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(54) Title: ANGLE MEASURING DEVICE

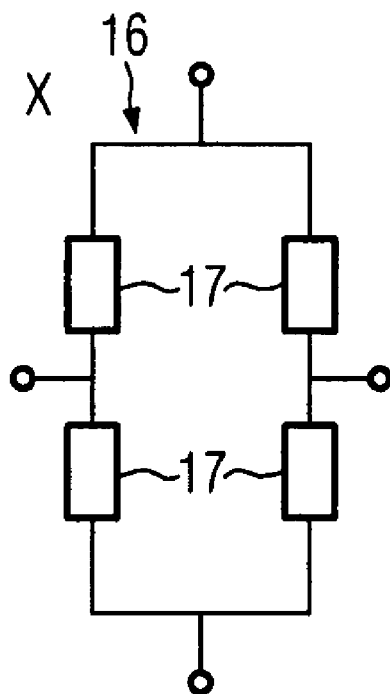


FIG. 4

(57) Abstract: An angle measuring device serves for capturing a turning position of a rotatable shut-off body (2) of a shut-off valve (3) for a duct (4) flowed through by a fluid. The shut-off body is connected to a rotary drive (5) via a shaft. A number of permanent magnets (7, 8, 9, 10) are arranged on the shaft (6). At least one magnetic field sensor (11) is assigned to the shut-off valve (6) in order to capture magnetic field vectors (12) or components of magnetic field vectors, which especially extend radially with respect to the shaft (6). Such an angle measuring device under respective conditions in the production of mineral oil/natural gas enables a respective turning position of the shut-off body with the required precision and resolution and with simple construction and low costs.

Angle Measuring Device

The invention relates to an angle measuring device for capturing a rotational position of a rotatable shut-off body. This is part of a shut-off valve for a duct through which a fluid flows. The shut-off body is connected to a rotary drive by a shaft.

- 5 Such a shut-off valve is for example a bore valve and especially a deep-sea bore valve. Such a bore valve is also called rotary valve. It has a pierced ball as shut-off-body. This is connected to for example to a lever as a rotary drive in order to be turned about 90° . Between this and the ball, a respective shaft extends. By activating the lever, the ball is respectively rotatable by 90° , wherein the hole in the bore depending on an open or closed position, respectively, is arranged
10 relatively with respect to the duct through-which a fluid flows.

Of course it is also possible that instead of a lever as a rotary drive another type of drive and likewise also a hydraulic or electric drive is applicable. In the following, especially the shaft between the rotary drive and the shut-off body is to be taken into account, to which the angle measuring device according to the invention is associated.

- 15 In such deep-sea bore valves it is further to be noticed that they are designed such that they withstand strong vibrations under a pressure of up to 300 Bar. Such bore valves are used in the production of mineral oil/natural gas, such that the corresponding duct is flowed through for example by mineral oil.

Further requirements to such a bore valve are low costs and a compact construction.

- 20 The object underlying the invention is to provide an angle measuring device, which, under the respective circumstances, enables a respective rotational position of the shut-off body with necessary precision and resolution while having a simple construction and low costs.

This object is achieved by the features of patent claim 1.

- 25 The angle measuring device according to the invention is also retroactively attachable to bore valves or other shut-off valves which are already existing. It has a number of permanent magnets which are arranged at the shaft between the rotary drive and the shut-off body. Furthermore, the angle measuring device has at least one magnetic field sensor, which is assigned to the shut-off valve in order to capture magnetic field vectors or components of magnetic field vectors which are in particular extending radially with respect to the shaft.

The respective permanent magnets are locatable directly on the shaft from the outside or are also locatable within respective recesses of the shaft. Thereby, the corresponding installation space is enlarged only slightly or not at all. By arranging the permanent magnets directly on the shaft, as the case may be also outside of a corresponding housing of the shut-off valve, the respective requirements which are put on for example a deep-sea bore valve are still fulfilled. This relates for example to the pressure resistance of up to 300 Bar, the resistance against strong vibrations and alike. Due to the arrangement of the permanent magnets on the shaft, a magnetic field extends away from the shaft and has field vectors or at least components of field vectors which are extending especially radially with respect to the shaft. Such a component of a field vector is a respective projection of a field vector towards the direction which is radial to the shaft.

These field vectors or components of field vectors may be captured by at least one magnetic field sensor and are transferrable into a rotational position of the rotatable shut-off body.

In this manner, an absolute measurement of the angle of the rotational position is possible.

