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(71) Applicant *(for all designated States except US)*: **CAMERON INTERNATIONAL CORPORATION** [US/US]; 1333 West Loop South, Suite 1700, Houston TX 77027-9109 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **BIESTER, Klaus** [DE/DE]; Lückenweg 1, 29227 Celle (DE). **KUNOW, Peter** [DE/DE]; Gerhard-Winkler-Weg 3a, 12355 Berlin (DE). **ZABE, Volker** [DE/DE]; Mönkeburgstrasse 33, 31303 Burgdorf (DE).

(74) Agent: **HILGERS, Hans**; Grünecker, Kinkeldey, Stockmair & Schwanhäusser, Leopoldstrasse 4, 80802 München (DE).

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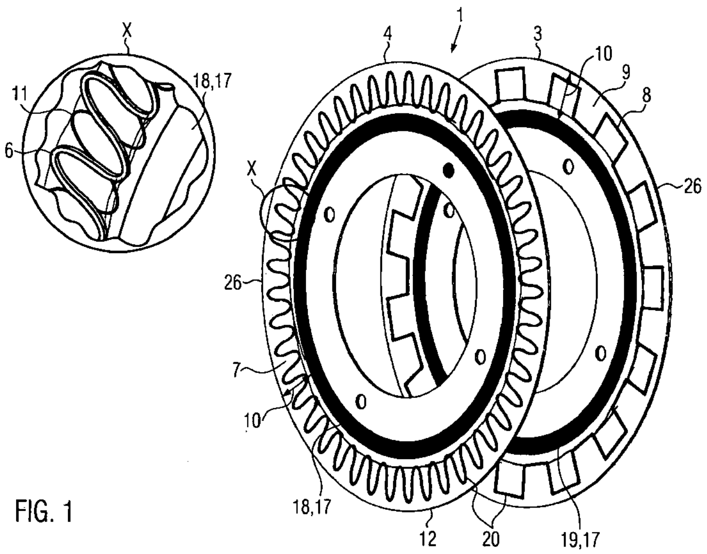


FIG. 1

**(57) Abstract**: A disc resolver of an electric motor, especially of a brushless direct current electric motor, has at least one rotating disc (3), (resolver rotor) and one stationary disc (4), (resolver stator). The two discs are arranged essentially in parallel with respect to each other and distanced from each other by an axial gap (5), wherein the resolver stator has at least one first stator winding (6) at a first stator front side (7) and the resolver rotor (3) has at least one rotor winding (8) at a rotor front side (9) facing the gap (5). The rotor winding runs according to the arrangement and number of motor poles, especially half poles of an electric motor (2). Thereby, a disc resolver of an electric motor is provided, which, under simple construction and cost-efficient manufacturing, enables very precise position evaluation in quite different rotational speed ranges and, especially under creep speed, also under high pressure.

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DISC RESOLVER AND BRUSHLESS DIRECT CURRENT MOTOR INCLUDING THE SAME

## Background

It is known to control electric motors and, in particular, especially brushless direct current motors, sensorlessly or dynamically with a sensor in a feed-forward control, or feed-back control, respectively. A particularly critical case with such motors is the start up under changing load from a standing position. In this case, a premature identification of the file location/position of the rotor of the electric motors is necessary for controlling the motor at low rotational speeds. Two operational conditions of such electric motors may occur, during which only one or a few rotations per minute take place, which may be referred to as “creep speed under full torque.”

Sensorless electric motors have a minimum quality of control threshold that is approached during such operational conditions, even if modern motor controllers and error-tolerant software are used. Also in sensor-controlled electric motors, problems may arise, especially in high-pressure operating environments. Such high pressures may arise during the utilization of the electric motors and actuators for operating valves or the like in oil/natural gas production. One or more such electric motors are arranged within a respective actuator. A drive shaft of the electric motor drives a gear shaft, as the case may be, via an interposed transmission or gear. This can transform a respective rotational movement into a linear movement by means of a ball-type linear drive or the like. In certain valves, however, the rotational movement may also induce a respective movement of a valve member for opening or closing a duct through which a fluid flows.

Especially in the field of oil/natural gas production, very high pressures occur not only due to the fluid flowing within the ducts but for example also during placement of respective valves with actuators at the bottom of the sea. This means that sealing problems may arise within the actuator or electric motor, respectively, so that they are subject to certain constraints in their construction with respect to size and precision.

In such a field of application, constraints to rotational speeds and a precise creep speed under full torque or an application in high rotational speed ranges may be necessary.

Corresponding precise sensors are, however, as a general rule very expensive and faults may be caused due to high pressures and electromagnetic interferences.

**Brief Description of the Drawings**

In the following, an advantageous embodiment of the present disclosure is described in detail by reference to the figures attached in the drawings.

In the drawings:

Fig. 1 shows a schematic illustration of a disc resolver with a magnified detail "X" in accordance with various embodiments of the present disclosure;

Fig. 2: shows a top view of a further embodiment of the disc resolver in accordance with various embodiments of the present disclosure;

Fig. 3: shows a top view in analogy to Fig. 2, without coils in accordance with various embodiments of the present disclosure;

Fig. 4: shows a perspective view in analogy to Figs. 2 and 3 with first and second stator windings which are offset with respect to each other in accordance with various embodiments of the present disclosure;

Fig. 5: shows a cross-section through Fig. 2 along the line "V-V" in accordance with various embodiments of the present disclosure;

Fig. 6: shows a magnification of the detail "X" from Fig. 5 in accordance with various embodiments of the present disclosure;

Fig. 7: shows an explanatory sketch in accordance with various embodiments of the present disclosure;

Fig. 8: shows an explanatory sketch for winding around and winding direction of the rotor winding in accordance with various embodiments of the present disclosure;

Fig. 9: shows a sketch for explaining the offset of the phase and winding direction of the first and second stator winding in accordance with various embodiments of the present disclosure; and

Fig. 10: shows a longitudinal section through the actuator for a valve with a disc resolver according to the invention in accordance with various embodiments of the present disclosure;

**Detailed Description**

The present disclosure relates to a disc resolver of an electric motor. Such an electric motor is especially a brushless direct current motor. The disc resolver has at least one rotating disc, the resolver rotor, and a stationary disc, the resolver stator. The two discs are arranged essentially in parallel to each other and distanced from each other by an axial gap.

In accordance with various embodiments, a disc resolver of an electric motor enables precise position evaluation in quite different rotational speed ranges and especially during creep speed also under high pressure, while being simple and cost-effective to construct and manufacture.

