O-ring 5. In an opposite direction of the optical sensor 3, there is an air inlet 12. Near the sensing area, i.e. between the O-ring 5 and the right-side edge of the front cover 6, there is a bushing element 10 and a rod sealing element 7. On the other side of the barrel 11, i.e. in the same side where the optical sensor 3 is located, there is a connection cable 2 connecting the sensor to a main controller of the system or to a data acquisition device. In one embodiment, the sensor may comprise a microcontroller so that these two parts of the arrangement are integrated together.

Now discussing the optical sensor 3, it is in one embodiment based on a high speed and low resolution camera. As discussed earlier, the principle of the camera is to take pictures consequentially, and to compare these pictures in the sequence in order to determine, how the current image and its characteristics are situated compared to the previous image. Based on the determined directional change, the system is able to determine how much the sensor has moved in relation to the surface locating underneath it.

The sensor system thus needs at least some pattern on the surface of the cylinder which is e.g. made from metal. In view of the camera and the sensor sensitivity, fortunately almost all applicable materials and their surfaces have such a pattern, as such, without any further action required in the surface of the cylinder, other than the symbol markings, of course. This applies even for shiny metallic piston rods.

The main principle is to output incremental movement data which is sampled in a microcontroller on the sensor itself, in one embodiment. This principle can be called as incremental tracking. The movement data can then be added to an internal variable representing the position. Furthermore or alternatively, the movement data can also be used to measure the relative speed of the surface in relation to the sensor.

In an embodiment of the invention, the sensor output data can be adjusted within a preselected range of 100 … 8200 counts per inch (or “CPI”). Because the material of the rod or cylinder can be e.g. metal, hard plastic, or ceramic substance, the surface quality can vary as well. Also the mounting distance and the individual characteristics of the sensors, the above value within the range can differ between installations. Therefore, it is beneficial to calibrate the sensor so that with a given position the sensor position information is accurately obtained, i.e. the sensor is calibrated in this regard. When the position reference point is accurately known, all the movement can be calculated in view of the obtained reference point. In practice, the error occurring in the measured position is relative to the measured length from the reference point. For instance in an example, the error can be 1 % of the measured distance from the reference point. Therefore, in practice, the absolute value of the error increases when the measured position values increase from the reference position.

In another embodiment of the invention, instead of an incremental tracking, a so-called semi-absolute tracking can be applied. This name is just derived for explaining purposes so therefore there is no accomplished meaning in this phrase. By the semi-absolute tracking we mean that there are plurality of fixed reference points, which are represented by the code bar markings. Thus, each marking is detected and when the marking is recognized, its position is marked as a reference point, such in the above incremental tracking principle discussed this matter. In the semi-absolute tracking, when the whole cylinder length with markings has been gone through, there are obtained the same number of reference points for the location as there are markings on the cylinder or the rod. Therefore, all the positional information can be measured from the previous marking and not from the starting point of the rod (i.e. left end of the rod). The positional error will then be e.g. 1 % of the distance to the previous marking which gives significantly better positional data compared to the incremental tracking method with a single reference point only. In this embodiment, the bar code markings are beneficially placed in uniform intervals along the cylindrical rod.

In an embodiment, the marking is detected and recognized the following way. The sensor chip will automatically change the shutter speed after every sampled image has been taken. This is done in order to compensate for different light conditions and in order to create a high contrast image for obtaining a better tracking performance. The shutter values corresponding to various different lighting conditions and surface characteristics of the cylindrical rod can be saved to the sensor chip. The microcontroller of the system is able to read these values and to pick the correct shutter speed value for each location to be imaged.

The shutter value can of course be a relatively low value when a shiny rod is imaged. Correspondingly, a black area requires increasing of the shutter value. The same logic applies preferably also to black areas of the bars and the spacings between the (black) bars. This makes the recognition of the bar and spacing widths more accurate and thus, more reliable.

Generally speaking regarding the cylinder with the markings, and the optical sensor, either the cylinder or the optical sensor can move while the other one is stationary. In the preferred embodiment, the cylinder with the markings moves along the axis defined by the cylinder itself, and the optical sensor in either an external fixed element, or placed e.g. on a jacket surrounding the cylinder. By the jacket we mean the external concentric element or pipe-type of a structure which surrounds the moving cylinder. The optical sensor needs to of course locate on an inner surface of such a pipe-shaped jacket structure.