It is usually not necessary that the permanent magnets extend around the entire shaft. The corresponding angle of revolution or angular position of the shut-off body amounts to generally 90° , so that for example in a measuring range of 90° plus/minus 10° or also lesser degrees is sufficient. For such a measuring range, it is also sufficient if the permanent magnets are arranged at least on a circumferential region of the shaft corresponding to such a maximum angle of rotation of the shut-off body. This means that under a maximum angle of rotation of 90° for example, an extension along a circumferential region of about a quarter of the entire circumference of the shaft is sufficient.

In order to enable a sufficient resolution and precision during a measurement of the angle of rotation, a corresponding number of permanent magnets are arranged, wherein these are especially arranged next to each other in a circumferential direction under changing polarity. The magnet field sensor is manufacturable in a simple manner and with only little installation space when it is designed as a magneto-resistive magnetic field sensor. A corresponding magneto-resistive effect occurs in ferromagnetic alloys. The electrical resistance of such an alloy depends from the angle between the direction of current and the direction of the magnetisation in the interior of the alloy. The resistance is the highest when both are in parallel and it is the smallest at 90° between such directions.

In order to make full use of this effect, the magneto-resistive magnetic field sensor may have a bridge circuit of at least magneto-resistive resistors. These may be designed in an advanta-

geous manner also as thin-film resistors. The corresponding field vectors extend through these resistors and the magnetic field in the interior of the resistors is varied by this outer magnetic field. This variation is transferred into a change of the resistance, which is measured. Through the bridge circuit, external influences of temperature or alike are decreased. The bridge circuit
5 may have further components such as coils, resistors or alike.

For a corresponding measurement of the field vectors and thereby capturing of a respective turning position, evaluation electronics with especially at least one analogue/digital converter may be assigned to the bridge circuit.

Also the possibility exists that the entire magneto-resistive magnetic field sensor is integrated
10 within a sensor chip, this means that on the sensor chip, the bridge circuit is formed of magneto-resistive resistors and also the evaluation electronics with the analogue-digital-converter are formed.

During the capturing of the field vectors, it is to be considered that systematic distortions of the field vectors may result during the corresponding radial measurement. Such distortions depend
15 on the distance of the magnetic field sensors from the magnets, the scale of the region of angles to be measured and also the field strength of the permanent magnets. At a small distance of the magnetic field sensors from the permanent magnets, distortions may reach a magnitude where a change of the measured angle per actual change in the rotational angle is very small or even tends towards zero. Consequently, small distances are disadvantageous.

However, also at a big a distance, a disadvantage arises in that the corresponding field strength
20 is very small or disturbing fields become noticeable for example because of the magnetic field of the earth.

A corresponding arrangement of the magnetic field sensors relative to the permanent magnets is called near or far field of field vectors. In order to hold the influences of both fields as small as
25 possible, preferably the magnetic field sensor is arranged in a transitional area between the near and the far field of the field vectors.

In such a transitional area also an AD-converter with a small resolution is sufficient in order to be able to determine a corresponding absolute angle from the captured analogue signal by means of the bridge circuit.

The basic magnetic field sensor may be provided as a separate component and may be at-
30 tached to the corresponding shut-off valve from the outside. In order to make a measurement possible in an easy way and without noticeable influences in this context, the magnetic field

sensor may be arranged within a housing made of material which is not magnetisable, such as especially submarine-steel. Such submarine-steel is a special type of steel which is characterised by a high strength and corrosion resistance. The corrosion resistance is especially effective with regard to sea water. In addition thereto, such a submarine-steel is also characterised by the absence of a corresponding magnetisability.

During a measurement of the angular position of the shut-off body, systematic errors may occur which may especially result from distortions of the magnetic field. This systematic error may be compensated by a data processing system. Such distortions of the field vectors may arise for example in case of a very close arrangement of the magnetic field sensor and the magnets.

10 In the following, an advantageous embodiment of the invention is described in detail on the basis of the attached figures.

In the figures:

Fig. 1: shows a longitudinal section through a deep-sea ball valve as a shut-off valve in the open and closed state.

15 Fig. 2: shows principle sketch of an angle measuring device according to the present invention;

Fig. 3: shows a diagram for illustrating an error function based on field vector distortions, and

20 Fig. 4: shows a further principle sketch of an angle measuring device according to the present invention with a detailed illustration of the magnetic field sensor.