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

The disc resolver according to the present disclosure has at least one first stator winding on a first stator front side and the resolver rotor has a rotor winding on a rotor front side facing the gap. In order to form the respective motor poles of the electric motor in an advantageous manner by means of the disc resolver, the motor winding extends according to the arrangement and number of the motor poles of the electric motor.

Due to the construction of discs and the close parallel arrangement of the disc-shaped resolver stator and the disc-shaped resolver rotor, a compact and simple construction of the disc resolver results. Furthermore, due to the arrangement and allocation of the different coils, for example the allocation to the motor poles, a precise evaluation of the positions of the electric motor is possible, particularly at creep speed. The allocation of motor windings to motor poles may be adapted according to the respective number of poles and the construction of the motor poles as well as also the arrangement of the motor poles.

The position evaluation may be carried out more precisely if the first stator winding has a periodic run and circulates along an outer region of the resolver stator. Therefore, the first stator winding may be arranged oppositely to the rotor winding.

The precision of the position evaluation may be further improved where a second stator winding on a second stator front side is provided. If the first and the second stator winding are formed with a phase shift, a precise position evaluation also results during higher rotational speeds. In this case, both stator windings are running periodically. An example of such a periodic run are sinus-shaped or cosinus-shaped runs, for instance. Other periodic runs are rectangular or otherwise shaped runs which are arranged at certain distances in circumferential direction and are repeated at constant distance intervals along the circumferential direction.

In some embodiments, two stator windings may be arranged on one side of the resolver stator. A respective rotor winding may be arranged opposite to these windings.

In the construction of the disc resolver described above, many disc sizes are possible, particularly with respect to the diameter. In this case, a simple adaptation to the rotor and the stator of the electric motor results. Furthermore, a slim construction is enabled with the various sizes of the respective discs and the gap between the two discs may be quite narrow.

Moreover, the disc resolver according to the present disclosure is oil-resistant and pressure-resistant and different forms of construction of the respective discs and the resolver stator with stator windings are possible. The disc resolver according to the present disclosure is easy to install and replace onsite, since common standard mountings may be used. No power losses arise during the construction of such a disc resolver within an actuator or the like, or losses on the side of the actuator or the member controlled thereby.

In order to further simplify a reproduction of the motor poles and also to be able to electrically and/or magnetically transform the rotor anchor with uneven, offset or otherwise arranged poles precisely, the rotor winding may have a rectangular and periodic run. In other words, the rotor winding extends in an outer region of the resolver rotor oppositely to the corresponding motor poles of the electric motor and runs with different substantially rectangular kinks in a meandering shape in a circumferential direction around the disc.

An easy and fixed allocation of the resolver rotor and respective motor poles of the electric motor may result due to the resolver rotor being connected to the drive shaft of the electric motor in a torque-proof manner.

Similarly, the resolver stator may be attached to but detachable from the motor housing and a support disc mounted to the motor housing.

Generally, energy is supplied via the resolver stator, such that the resolver stator is connected to a voltage supply and current and voltage, respectively, may be transferred contactless to the resolver stator. Due to this contactless transfer, slip rings or other transfer devices are not necessary and no wear occurs. A simple embodiment of such a contactless transfer may result from a flat transformer being formed between the resolver rotor and the resolver stator. An exemplary embodiment for such a flat transformer are flat coils, opposing each other respectively at the resolver stator and the resolver rotor.

In order to be able to manufacture the corresponding windings and coils, respectively, in a simple manner, they may be formed as conductor paths or strip conductors, for example copper strip conductors. For manufacturing such conductor paths, various methods may be applied, for example optical etching methods, gluing on of the respective conductors or coils, sputtering, CVD, PVD or the like.

The respective conductor paths are also workable as fine line webs or paths, such that parallel-arranged multi-coil conductor paths are produced. These may be serially-wired or arranged, respectively, similar to the two stator windings.

Due to the corresponding construction of the disc resolver according to the present disclosure, the disc resolver may be free from wear for its lifetime.

Due to the respective arrangement of the cords and windings, a respective calibration of the sensor technology with respect to the anchor position of the electric motors is possible over the full 360° of rotation.

In order to prevent an electrical or magnetic influence of the disc resolver during the position evaluation, a shielding plate may be arranged between the disc resolver and the electric motor. Generally, the shielding plate may be arranged directly next to the disc resolver and thus prevents an influence of the electric motor on the disc resolver.

Even when utilizing such a shielding plate, it may be advantageous for the resolver rotor to be arranged directly at the rotor of the electric motor, as the case may be, under interposition of the shielding plate.

The present disclosure also relates to a brushless direct current motor with such a disc resolver. The direct current motor is arranged within an actuator. In some embodiments, two or more such direct current motors may be arranged within the actuator for a simultaneous drive or for redundancy reasons. The actuator is allocated to a valve or the like for oil/natural gas production. Such valves are for example gate valves, chokes, ball-type valves, blow-out preventers or the like. Each of these valves has a valve member which is adjustable by means of the actuator. This closes or opens a duct through which a fluid flows. The brushless direct current motor also has a stator and a rotor, whereby respective actuators with valves are described in WO 2011/009471 or WO 2011/006519 for examples.

With more than one brushless direct current motor, a respective disc resolver may be allocated to each of these direct current motors. In particular, the resolver rotor is allocated to the motor anchor or to the motor pole of the electric motor, respectively.

In order to be able to mount the respective windings in a simple manner, the resolver stator and/or resolver rotor may have protrusions arranged in recesses along the circumference and coil loops of the respective windings may be placed around the protrusions. As a result the windings are put into the respective recesses and, due to the placement of the coil loops around the protrusions, they are fixed in their positions. In this respect, the first and second stator windings are arranged only at one stator front side above each other in the respective recesses. Thus, the windings may be provided with an insulating coating or an insulation layer may be arranged between the windings.

This also applies to the resolver rotor, which in general only has one winding.

In some embodiments, the windings and their coil loops may be arranged such that respective coil loops are placed around respective adjacent protrusions with different phasing. This means, for example, that one coil loop of the first stator winding is wound around two protrusions clockwise, whereas the next coil loop of the first stator winding is wound around the next two adjacent protrusions counterclockwise. However, the windings with their coil loops may also be pre-manufactured and only be placed into the respective recesses or, in some embodiments, the respective coil loops may be placed around two adjacent protrusions each.

As explained above, the first and second stator windings may be arranged in a phase-shifted manner with respect to each other. A simple realization of such a phase shift may be seen when first and second stator windings are arranged around at least one protrusion in phase-shift with respect to each other.