There are various different application areas for the position tracking sensor according to the present invention. The absolute positioning in the hydraulic and

20175374 PRH 09 -02- 2018

pneumatic cylinders is a main application area. Further, the end dampening and stop sensors in the hydraulic cylinders can be implemented with the present invention. In this case, the present invention has a great advantage because in prior art applications, even four individual sensors have been required, one close to each end indicating when to slow down the movement and one in each end to indicate full stop. With the present invention, only a single position tracking sensor using only two markings is much more cost-effective solution for the same purpose. Furthermore, the present invention is suitable for automated vehicle use as well, e.g. for autonomous forklifts.

Also, the present invention is highly suitable for detecting intermediate exact positions in long travel machines, such as cranes, elevators, and automated warehouse systems. In many such application such as in elevator systems, there is no need to know the exact location in all the places (e.g. between the floors), but it is sufficient to know the location accurately in certain predetermined places such as the places where the elevator stops so that the elevator floor is there accurately aligned with the building floor level. In that kind of an example where the accurate positional information is more important in specific locations than elsewhere, the markings can be manufactured in the critical area or range of the moving cylinder. The markings can also be manufactured in an irregular, but relatively thick manner along a certain important range along the moving cylinder, and in less thick fashion elsewhere along the cylinder. With thickness we mean the gaps between two subsequent symbols along the cylinder; the thicker manner means smaller gaps (i.e. more symbols per absolute length unit) in this context.

Also positioning of a rotational element or equipment is possible. A further purpose for the present invention is to measure manufactured lengths of various bars, rods, sheets or otherwise shaped objects. Furthermore, two-dimensional movements are also trackable with the principle of the position tracking sensor.

In yet another embodiment of the invention, the position information from a hydraulic cylinder mounted on an excavator, when taking the excavator's geometry into account, can be used to calculate the position of the bucket in relation to the center of the excavator. This information can later be used to inform the driver about the depth of the digging. Another possible use on heavy machinery is to use the cylinder’s speed data as feedback when controlling the movements of the cylinder, thus restricting excess flow when it is not needed. This results in energy savings.

The options and advantages of the present invention are thus various. The measured position or distance information accompanied with pressure information in the cylinders allows calculating the power. The information obtained from a gym device or a rehabilitation device after the exercising session performed by the user can be also shown directly to the user and/or saved to a database. The saved information can be presented to a specialist, such as a doctor or a physiotherapist, either locally or via transferring the data to an external computer or even to a cloud service. The examination by a specialist can also be performed immediately after the exercise or afterwards by examining the saved pieces of information e.g. in a medical center. Generally, the present invention can be used e.g. in following up rehabilitation or detecting e.g. differences in strength of the left and right side muscles of the user. Furthermore, the position information of the performed movement can be used in giving feedback or instructions to the user, whether a performed movement is correctly or sufficiently performed (regarding the magnitude of the movement). This is done in order to avoid any injuries after e.g. an operation. This indication of feedback can be either visual or audible or both. Furthermore, range limiters or other kinds of physical “barriers” can be used in the actuators in order to prevent movement over a predetermined location.

While the apparatus is discussed as a first aspect of the present invention, the present invention comprises also a corresponding method and use (i.e. application areas) for the presented method and apparatus.

The present invention is not merely restricted to the embodiments presented above but the invention may vary within the scope of the claims.

Claims

1. An arrangement for measuring a position of a movable element (8) in relation to a stationary element or surface, wherein the arrangement comprises:
– a sensor (3) for sensing optically a section of a surface of a movable element (8);
– a microcontroller configured to control the arrangement, and to save obtained measurement results, and to send forward obtained information at least partially;
wherein the arrangement further comprises
– at least one optically visible marking (9) on or in the movable element (8), where each marking (9) comprises a bar code wherein each different bar code corresponds to a dedicated symbol;
– the microcontroller configured to determine the symbol from the optically sensed bar code;
– the microcontroller is configured to determine a position of the movable element (8) in view of the sensor (3) by taking the determined symbol and/or incremental movement data between the markings (9) into account; **characterized** in that
– the sensor (3) is configured to optically take a first image of an area on the surface of the movable element (8), then the sensor (3) is configured to take a second image after a given period of time and after a possible movement of the movable element (8) in relation to the sensor (3), then the microcontroller is configured to compare locations of the components visible in both taken images, and the microcontroller is configured to obtain a movement speed for the movable element (8) based on the obtained change of the location of the components.

