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Actuating Device

The invention relates to an actuating device for regulating a control mechanism which is subjected to a force against the direction of regulation. Said actuating device comprises a drive device which has a drive shaft and is connected in a moveable manner to a rotating spindle, by which means an actuating element can be axially displaced in the direction of regulation, in a housing receiving the device.

Such an actuating device is, for example, known from EP 1 024 422. Such actuating devices are used especially for regulating control devices such as valves, throttle devices and other control mechanisms, especially in applications in oil and gas production. The actuating device is used for maritime and terrestrial locations which may be remote or have difficult access. By displacing the actuating element using the rotating spindle, a valve, for example, is closed or appropriately opened as a control device. Generally in this connection, such a valve is subjected to a force in the direction of the open position, produced by a spring element or similar. To regulate the rotating spindle, it is connected in a movable manner to a drive shaft which is driven by a drive device for regulating the rotating spindle and correspondingly the actuating element in the regulation direction. The actuating device comprises a device housing in which essentially all parts of the actuating device are accommodated and protected against harsh ambient effects in appropriate regions of deployment of the actuating device.

Generally, the point of use of such actuating devices is positioned remotely to the associated monitoring and motor control device and additionally it is usually difficult to access, such as for example, with maritime oil and gas production in which the actuating device and the associated control device are located on the sea bed. In order to be able to operate the control device even during a failure or with insufficient effect from the actuating device, a second independent actuating device can be assigned to the same control device. This means that

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with the failure of one actuating device the other one is employed and remotely operated appropriate to the actuation of the control device.

The constructive complexity and financial cost for the arrangement of two actuating devices for only one control device is quite high. In addition, in this case both actuating devices must be maintained and installed at the location of use, whereby often insufficient space is available.

The object of the application is therefore to improve an actuating device of the type mentioned at the beginning such that actuation of the control device is ensured in a constructively simple and less expensive manner.

The object is solved according to the invention in conjunction with the characteristics of the generic term of Claim 1 in that the drive device comprises at least two independent electric motors which can respectively be actuated and controlled for the rotation of the drive shaft.

Through the use of the two electric motors it is ensured that with the failure of one motor the other one can continue to drive the drive shaft in order to move the rotating spindle and the actuating element appropriately in the regulating direction. All other parts of the actuating device are present in the usual numbers and only the number of electric motors is doubled. According to the invention, a second drive shaft is also not needed on which the second electric motor acts and through which it controls the rotating spindle and actuating element. As a consequence, overall the actuating device according to the invention is in its dimensions essentially unchanged with respect to the previously known actuating device.

An especially simple and space-saving arrangement can be seen in that the electric motors are arranged one behind the other in the longitudinal direction of the drive shaft.

In order to be able to control each of the electric motors individually and essentially independently of one another, a dedicated motor control device can be assigned to each motor. The said motor control device contains a suitable microprocessor, memory devices and similar devices. Each of the electric motors can be operated according to requirements through an appropriate software program using the microprocessor.

In order to achieve a very accurate motion control with high reliability and high efficiency of the electric motors, the said motors can be realised as servomotors.

In order to obtain a bearing mechanism of high quality and high efficiency which is at the same time reversible in its movement in a simple manner, a rotating sleeve can be driven by a drive shaft via a transmission device, the said rotating sleeve being rotationally rigidly connected to a ball nut of a feed device, whereby the rotating spindle formed as a recirculating ball spindle for movement in the regulating direction is rotationally supported in the ball nut. In this way the drive force of the electric motors is transferred to the ball nut via the rotating sleeve. The said ball nut rotates together with the rotating sleeve and with the suitable rotation the recirculating ball spindle is moved in the regulating direction and consequently also the actuating element. It is also possible that instead of the previously described ball screw drive a roller screw drive is analogously applied.

In order to prevent reactions by the control device, which is subjected to force in the direction opposite to the regulating direction, via the actuating element and rotating spindle or recirculating ball spindle on the electric motors, the rotating sleeve can be fixed by a first spiral spring opposing a feed rotational direction on a ring flange rotationally rigidly arranged in the device housing. The feed rotational direction corresponds here to a rotation of the recirculating ball spindle for the regulation of the actuating element or the rotating spindle in the regulating direction.