In order to be able to produce a corresponding relation to the used electric motor by the protrusions, the possibility exists that a number of protrusions is a multiple of a number of half poles of the respective electric motor. For example, if the electric motor has 36 half poles, 72 (i.e., a multiple of 36) protrusions may be used. In order to secure the windings after mounting the windings to the resolver stator and resolver rotor, the windings may be molded within their respective recesses. Such a molding may be achieved by a cast resin or the like.

By inserting the windings into the recesses and placing the windings around the protrusions as pre-manufactured winding bodies, a simple and fast manufacturing process for rotors and stators is achieved. Additionally, the coils may be pre-manufactured on, for example, printed circuit boards, which may also be inserted into the recesses.

In Fig. 1, a perspective illustration of an exemplary embodiment of a disc resolver 1 according to the present disclosure is illustrated. The disc resolver 1 has a rotating disc 3, (a resolver rotor) and a stationary disc 4, (resolver stator). The two discs in Fig. 1 are illustrated as being separated in order to be able to include more detail. In accordance with various embodients, the two discs may be installed with a narrow axial air gap between them. The respective installation condition of the two discs results from Fig. 2, wherein in the present case, a narrow axial air gap 5 is formed between them.

The resolver stator 4 has two sides opposing each other, where on each of these front sides, see first stator front side 7 and second stator front side 12, a stator winding 6 and 11, is applied as shown in the expanded view X. The first stator winding 6 and the second stator winding 11 are running periodically in circumferential direction and are arranged at an offset with respect to each other.

The respective stator windings 6, 11 are arranged in an outer region 10 of the resolver stator 4, which extends essentially between a flat coil 18 and an outer rim 26. The stator windings are arranged in a meandering shape around the circumferential direction. The two stator windings are for instance, arranged as conductor paths and, in particular, copper paths arranged around the respective disc. The paths may be manufactured as fine line webs or paths. In this manner, multi-coil conductor paths may be produced in parallel and are arranged in series.

For manufacturing the conductor paths 20 on each of the resolver stator 4 and the resolver rotor 3, an optical etching method, a gluing of the conductor path, sputtering, CVD (chemical vapor deposition), PVD (physical vapor deposition) or the like may be applied. By each of these methods, the conductor paths 20 may be manufactured and positioned with high precision.

The flat coil 18 forms a part of the flat transformer 17 for a contactless transfer of voltage and current, respectively, between the resolver stator 4 and the resolver rotor 3.

Some bores at the resolver stator are provided radially within the flat coil 18, by means of which this may be mounted to a respective housing, for example as shown in Fig. 2.

The resolver rotor 3 may comprise approximately the same dimensions with respect to the resolver stator 4. The resolver rotor 3 comprises a rotor winding 8 in an outer region on a rotor front side 9. The rotor winding 8 runs along the outer region and thus forms a closed winding.

The rotor winding 8 is shown as having a rectangular-shaped period. Through this run, a mapping of respective motor poles of an electric motor, for example as shown in Fig. 2, onto the rotating disc is carried out. The rectangular shape and wavelength of the rotor winding 8 may correlate to the number and shape of the respective motor poles.

Furthermore, flat coils 19 of the flat transformer 17 are shown with respect to the resolver rotor 3 positioned radially on the inner side of the rotor winding 8. As already described, the two flat coils 18, 19 of the flat transformer 17 serve for a contactless transfer of voltage and current, respectively, from the resolver stator 4 in the direction towards the resolver stator 3.

The resolver rotor 3 also has corresponding bores for mounting on a drive shaft 3 or on a rotor 22 of an electric motor 2, as will be explained in further detail below.

Fig. 2 shows a top view of further exemplary embodiment of a disc resolver, wherein a resolver stator 4 with a first and a second stator winding 6, 11 is illustrated. The resolver rotor is constructed analogously, however, has only one rotor winding 8. The stator windings 6, 11 extend along the circumference of the resolver stator 4 close to its outer circumference. These windings 6, 11 have rectangular regions, which are each placed around two protrusions as respective coil loops, for example as shown in Fig. 3. These protrusions 29 are arranged within respective recesses 30. Furthermore, the phase of the respective coil loops 31, 32 (i.e. coil loops that are directly neighboring each other) is reversed. This will be described later with reference Figs. 8 and 9.

In addition, other arrangements of the windings 6, 11 as rectangles are also possible, see for example Fig. 1.

In Fig. 3, a top view of a resolver stator 4 and resolver rotor 3, respectively, is illustrated without inserted windings. On one of the front sides of the respective disc, two recesses 30 and 33, are arranged in the circumferential direction and are formed concentrically with respect to each other. In the radially outer recess 30, a multitude of protrusions 29 are arranged, around each of which pairs of respective coil loops 31, 32 are placed (e.g., as shown in Fig. 2 above). At the resolver stator 4, two windings 6, 11 are provided, which are offset with respect to each other. In some embodiments, the offset amounts to one protrusion. The number of protrusions 29 corresponds to a multiple of half of the number of poles of the electric motor 2, which will be explained in further detail in Fig. 10. For instance, with a half pole number of 36, 72 protrusions may be provided. In this manner, a reproduction of the half poles through the respective protrusions is the result.

The depth of the recesses 30, 33 is sufficient for inserting the windings 6,11 and the flat coil 18, and they may be encapsulated. Such an encapsulation may be carried out by a cast resin or the like.

The windings 6,11 and the flat coil 18 may be pre-manufactured on boards (e.g., printed circuit boards) such that, the boards may be inserted into the recesses 30, 33 and may be placed around the protrusions 29 with the respective coil loops.

The disc according to Figs. 2 and 3 may be manufactured from aluminum for example. The disc may be formed directly on the rotor and stator, respectively, of the disc resolver, and it is also possible that the disc illustrated in the Figs. 2 and 3 is, as the case may be, arranged on a support body, particularly in the form of a disc.

In Fig. 4, a perspective top view of the resolver stator 4 according to Fig. 2 is illustrated, wherein the respective first and second stator windings 6, 11 are illustrated in a lifted position.

In this position of the stator windings 6,11, it is shown that the winding 6 is formed substantially from an inner circular construction having rectangularly shaped winding coils 31,32 extending radially towards the outside therefrom. This similarly applies for the second stator winding 11, wherein there the respective circular part is arranged outside and the winding coils 31, 32 protrude radially towards the inside. The winding coils are arranged offset with respect to each other by exactly one protrusion 29, as shown in Fig. 2. The phase is reversed with respect to adjacent coil loops 31, 32 so that, for example, the phase of the coil loop 31 is clockwise and the phase of the coil loop 32 is counterclockwise. This also applies for adjacent winding coils 31, 32 of the second stator winding 11.