2. The arrangement according to claim 1, **characterized** in that the width of the each marking (9) is taken into account in the position determination.

3. The arrangement according to claim 1, **characterized** in that a single bar code comprises thin bars, wide bars, thin spacings and/or wide spacings between the bars, as parts of the bar code.

4. The arrangement according to claim 3, **characterized** in that a bar code represents a 3-bit symbol where two bars and a single spacing each correspond to a bit in a consequential fashion.

5. The arrangement according to claim 3, **characterized** in that the wide part corresponds to bit “1” and a thin part corresponds to bit “0”.

20175374 PRH 09 -02- 2018

6. The arrangement according to claim 3, **characterized** in that a bar code represents a 5-bit symbol where three bars and two spacings each correspond to a bit in a consequential fashion.

7. The arrangement according to claim 3, **characterized** in that in case all the sensed parts are of equal width, the symbol is determined to be all zeros.

8. The arrangement according to claim 1, **characterized** in that the markings (9) are manufactured on the movable element (8) by etching or laser carving.

9. The arrangement according to claim 1, **characterized** in that all markings are manufactured on the movable element (8) with uniform spaces between subsequent markings.

10. The arrangement according to claim 3, **characterized** in that the wider part is over two times wider than the thinner part.

11. The arrangement according to claim 10, **characterized** in that in the microcontroller, it is configured to compare subsequent parts of the marking and if a width ratio of a first part and a second part is over 1, and a width ratio of a halved first part with a second part is also over 1, it is determined that the first part is “1” and the second part is “0”.

12. The arrangement according to claim 10, **characterized** in that in the microcontroller, it is configured to compare subsequent parts of the marking and if a width ratio of a first part and a second part is over 1, and a width ratio of a halved first part with a second part is less than 1, it is determined that the first part and the second part have same bit values.

13. The arrangement according to claim 1, **characterized** in that the microcontroller is configured to calculate a reference location point at the start or end of each sensed marking, and to calculate a position of the movable element (8) in relation to the previously calculated reference location point.

14. The arrangement according to claim 1, **characterized** in that the arrangement is configured to automatically change the shutter speed after every sampled image has been taken, in order to compensate different lighting conditions, and shiny and black areas on the surface of the movable element.

15. The arrangement according to claim 1, **characterized** in that in case where accurate positioning is required in a given range of the movable or stationary ele-

20175374 PRH 09 -02- 2018

ment, the markings (9) are configured to be manufactured in relatively thick intervals along the given range of the movable or stationary element.

16. A use for an arrangement for measuring a position of a movable element (8) in relation to a stationary element or surface according to any of the claims 1-15, **characterized** in that the arrangement is applied in hydraulic or pneumatic cylinders, industrial machines, vehicles, robotic arms, training devices, in medical or rehabilitation testing devices or in academic testing devices.

17. A method for measuring a position of a movable element (8) in relation to a stationary element or surface, wherein the method comprises the steps of
– sensing optically a section of a surface of a movable element (8) by a sensor (3);
– controlling the measurement steps and saving obtained measurement results and sending forward obtained information at least partially by a microcontroller;

– at least one optically visible marking (9) has been manufactured on or in the movable element (8), where each marking (9) comprises a bar code wherein each different bar code corresponds to a dedicated symbol;
wherein the method further comprises the steps of
– determining the symbol from the optically sensed bar code by the microcontroller;
– determining a position of the movable element (8) in view of the sensor (3) by the microcontroller by taking the determined symbol and/or incremental movement data between the markings (9) into account; **characterized** in that the method further comprises the steps of
– taking optically by the sensor (3) a first image of an area on the surface of the movable element (8), then taking by the sensor (3) a second image after a given period of time and after a possible movement of the movable element (8) in relation to the sensor (3), then comparing by the microcontroller locations of the components visible in both taken images, and obtaining by the microcontroller a movement speed for the movable element (8) based on the obtained change of the location of the components.