A constructively simple way of arranging such a ring flange can be seen in that the said ring flange sticks out from a transverse wall in the device housing essentially coaxially to the drive shaft or to the rotating sleeve.

In order to enable resetting of the actuating element in the direction opposing the regulating direction despite this when the control of the actuating device fails, a retaining sleeve can be rotationally rigidly connected at one of its ends to the transverse wall, whereby the retaining sleeve is rotationally rigidly connected at its other end via a second spiral spring to a guide sleeve in the direction opposite to the feed rotational direction, the actuating element connected to the recirculating ball spindle being supported for longitudinal displacement, but rotationally rigidly in the said guide sleeve. If this second spiral spring is released during a failure of the usually provided control for the actuating device, the guide sleeve can rotate in the direction opposite to the feed rotational direction due to the force which is transferred via the actuating element and which is acting on the control device to be actuated. Through this rotation the rotating spindle is turned back in the recirculating ball nut also in the direction opposite to the regulating direction until the actuating element is again arranged in its initial position.

In this connection, in order to prevent the actuating element itself from being rotated in the direction opposite to the regulating direction when being displaced, a spindle head for mutual connection can be arranged between the said actuating element and the recirculating ball spindle. The actuating element is decoupled with regard to rotation from the recirculating ball spindle by this spindle head.

In order to enable appropriate guidance and retention with regard to the guide sleeve as mentioned above, the spindle head can comprise at least one guide element protruding radially outwards, which engages a longitudinal guide running in the guide sleeve in the regulating direction.

In order to wind up the second spiral spring for the rotationally rigid connection of the retaining sleeve and guide sleeve sufficiently tightly on them, the said spring can be drive-connected to at least one electric motor. A sufficiently rotationally rigid connection between the retaining sleeve and the guide sleeve is produced by suitable actuation of the electric motor for winding up the spiral spring, especially before regulation of the recirculating ball spindle and actuating element.

In order to be able to accommodate the appropriate electric motor at a convenient point within the device housing, the electric motor can be drive-connected to a clamping sleeve from which a dog protrudes radially inwards which can be motion-connected to essentially one end of the second spiral spring. Due to the arrangement of the clamping sleeve, the electric motor can be located remotely with respect to the second spiral spring. Here, the arrangement is preferably realised such that a space available in the device housing is optimally used.

In order to be able to arrange the actuating device suitably compact and with small outer dimensions, the clamping sleeve can be rotationally supported on an external side of the retaining sleeve and on an external side of a ring flange which engages in the device housing, whereby the ring flange protrudes from an inner side of a housing cover.

A simple type of drive connection between the electric motor and clamping sleeve can be seen in that the electric motor drives a gearwheel which engages teeth on especially one end of the clamping sleeve.

In order to achieve redundancy also in connection with the drive of the clamping sleeve, another electric motor can be arranged, especially diametrically opposed to the first electric motor, through which a gearwheel that meshes with the teeth can be driven. In this way the clamping sleeve can be alternatively

driven by the first or second electric motor and especially with the failure of one electric motor the other one is used.

In order to be able to still release the second spiral spring with the failure of both electric motors, a torsion spring can be arranged between the clamping sleeve and ring flange, the said torsion spring being able to be tensed during the rotation of the clamping sleeve for winding up the second spiral spring. If therefore the clamping sleeve is no longer held by one of the electric motors during the failure of its electrical supply in such a position in which the second spiral spring is wound up, the torsion spring rotates back the clamping sleeve at least so far that the second spiral spring is relieved for the release of the rotationally rigid connection between the retaining sleeve and the guide sleeve.

In order to be able to finely and accurately control the rotation of the clamping sleeve, the first and second electric motors can be stepper motors.

In order to supply the motors of the actuating device with electricity also independently of one another at least two separate electrical connections can be arranged on the device housing and especially on the housing cover adjacent to the electric motors. The appropriate voltage supply as well as the data interchange or interchange of control signals can be implemented via these electrical connections. Each of the electrical connections can be provided for one of the electrical motors, i.e. servomotors. In this connection it is also possible that each of the electrical connections is assigned to a stepper motor. A further possibility is also the provision of separate electrical connections for the stepper motors.