In Fig. 5, a section along the line V-V from Fig. 2 is illustrated. The detail "X" in Fig. 6, shows that the section is placed along a rectangular side at a respective coil loop through the first stator winding 6, whereas for the second stator winding 11, the section is placed through two rectangular sides of a respective coil loop, which are distanced from each other.

This indicates the offset of the two stator windings 6, 11 with respect to each other by just one protrusion 29.

The discs may be screw-fastened to respective parts of the actuator by means of holes or bores 34, also shown in Fig. 10.

Fig. 7 shows a principal sketch for explaining the functional principals of the disc resolver 1 in accordance with various embodiments.

The first stator winding 6, the second stator winding 11, and the rotor winding 8 are illustrated in a simplified manner. By means of the flat coils 19 of the flat transformer 17, a feeding of an alternating voltage into the rotor winding 8 takes place. Thereby, a corresponding alternating magnetic field results in the coil loops of the rotor winding 8. This is captured by the coil loops of the first and the second stator winding 6, 11 and used for the position evaluation of the half poles of the electric motor. It was noted above that the number of protrusions and therefore the number and arrangement of the coil loops corresponds to the number and arrangement of the half poles. However, only the coil loops of the first and second stator windings 6,11 are arranged offset with respect to each other, so that different signals may be captured from both stator windings in relation to the position of the rotor winding. Due to the comparison of these signals a respective turning position of the electric motor can be derived.

In Figs. 8 and 9, the rotor winding 8 and the stator windings 6, 11, being offset to each other, are illustrated in a simplified manner in which they are each wrapped around pairs of protrusions 29 and with a noted winding direction. In Fig. 8, the illustration of the rotor windings 8 corresponds to the resolver rotor 3.

The coil loop 31 for example is led around two adjacent protrusions 29 and the phase corresponds to the counterclockwise direction. The next coil loop 32 in turn is wrapped around two protrusions 29, however, with reverse phase, i.e. in the clockwise direction.

This also applies to the resolver stator with the first stator winding 6 and the second stator winding 11. However, these two stator windings 6, 11 are arranged around a protrusion 29 offset with respect to each other, e.g. that one coil loop 31 of the first stator winding 6 is wrapped around protrusions 35, 36 in the counterclockwise direction, whereas an analogous coil loop of the second stator winding 11 is wrapped around protrusions 34 and 35 in the counterclockwise direction. In a corresponding manner, a winding of a coil loop of the first stator winding takes place in the clockwise direction around protrusions 37 and 38 and of the second stator winding around protrusions 36 and 37 in the clockwise direction. This continues in the circumferential direction of the respective discs.

In Fig. 10, a partly illustrated longitudinal section through an actuator 23 with an associated valve 25 is illustrated. Parts of the actuator 23 include an electric motor, such as a brushless direct current motor, and the disc resolver 1 according to the present disclosure.

The valve 25 is illustrated only exemplarily, and may be a valve or the like used in oil/natural gas production. Such valves for example are gate valves, chokes, ball valves, blow-out preventers or the like. The corresponding electric motor 2 has a stator 24 and a respective rotor 22. The rotor 22 is coupled to a drive shaft 13. This transfers the rotational movement onto a gear shaft 27. In some cases, a transmission gear may be arranged between the drive shaft and the gear shaft. The gear shaft 27 is then directly or by interposition of an adapter of a ball type linear drive or the like connected to a valve through which a fluid flows.

The disc resolver is disposed between the electric motor 2 and the rear wall 28 of a motor housing 14. The motor housing may be the respective actuator housing.

In the illustrated exemplary embodiment as shown in Fig. 2, the resolver stator 4 is attached to a supporting disc 15, which is connected to the respective rear wall 28 in a detachable manner. Within the rear wall 28, a voltage supply 16 extends to the resolver stator 4 and is connected to the respective stator windings and the flat transformer 17. A contactless transfer of voltage/current onto the resolver rotor 3 is carried out via the flat transformer 17 and the flat coils 18, 19. Signals are transmitted from the stator windings via respective leads and transmitted to data processing equipment for analysis and position evaluation.

The resolver stator 4 and the resolver rotor 3 as shown in Fig. 2 are arranged in parallel to each other at a small distance and under inclusion of the axial air gap 5. The resolver rotor 3 is attached to the drive shaft 13 or to the rotor 22 of the electric motor 2 and rotates together therewith. The installation of the resolver rotor 3 takes place in such a manner that the respective rotor windings are a reproduction of the motor poles.

If the respective motor anchor with the motor poles has an uneven or offset arrangement, a corresponding adaptation of the resolver rotor and the rotor winding may be utilized.

For shielding the disc resolver 1 with respect to electric or magnetic influences of the electric motor 2 and further electric equipment within the actuator 23, a shielding plate 21 is provided. The shielding plate 21 extends essentially between the motor housing 14 and the drive shaft 13.

The disc revolver 1 according to the present disclosure serves for controlling the electric motor 2, when in certain actuators such as chokes or blow-out preventers, the valve 25 is driven against an abutment and/or in an end position of the valve 25 a sealing effect is required to be generated with slow rotational speeds and under full torque of the motor 2 or pre-loads. In these applications, a highly precise position control of the electric motor 2 and thereby of the actuator as well as the valve 25 is necessary. This may be achieved by utilizing the disc resolver in accordance with various embodiments of the present disclosure.

At the same time, the disc resolver is easy to manufacture, cost-efficient, oil-resistant and pressure-resistant as well as maintenance-free over its lifetime.

## Claims

1. A disc resolver (1) of an electric motor (2), comprising:

a resolver rotor (3)comprising a rotor winding (8) on a rotor front side (9), the rotor winding runs analogously to an arrangement and number of motor poles of the electric motor; and

a resolver stator (4) comprising at least one stator winding (6) on a first stator front side (7);

wherein the resolver rotor and the resolver stator are arranged substantially in parallel to each other and distanced from each other by an axial gap (5) and the rotor winding faces the gap.

2. The disc resolver according to claim 1, wherein the first stator winding (6) has a periodical run in a circumferential direction and runs along an outer region (10) of the resolver stator (4).

3. The disc resolver according to claim 1 wherein the resolver stator (4) comprises a second stator winding (11) that is arranged on a second stator front side (2) of the resolver stator (4).

4. The disc resolver according to claim 3, wherein the second stator winding (11) has a periodical run and extends along the first stator winding (6).

5. The disc resolver according to claim 3, wherein the first and the second stator winding (6, 11) are phase-shifted from each other by *90°*.