Patenttivaatimukset

1. Järjestely liikkuvan osan (8) paikan määrittämiseksi suhteessa paikallaan olevaan osaan tai pintaan, joka järjestely käsittää:

– anturin (3) liikkuvan osan (8) pinnan osuuden optiseen havaitsemiseen;

– mikrokontrollerin, joka on järjestetty ohjaamaan järjestelyä ja tallentamaan saadut mittaustulokset sekä lähettämään saadut tiedot eteenpäin ainakin osittain;

joka järjestelmä käsittää lisäksi

– ainakin yhden optisesti näkyvän merkinnän (9) liikkuvassa osassa (8) tai sen päällä, jolloin kukin merkintä (9) käsittää viivakoodin ja kukin erilainen viivakoodi vastaa tiettyä symbolia;

– mikrokontrollerin, joka on järjestetty määrittämään symboli optisesti havaitusta viivakoodista;

– mikrokontrolleri on järjestetty määrittämään liikkuvan osan (8) paikka anturiin (3) nähden ottamalla huomioon määritetty symboli ja/tai merkintöjen (9) väliltä kertynyt liiketieto; **tunnettu** siitä, että

– anturi (3) on järjestetty ottamaan optisesti ensimmäinen kuva liikkuvan osan (8) pinnan alueesta; tämän jälkeen anturi (3) on järjestetty ottamaan toinen kuva tietyn ajanjakson jälkeen ja liikkuvan osan (8) mahdollisen anturin (3) suhteen tapahtuneen liikkeen jälkeen; tämän jälkeen mikrokontrolleri on järjestetty vertaamaan kummassakin otetussa kuvassa näkyvien komponenttien sijainteja, ja mikrokontrolleri on järjestetty laskemaan liikkuvan osan (8) liikenopeus komponenttien sijainnissa havaitun muutoksen perusteella.

2. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että paikan määrittämisessä otetaan huomioon kunkin merkinnän (9) leveys.

3. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että yksittäinen viivakoodi käsittää viivakoodin osina ohuita viivoja, paksuja viivoja, kapeita välejä ja/tai leveitä välejä viivojen välillä.

4. Patenttivaatimuksen 3 mukainen järjestely, **tunnettu** siitä, että viivakoodi vastaa 3-bittistä symbolia, jossa peräkkäiset kaksi viivaa ja yksi väli vastaavat kukin yhtä bittiä.

5. Patenttivaatimuksen 3 mukainen järjestely, **tunnettu** siitä, että leveä osa vastaa bittiä "1" ja kapea osa vastaa bittiä "0".

6. Patenttivaatimuksen 3 mukainen järjestely, **tunnettu** siitä, että viivakoodi vastaa 5-bittistä symbolia, jossa peräkkäiset kolme viivaa ja kaksi väliä vastaavat kukin yhtä bittiä.

7. Patenttivaatimuksen 3 mukainen järjestely, **tunnettu** siitä, että jos kaikki havaitut osat ovat yhtä leveitä, symboli määritetään olevan pelkkiä nollia.

8. Patenttivaatimuksen 1 mukainen järjestely **tunnettu** siitä, että merkinnät (9) on tehty liikkuvaan osaan (8) etsaamalla tai laserkaiverruksella.

9. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että kaikki merkinnät on tehty liikkuvaan osaan (3) tasavälein peräkkäisten merkintöjen välillä.

10. Patenttivaatimuksen 3 mukainen järjestely, **tunnettu** siitä, että leveämpi osa on yli kaksi kertaa leveämpi kuin kapeampi osa.

11. Patenttivaatimuksen 10 mukainen järjestely, **tunnettu** siitä, että mikrokontrolleri on järjestetty vertaamaan merkinnän peräkkäisiä osia, ja jos ensimmäisen osan ja toisen osan välinen leveyssuhde on suurempi kuin 1 ja puolitetun ensimmäisen osan ja toisen osan välinen leveyssuhde on myös suurempi kuin 1, määritetään, että ensimmäinen osa on "1" ja toinen osa on "0".

12. Patenttivaatimuksen 10 mukainen järjestely, **tunnettu** siitä, että mikrokontrolleri on järjestetty vertaamaan merkinnän peräkkäisiä osia, ja jos ensimmäisen osan ja toisen osan leveyssuhde on suurempi kuin 1 ja puolitetun ensimmäisen osan ja toisen osan leveyssuhde on pienempi kuin 1, määritetään, että ensimmäisellä osalla ja toisella osalla on sama bittiarvo.

13. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että mikrokontrolleri on järjestetty laskemaan vertailusijaintipiste kunkin havaitun merkinnän alussa tai lopussa sekä laskemaan liikkuvan osan (8) paikka suhteessa aiemmin laskettuun vertailusijaintipisteeseen.

14. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että järjestely on järjestetty muuttamaan automaattisesti sulkimen nopeutta kunkin kuvaotoksen ottamisen jälkeen eri valaistusolosuhteiden ja liikkuvan osan pinnassa olevien kiiltävien ja mustien alueiden kompensoimiseksi.

15. Patenttivaatimuksen 1 mukainen järjestely, **tunnettu** siitä, että jos liikkuvan tai paikallaan olevan osan tietyllä alueella tarvitaan tarkkaa paikannusta, merkinnät (9)

20175374 PRH 09 -05- 2018

on järjestetty tehtäviksi suhteellisen tihein välein liikkuvan tai paikallaan olevan osan tietylle alueelle.

16. Jonkin patenttivaatimuksen 1–15 mukaisen järjestelyn, joka on tarkoitettu liikkuvan osan (8) paikan määrittämiseen suhteessa paikallaan olevaan osaan tai pintaan, käyttö, **tunnettu** siitä, että järjestelyä käytetään hydrauli- tai paineilmasylintereissä, teollisissa koneissa, ajoneuvoissa, robottikäsivarsissa, harjoitteluvälineissä, hoitoon tai kuntoutukseen liittyvissä testauslaitteissa tai yliopistotutkimukseen liittyvissä testauslaitteissa.

17. Menetelmä liikkuvan osan (8) paikan määrittämiseksi suhteessa paikallaan olevaan osaan tai pintaan, joka menetelmä käsittää vaiheet, joissa
– havaitaan liikkuvan osan (8) pinnan osuus optisesti anturilla (3);
– ohjataan mittausvaiheita ja tallennetaan saadut mittaustulokset sekä lähetetään saadut tiedot ainakin osittain eteenpäin mikrokontrollerilla;

– on tehty liikkuvaan osaan (8) tai sen päälle ainakin yksi optisesti näkyvä merkintä (9), jolloin kukin merkintä (9) käsittää viivakoodin ja kukin erilainen viivakoodi vastaa tiettyä symbolia;
joka menetelmä käsittää lisäksi vaiheet, joissa
– määritetään symboli optisesti havaitusta viivakoodista mikrokontrollerilla;
– määritetään liikkuvan osan (8) paikka anturiin (3) nähden mikrokontrollerilla ottamalla huomioon määritetty symboli ja/tai merkintöjen (9) väliltä kertynyt liiketieto;
tunnettu siitä, että menetelmä käsittää lisäksi vaiheet, joissa
– otetaan optisesti anturilla (3) ensimmäinen kuva liikkuvan osan (8) pinnan alueesta; tämän jälkeen otetaan anturilla (3) toinen kuva tietyn ajanjakson jälkeen ja liikkuvan osan (8) mahdollisen anturin (3) suhteen tapahtuneen liikkeen jälkeen; tämän jälkeen verrataan mikrokontrollerin avulla kummassakin otetussa kuvassa näkyvien komponenttien sijainteja, ja lasketaan mikrokontrollerilla liikkuvan osan (8) liikenopeus komponenttien sijainnissa havaitun muutoksen perusteella.