Fig. 1 shows a longitudinal section through a shut-off valve 3 in the form of a deep-sea ball valve. In the upper part of Fig. 1, the shut-off valve 3 with its shut-off body 2 is shown in an open position 22 and in the lower part in closed position 23. The corresponding shut-off body is a pierced ball which is rotatable essentially about 90° by means of the assigned rotary drive 5 of the shut-off valve 3 and is supported in a corresponding duct 4 which is flowed through by a fluid. Via a shaft 6, the shut-off body 2 is connected to the rotary drive. The corresponding angle of rotation 14 is illustrated in principle in Fig. 1, wherein this corresponds to a rotation of the shut-off body 2 between the open position 22 and the closed position 23. Other rotary drives 5 are possible, which may also be driven hydraulically or electrically.

In Fig. 2, a principle illustration of an angle measuring device 1 according to the present invention is shown. This comprises at least a row of permanent magnets 7, 8, 9 and 10 as well as magnetic field sensor 11. Through the permanent magnets 7 to 10, field vectors 12 result, which, in the illustration according to Fig 2., are especially directed radially from the annularly arranged permanent magnets 7 to 10 towards the outside. There, they are capturable by the magnetic field sensor 11.

An actual arrangement of the permanent magnets 7 to 10 on the shaft 6 is shown in Fig. 4. Only a part of the shaft 6 is illustrated. The corresponding permanent magnets 7 to 10 are arrangeable on the outside of the shaft or likewise in recesses of the shaft. The permanent magnets 7 to 10 extend about a circumferential region 13 along the outside of the shaft 6. This circumferential region 13 corresponds to at least the maximum angle of rotation; see angle of rotation 14 according to Fig. 1. Furthermore, the permanent magnets 7 to 10 are arranged directly next to each other under a changing polarity. The arrangement and number of the permanent magnets is only exemplary and also higher numbers of permanent magnets may be provided. The arrangement is made especially in circumferential direction, wherein the magnetic field sensor 11 is assigned to the corresponding location of the shaft 6 along which the permanent magnets 7 to 10 are arranged. This is, according to Fig. 4, included in a separate housing 21 made of non-magnetisable steel. Thereby, the field vectors originating at the permanent magnets are not influenced by the material of the housing 21. Such a material is submarine-steel for example.

Evaluation electronics 18 are assigned to the magnetic field sensor 11, which evaluation electronics may be integrated into a sensor chip 20 together with the magnetic field sensor. An analogue/digital converter 19 is part of the evaluation electronics 18.

The magnetic field sensor is usually realised by means of a bridge circuit 16, see detail X from Fig. 4, wherein within this bridge circuit 16 four magneto-resistive resistors 17 may be arranged.

In Fig. 3, an error function on the basis of distortions of the field vectors during measuring of the angular position of the shut-off body is illustrated as an example. On the vertical axis, the angular errors and on the horizontal axis, the absolute angular positions are illustrated. The dotted line corresponds to the distance of the magnetic field sensor 11 from the permanent magnet of 10 mm for example, while the dashed curve in the manner of a line corresponds to a distance of 40 mm.

In a very close arrangement of the magnetic field sensor and the magnets, distortions of the field vectors may arise, which affect that changes of the measured angle per actual angular step are very small or even tend to go towards zero. Thereby, the error in the measurement of the

angle is relatively big in certain regions, see the amplitudes of the diagram up to 10 or more degrees.

At a bigger distance, the error may become smaller indeed, but also the magnetic field, so that the disturbing fields such as the magnetic field of the earth may become perceivable, see the dashed curve appearing like a line according to Fig. 3. An optimal position of the magnetic field sensors with respect to the permanent magnets results from a transitional area between the near field and the far field of the field vectors, see the drawn-through line according to Fig. 3.

Due to the invention, an angle measuring device results in which a radial measurement of the corresponding angular position of the shut-off body at the shut-off valve 3 is possible. The angle measuring device does not have moving parts and is therefore free from wear as well as maintenance-free. The measurement generally takes place in a contact-free manner, wherein it is measurable through the corresponding housing of the magnetic field sensor. The housing is also suitable for inhospitable environments, see for example deep-sea and high pressures. As a result of the arrangement of the permanent magnets and the assignment of the magnetic field sensor, an absolute measuring principle is at hand, in which no reference point or a reference run for measuring the angle of rotation is required. Furthermore, a high resolution and high precision is given in the entire measurement range and only a small installation space is required.

It is again pointed out that the corresponding direction of the lines of the magnetic fields is measured with the angle measuring device according to the present invention, wherein the direction extends essentially radially with respect to the corresponding shaft, a turning position of which and thereby the respective position of the shut-off body is detected.