6. The disc resolver according to claim 1, wherein the rotor winding (8) has a substantially rectangular run.

7. The disc resolver according to claim 1, wherein the resolver rotor (3) is connected to a drive shaft (13) of the electric motor (2) in a torqueproof manner.

8. The disc resolver according to claim 1, wherein the resolver stator (4) is mounted in a detachable manner to a motor housing (14) of the electric motor (2).

Possible new claim, based on removing the “supporting disc (15)” limitation of claim 8:

The disc resolver according to claim 8 wherein the resolver stator (4) is mounted to a supporting disc (15) attached to the motor housing (14).

9. The disc resolver according to claim 1, wherein the resolver stator (4) is connected to a voltage supply (16) such that current and voltage are transferrable to the resolver rotor (3) in a contactless manner.

10. The disc resolver according to claim 1, further comprising a flat transformer (17) between the resolver stator (4) and the resolver rotor (3)configured to transfer current and voltage between the resolver stator and the resolver rotor.

11. The disc resolver according to claim 10, wherein the flat transformer (17) is formed by flat coils at the resolver stator (4) and the resolver rotor (3) and the float coils are opposite of each other.

12. The disc resolver according to claim 11, wherein the rotor and/or stator flat coils are formed as conductor paths.

13. The disc resolver according to claim 12 wherein the conductor paths comprise copper conductor paths.

14. The disc resolver according to claim 1, wherein the resolver rotor (3) is arranged on a rotor (22) of the electric motor (2).

15. The disc resolver according to claim 1, wherein the resolver stator (4) and/or the resolver rotor (3) comprise protrusions (29) arranged within a recess (30) along the circumference and protrusion coil loops (31, 32) of the windings are placed around the protrusions.

16. The disc resolver according to claim 15, wherein the coil loops (31, 32) are each placed around two adjacent protrusions (29) with different winding directions.

17. The disc resolver according to claim 15, wherein the first and the second stator windings (6, 11) are arranged at least around one protrusion (29) under phase-shift with respect to each other.

18. The disc resolver according to claim 15, wherein a number of protrusions (29) is a multiple of a half pole number of the electric motor (2).

19. The disc resolver according to claim 1, wherein the windings (6, 11; 8) of the resolver stator (4) and/or resolver rotor (3) are encapsulated.

20. The disc resolver according to claim 15, wherein the windings (6, 11; 8) are positioned into the recess (30) and around the protrusion (29) as pre-manufactured winding bodies.

.21. The disc resolver of claim 1 wherein the electric motor comprises a brushless direct current motor.

22. A brushless direct current motor (2) of an actuator (23) for a valve (25) in oil and natural gas production, comprising:

a stator (25);

a rotor (22); and

a disc resolver (1), the disc resolver comprising:

a resolver rotor (3) comprising a rotor winding (8) on a rotor front side (9), the rotor winding runs analogously to an arrangement and number of motor poles of the electric motor; and

a resolver stator (4) comprising at least one stator winding (6) on a first stator front side (7);

wherein the resolver rotor and the resolver stator are arranged essentially in parallel to each other and distanced from each other by an axial gap (5) and the rotor winding faces the gap.