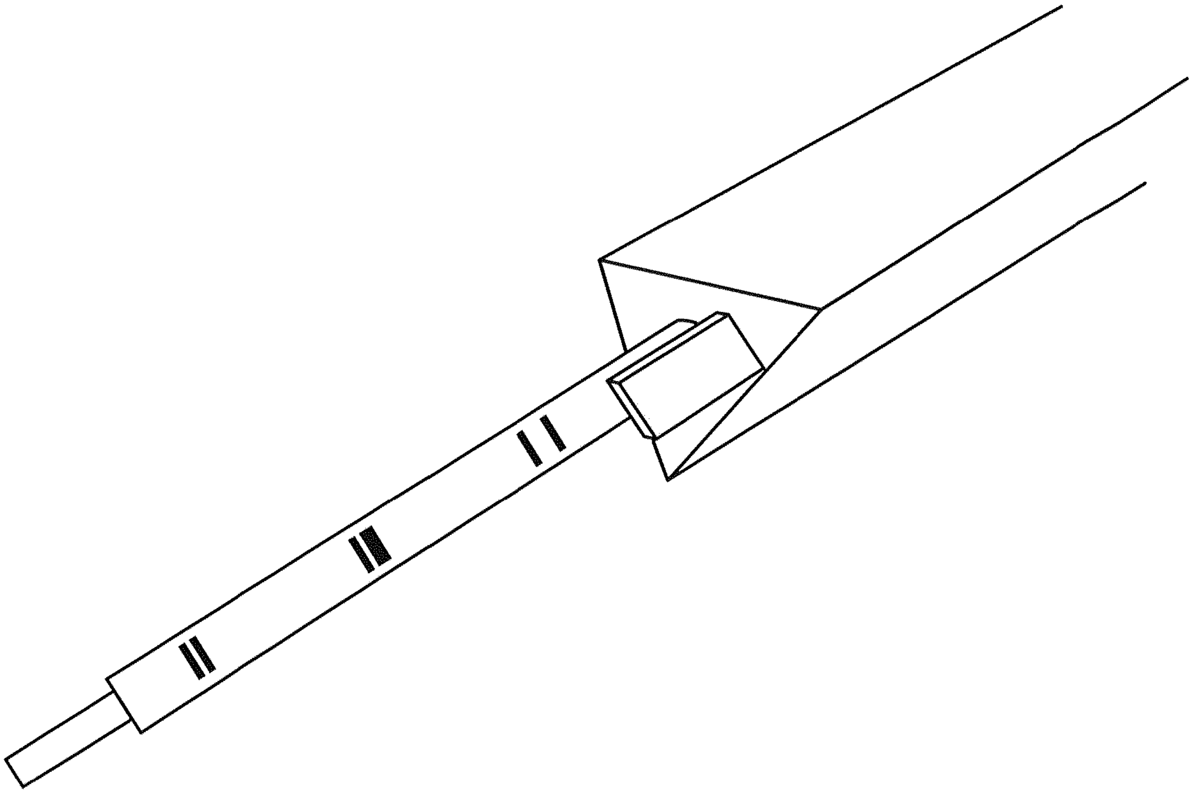


Figure 1a

20175374 PRH 09-02-2018

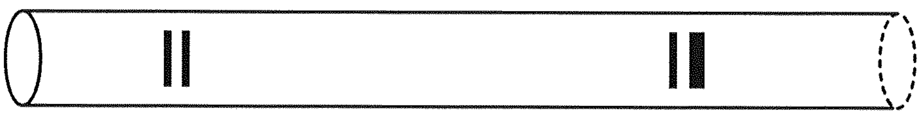


Figure 1b