Claims

1. Angle measuring device (1) for capturing a turning position of a rotatable shut-off body (2) of a shut-off valve (3) for a duct (4) flowed through by a fluid, which shut-off body (2) is connected to a rotary drive (5) via a shaft (6), wherein a number of permanent magnets (7, 8, 9 and 10) is arranged at the shaft (6) and at least one magnetic field sensor (11) for capturing magnetic field vectors (12) or components of magnetic field vectors especially extending radially with respect to the shaft (6) is assigned to the shut-off valve (3).
5
2. Angle measuring device (1) according to claim 1, **characterised in that** the permanent magnets (7 to 10) are arranged at least along a circumferential region (13) of the shaft (6), which circumferential region (13) corresponds to a maximum angle of rotation (14) of the shut-off body (2).
10
3. Angle measuring device (1) according to claim 1 or 2, **characterised in that** the permanent magnets (7 to 10) are arranged in the circumferential direction (5, 15) of the shaft (6) next to each other under changing polarity.
15
4. Angle measuring device (1) according to one of the preceding claims, **characterised in that** the magnetic field sensor (11) is designed as a magneto-resistive magnetic field sensor.
5. Angle measuring device (1) according to one of the preceding claims, **characterised in that** the magneto-resistive magnetic field sensor (11) has a half or full bridge circuit (16) of at least magneto-resistive resistors (17).
20
6. Angle measuring device (1) according to one of the preceding claims, **characterised in that** evaluation electronics (18) with especially at least one analogue/digital converter (19) are assigned to the bridge circuit (16).
- 25 7. Angle measuring device (1) according to one of the preceding claims, **characterised in that** the magneto-resistive magnetic field sensor (11) is integrated into a sensor chip (20).
8. Angle measuring device (1) according to one of the preceding claims, **characterised in that** the magnetic field sensor (11) is arranged in a transitional region between a near
30 and a far field of the field vectors.

9. Angle measuring device (1) according to one of the preceding claims, **characterised in that** the magnetic field sensor (11) is arranged within a housing (21) made of non-magnetisable material, especially of submarine-steel.
 10. Angle measuring device (1) according to one of the preceding claims, **characterised in that** a remaining systematic error due to distortions of the magnetic field is compensatable by means of a data processing system.
- 5

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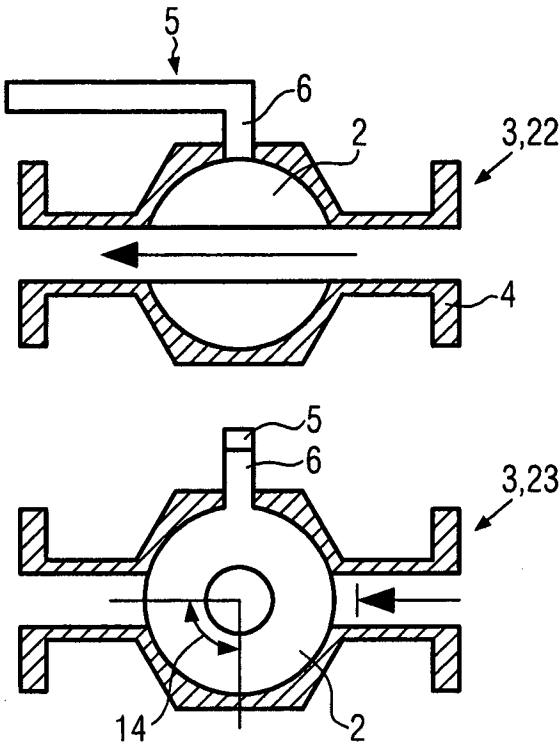