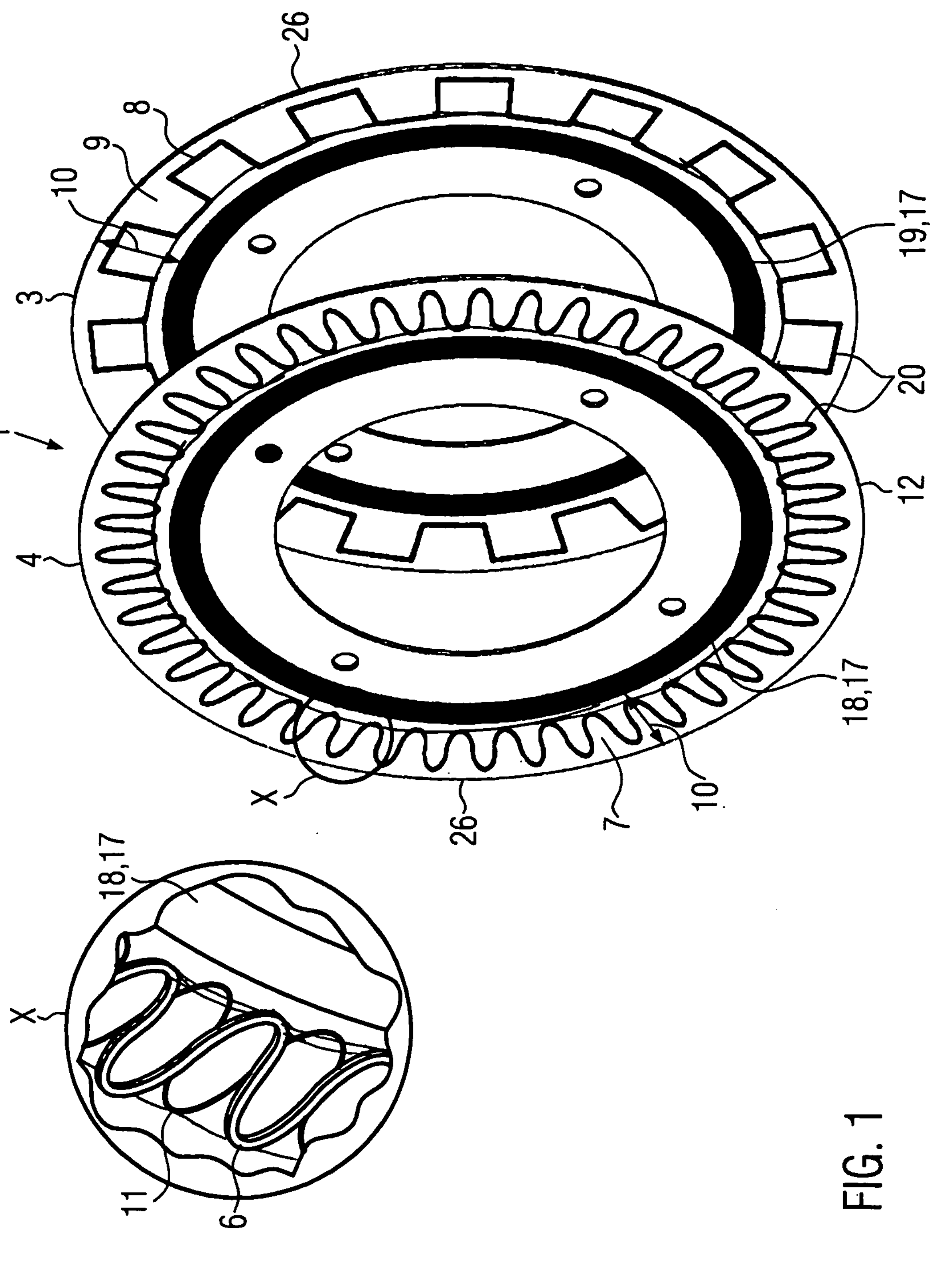


FIG. 1

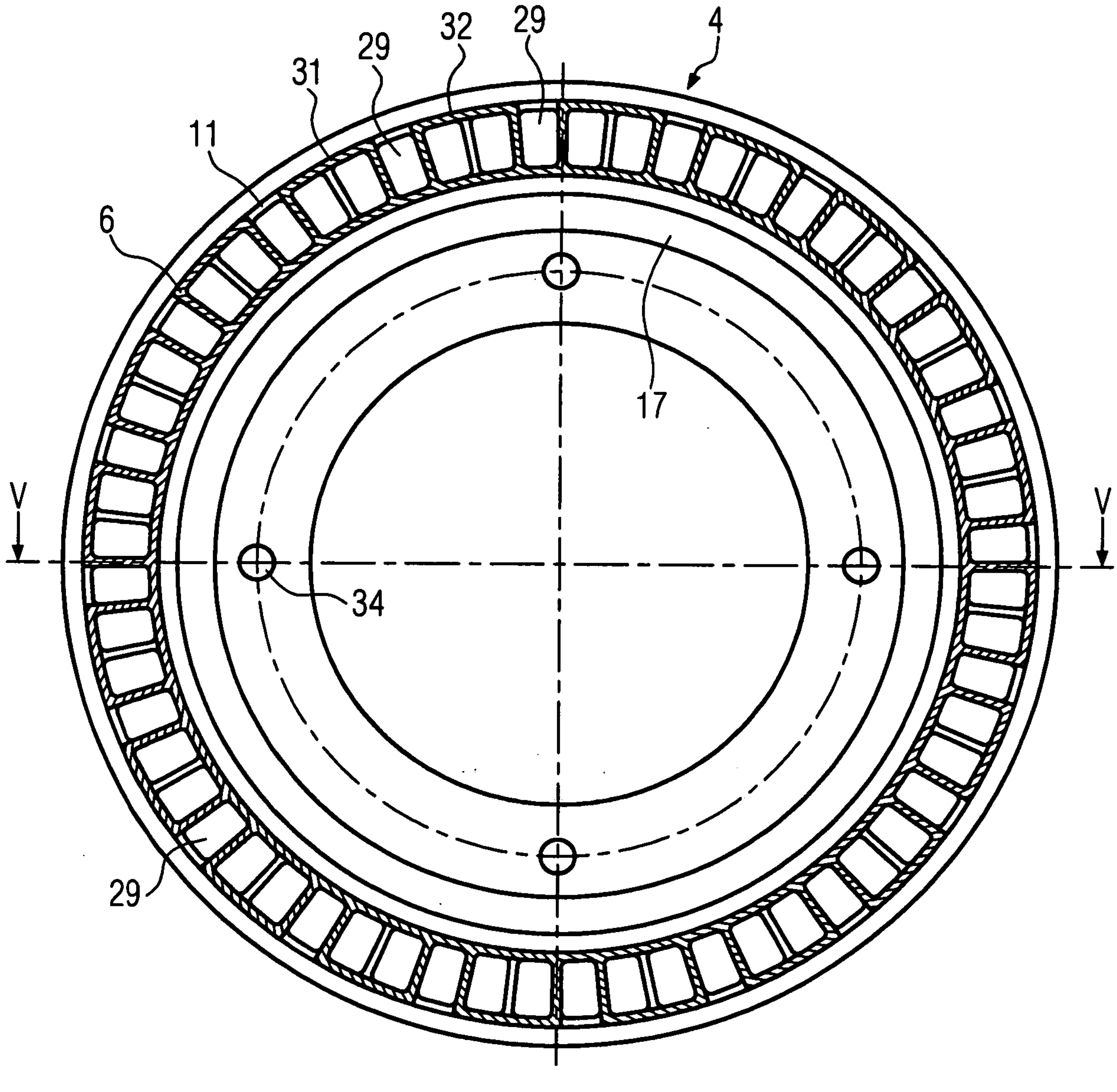


FIG. 2

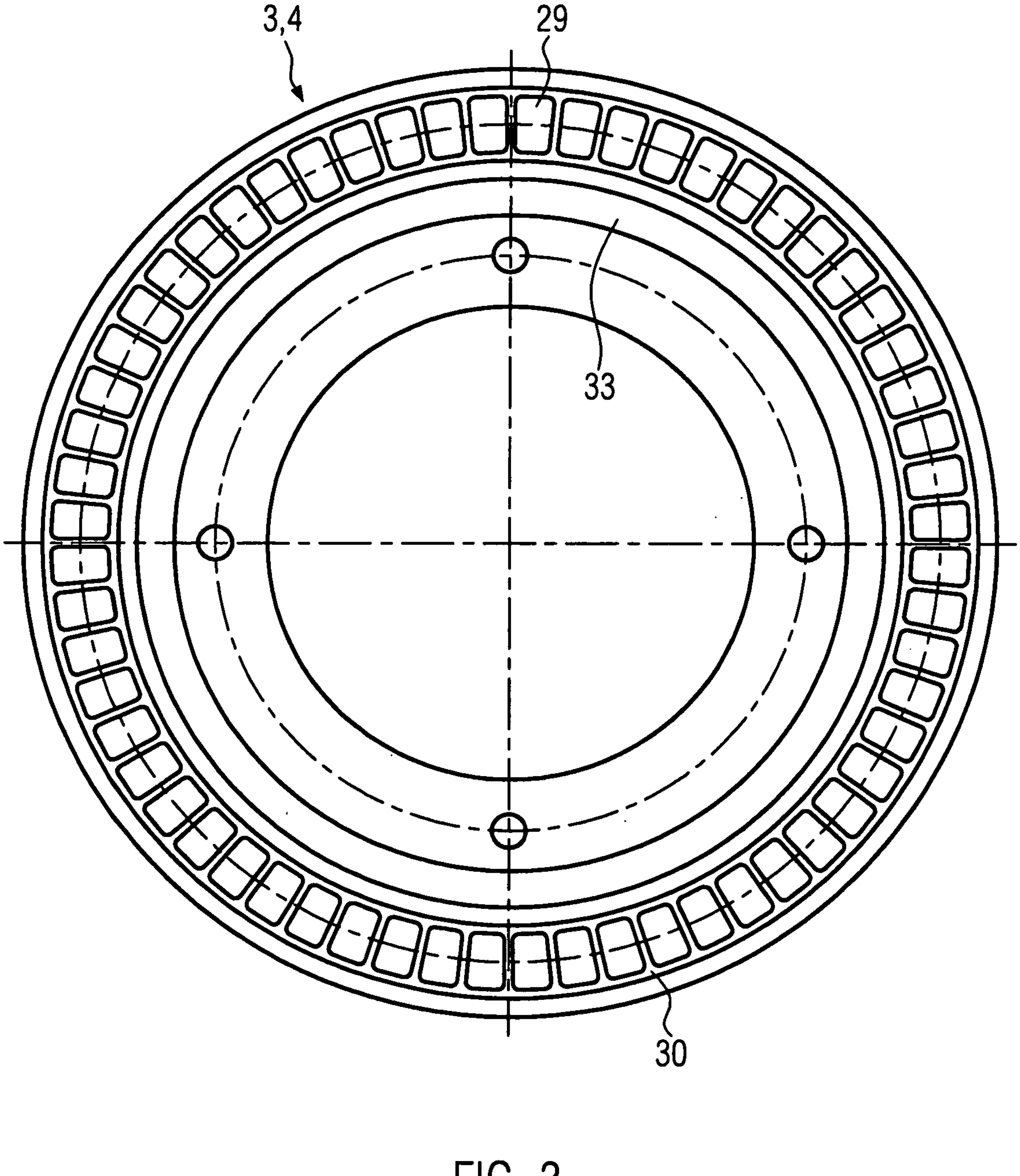


FIG. 3

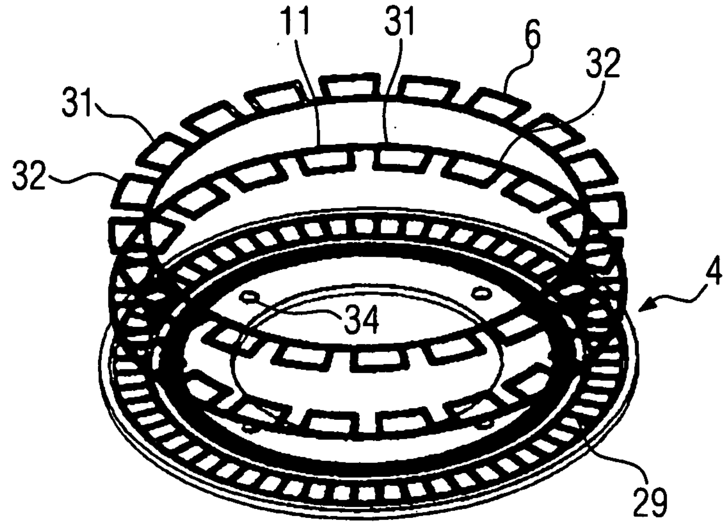


FIG. 4

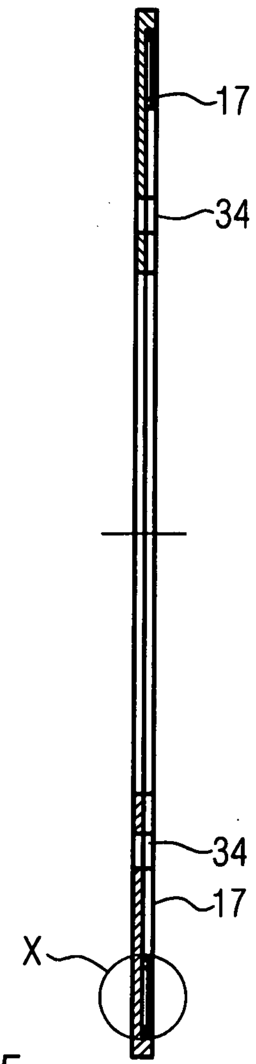


FIG. 5

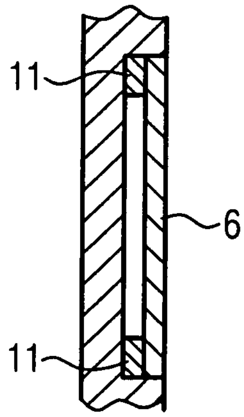


FIG. 6

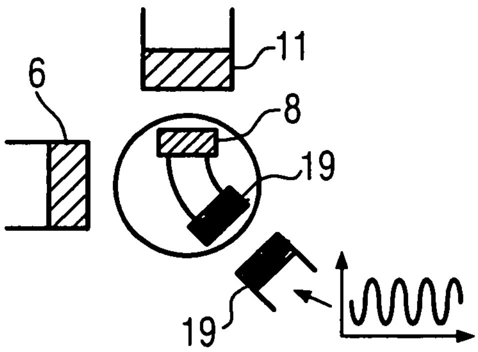


FIG. 7

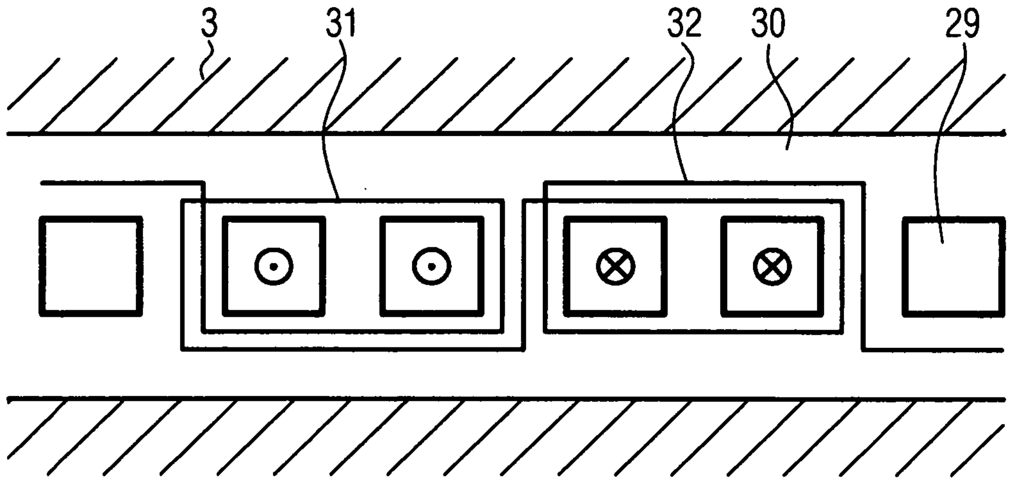


FIG. 8

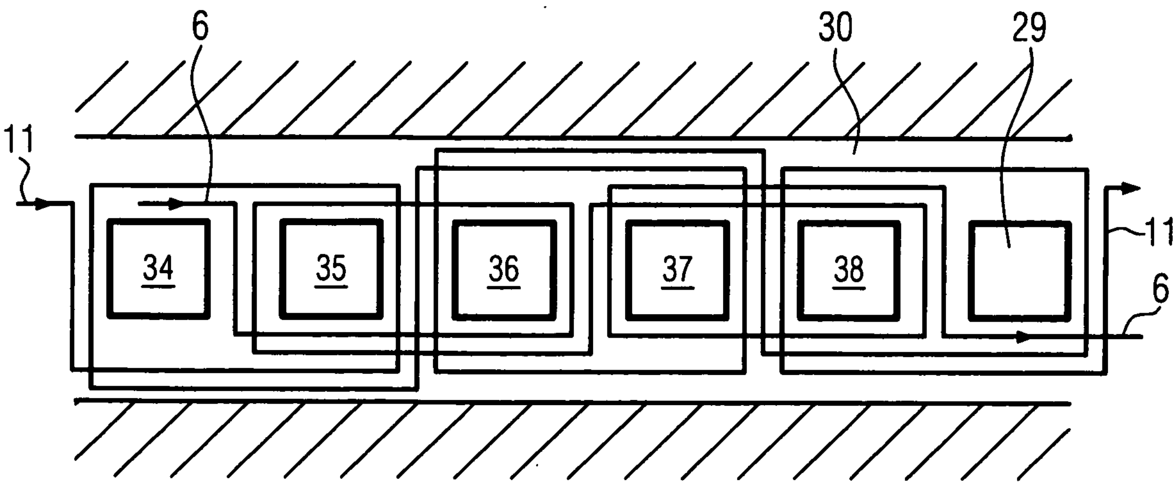


FIG. 9

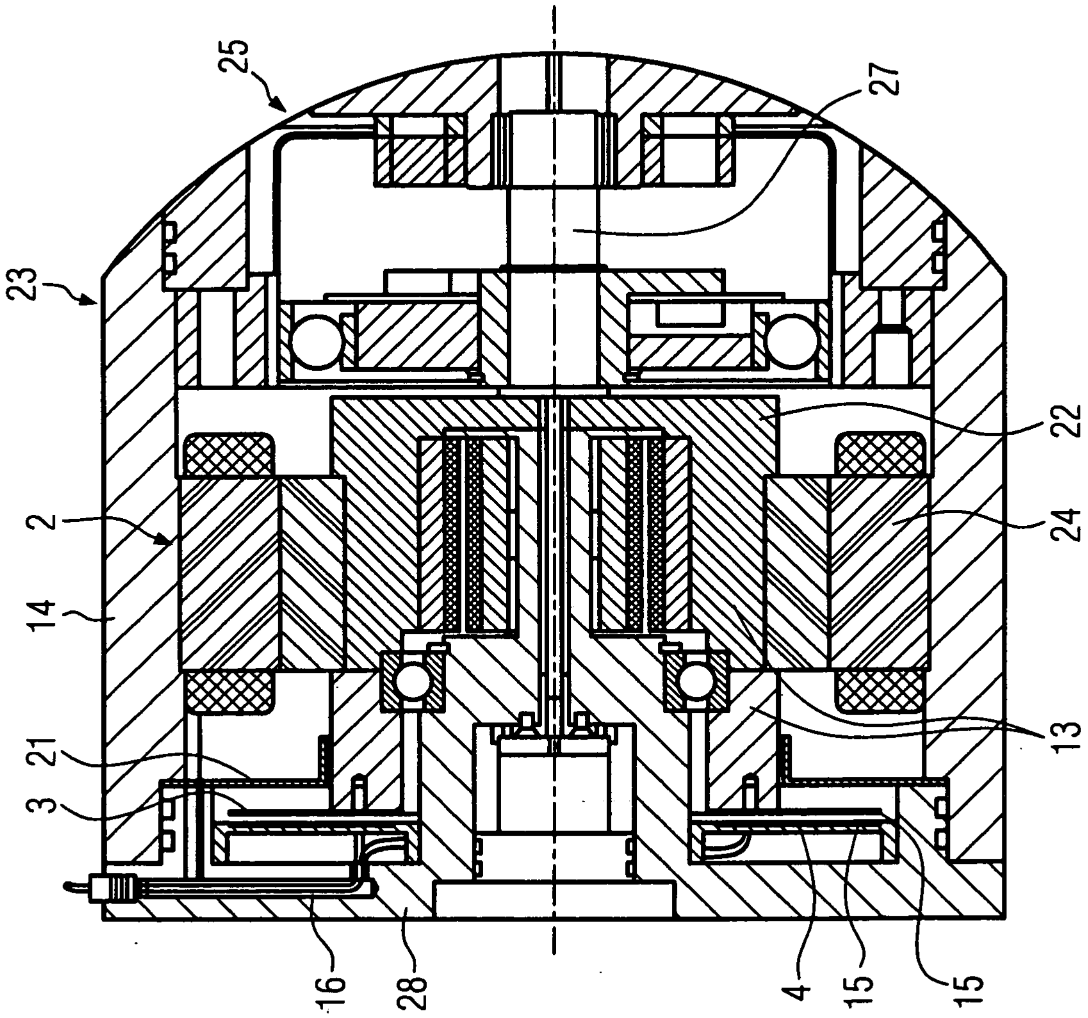


FIG. 10

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/003798

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G01D5/20 H02K29/12
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)
H02K G01D

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<br><br>Y | US 2010/109491 A1 (MIYAZAKI HIROAKI [JP] ET AL) 6 May 2010 (2010-05-06)<br>abstract; figures 1,2,4,5<br>paragraph [0001] - paragraph [0015]<br>paragraph [0054] - paragraph [0074]<br>paragraph [0143]<br>----- | 1-14,19,<br>21,22<br>15-18,20 |
| Y | JP 2007 171131 A (TOYOTA MOTOR CORP; MATSUO SEISAKUSHO KK)<br>5 July 2007 (2007-07-05)<br>abstract; figures 1,4<br>----- | 15-18,20 |
| A | US 4 458 168 A (WELBURN ROSS D [US])<br>3 July 1984 (1984-07-03)<br>column 1, line 20 - line 24<br>----- | 1,22 |
| A | US 6 392 322 B1 (MARES E JOSEPH [US] ET AL) 21 May 2002 (2002-05-21)<br>column 6, line 58 - column 7, line 50<br>----- | 22 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 May 2013 | 14/05/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Tano, Valeria |

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Information on patent family members

International application No

PCT/EP2012/003798

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