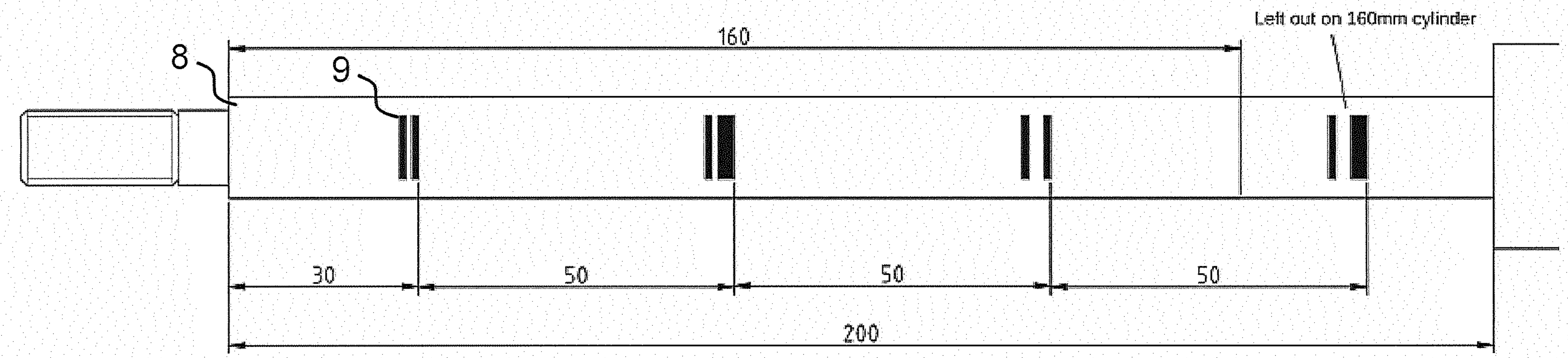


Figure 2

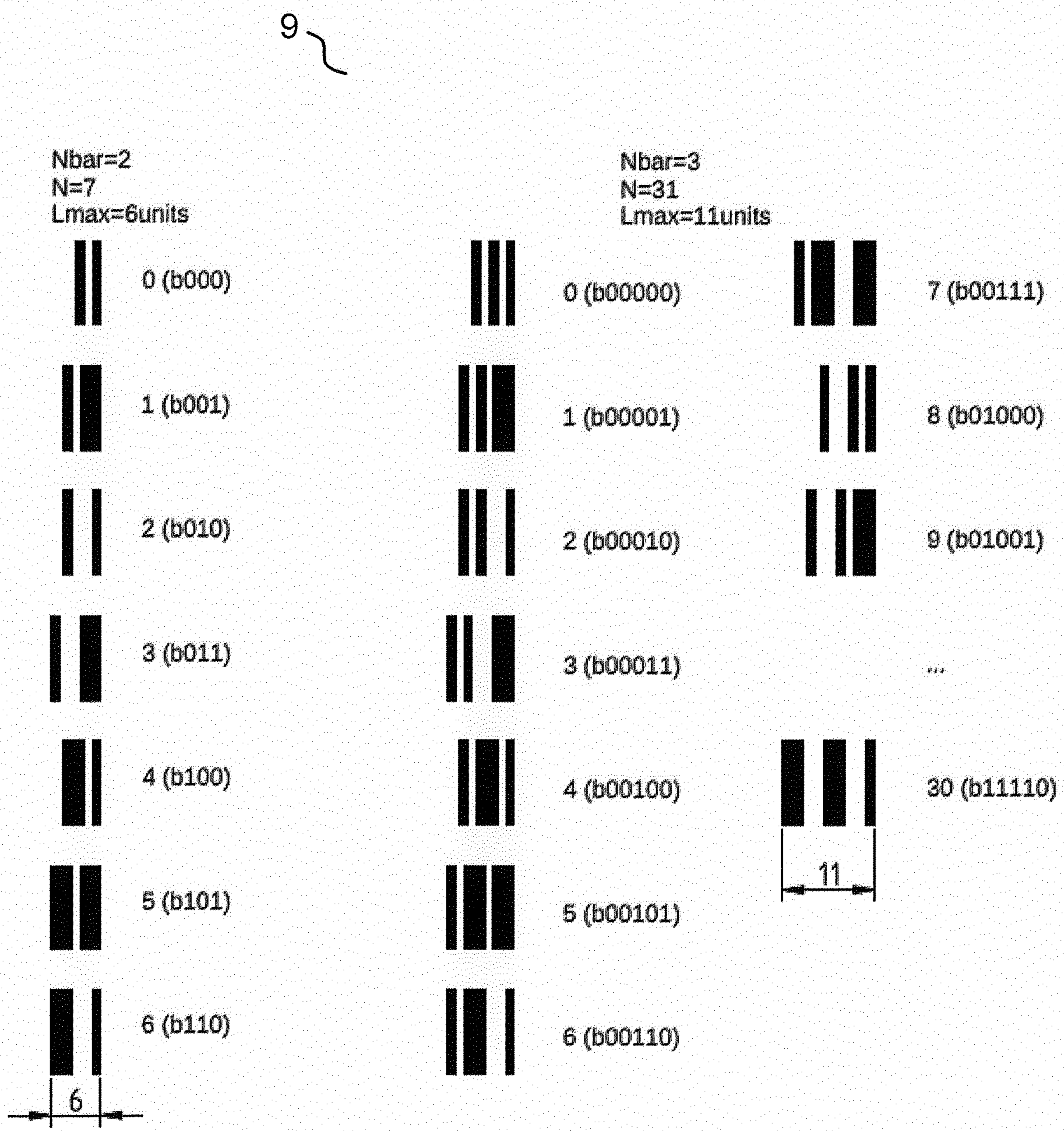


Figure 3

20175374 PRH 27 -04- 2017

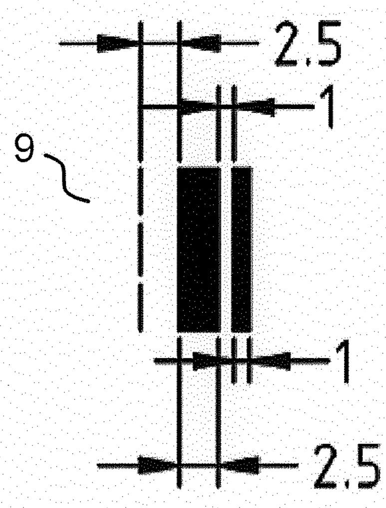