FIG. 1

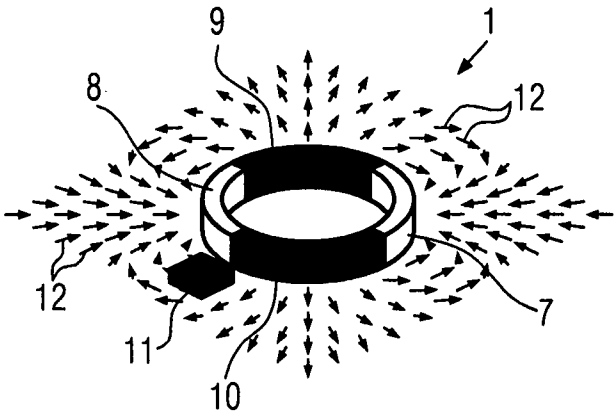


FIG. 2

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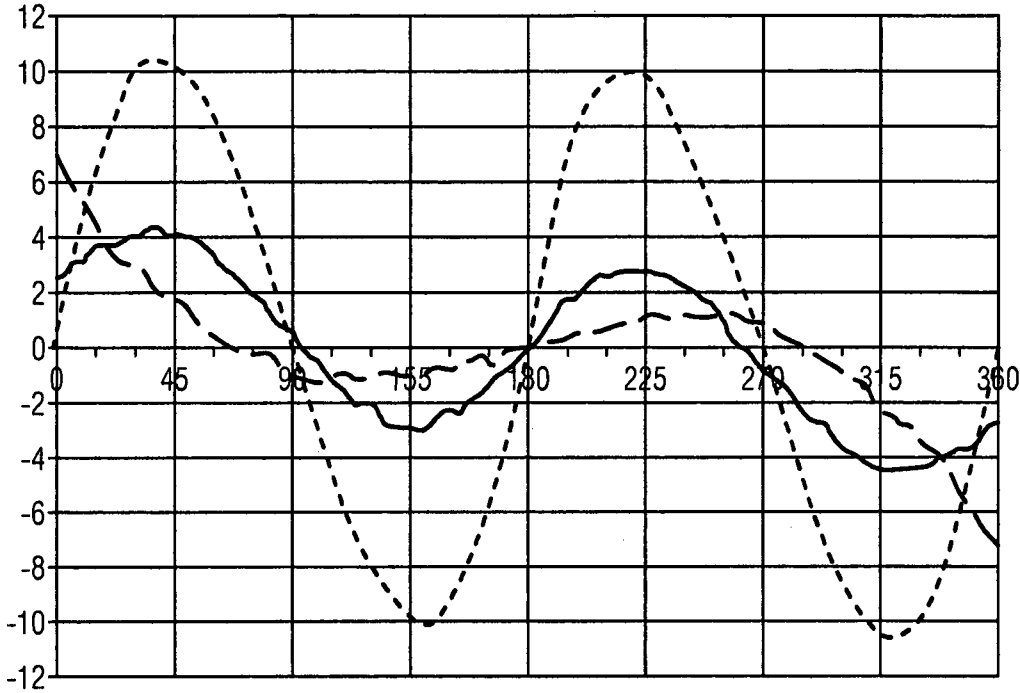


FIG. 3

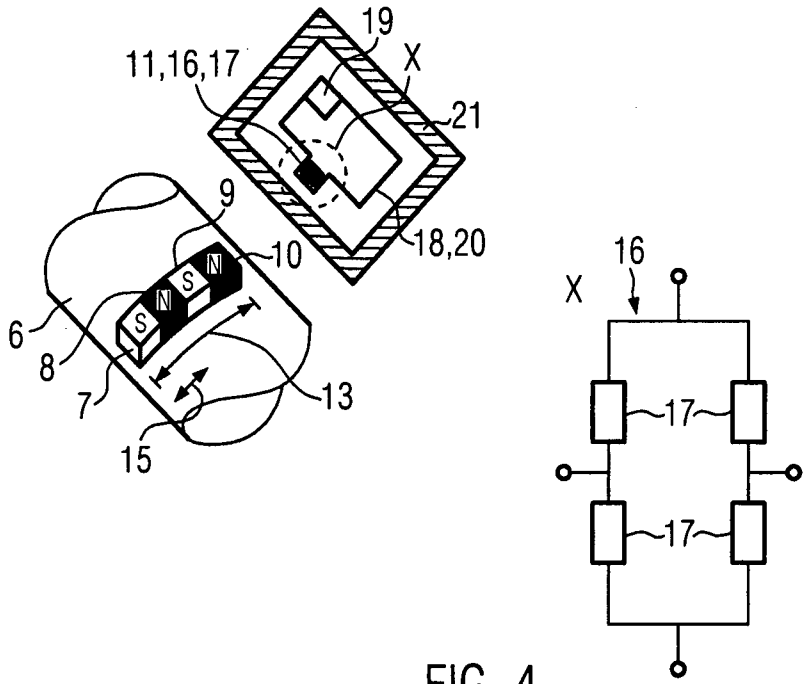


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/004865

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01D5/14

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01D E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/242331 A1 (DENGLER WERNER [AT] ET AL) 27 September 2012 (2012-09-27)	1-7
Y	the whole document	1-10
X	US 2012/038351 A1 (SARUKI SHUNJI [JP] ET AL) 16 February 2012 (2012-02-16)	1-9
Y	paragraph [0001] - paragraph [0034] paragraph [0133] - paragraph [0136]; figure 12	1-10
X	US 5 574 364 A (KAJIMOTO KAZUO [JP] ET AL) 12 November 1996 (1996-11-12)	1-9
Y	column 1 - column 2; figure 1	1-10
Y	WO 91/19168 A1 (REMOTE MARINE SYSTEMS LTD [GB]) 12 December 1991 (1991-12-12) the whole document	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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