Figure 4a

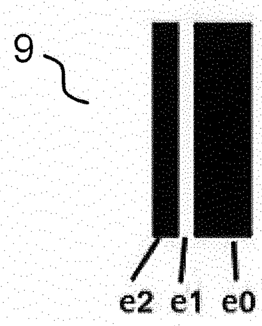


Figure 4b

20175374 PRH 27 -04- 2017

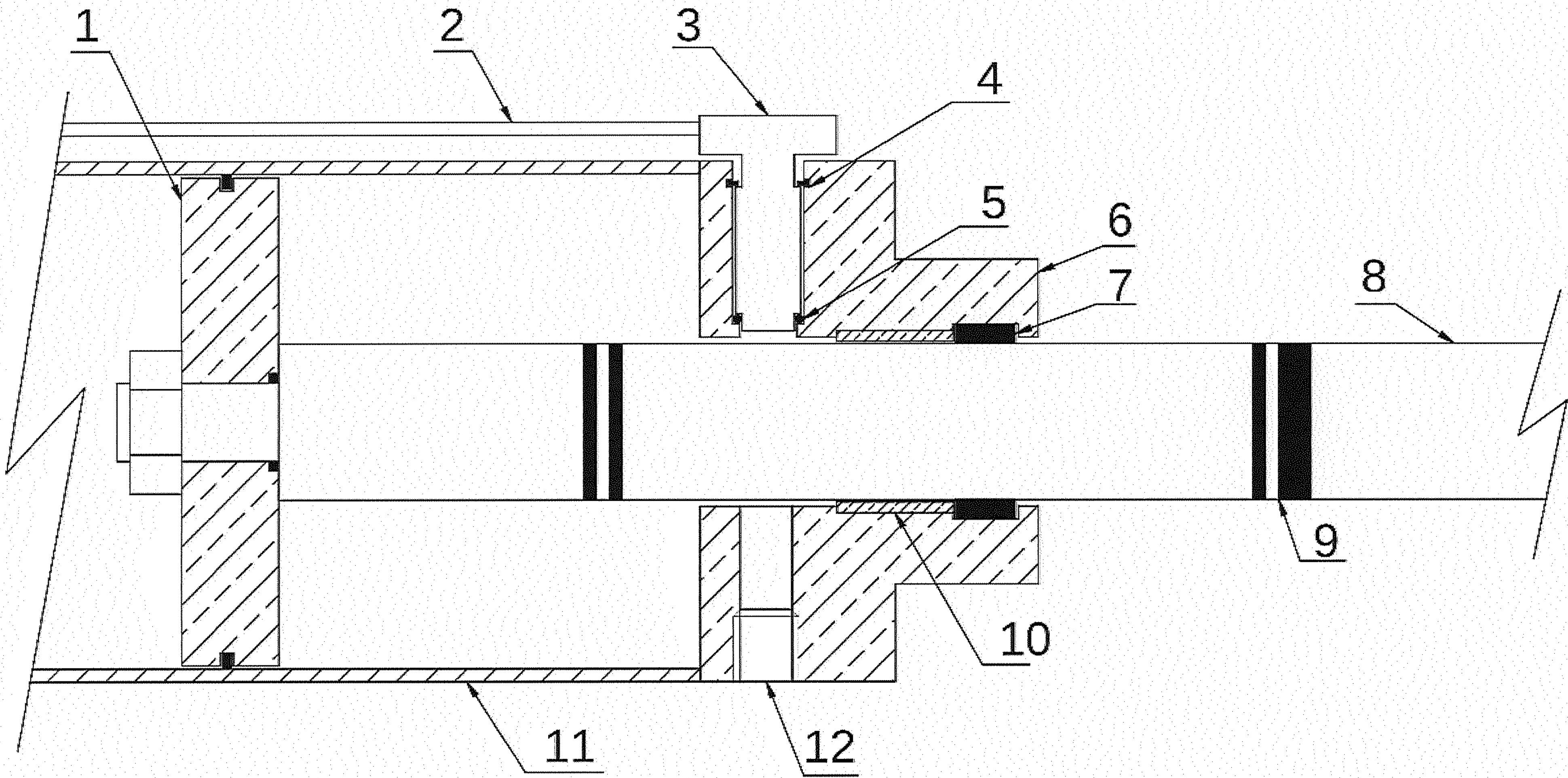


Figure 5