According to the invention, there is the possibility that the two electric motors can be controlled independently of one another for the separate drive of the drive shaft. In this case it is practicable to operate one of the electric motors in the idling mode when the other drives the drive shaft.



However, in order to be able to transfer a higher torque to the drive shaft when necessary and therefore to displace the actuating element in the regulating direction with a higher force, both electric motors (servomotors) can be operated simultaneously.

In this case, in order to prevent the motors from rotating the drive shaft with a phase displacement due, for example, to different motor characteristics or due to the formation of the separate electrical supply for both motors instead of providing mutual support during simultaneous operation, the servomotors can be especially synchronised by software via their associated motor control devices.

A simple type of synchronisation and control can be seen in that one servomotor is used as the master and the other as the slave.

It can be seen as being advantageous, especially for the transmission of a high torque if each of the servomotors is a direct current motor.

For the further monitoring of the actuating device according to the invention, especially remotely from said actuating device, a position sensor can be assigned to the drive shaft. With the said sensor it can be found, for example, how far the actuating element has been regulated, whether it has returned to its initial position, etc.

In the following an advantageous embodiment of the invention is explained in more detail and described based on the enclosed figures in the drawing.

The following are shown:

Fig. 1 shows a basic illustration of the actuating device according to the invention with two separate electric motors and associated control device;

Fig. 2 shows a front view of a housing cover of the actuating device according to the invention;

Fig. 3 shows a cross-section along the line III-III from Figure 2, and

Fig. 4 shows a cross-section along the line IV-IV from Figure 2.

Figure 1 shows the basic principle of the actuating device 1 according to the invention with two separate electric motors 8, 9 as drive device 3. The electric motors 8, 9 are realised as direct current servomotors and are both used, where necessary, independently of one another for rotating a drive shaft 2. As shown in the following figures, when the drive shaft 2 is rotated, a rotating spindle 4 is displaced in the regulating direction 6 and accordingly an actuating element 5 connected to it is also displaced. The actuating element 5 is used, for example, for closing or opening a valve as control device (not shown) to be actuated by the actuating device 1.

The servomotors 8, 9 are each electrically connected to a dedicated motor control device 11 or 12. These devices comprise appropriately a microprocessor, a memory device and other components necessary for the control. An appropriate software program for controlling the servomotors is held in the motor control devices.

Each of the motor control devices 11, 12 can be separately connected to the actuating device 1 via suitable connections 44, 45 (see for example Figure 2). In addition, each of the motor control devices 11, 12 is connected to a suitable voltage supply.

Figure 2 shows a front view of a housing cover 46 of a device housing 7, see Figures 3 and 4, of the actuating device 1 according to the invention. The

housing cover 46 can also be realised as the end of a subhousing, see Figures 3 and 4, which can be releasably connected to the rest of the device housing 7.

In the housing cover 46 especially the connections 44, 45 for the electrical supply and control of the servomotors 8, 9 are arranged. A smaller cover 48 is arranged centrally with respect to the housing cover 46, the said smaller cover covering a pot-shaped protrusion of the housing cover 46, see again Figures 3 and 4, in which a position sensor 47 is located.

Figure 3 shows a section along the line III-III and Figure 4 shows a section along the line IV-IV from Figure 2.

In the following the actuating device 1 according to the invention is described based on both of the Figures 3 and 4.

The two servomotors 8, 9 of the drive device 3 are arranged in the longitudinal direction 10 of the drive shaft 2 one behind the other. The drive shaft 2 extends adjacent to the position sensor 47. The said sensor is used to measure rotation of the drive shaft 2 and therefore for the determination of a feed of the actuating element 5 in the regulating direction 6.

The drive shaft 2 terminates in a transmission device 13, which, for example, can be realised as a so-called flex-spline gearbox without classical gearwheels. A rotating sleeve 14 is rotated by the drive shaft 2 via the transmission device 13, the said rotating sleeve being rotationally rigidly connected to a ball nut 15 as part of a feed device 16. A further part of the feed device 16 is formed by the rotating spindle 4 which is realised as a recirculating ball spindle.

A spindle head 25 is arranged on one end of the rotating spindle 4 which protrudes from the ball nut 15. The actuating element 5 is connected to the said spindle head on its side opposite the rotating spindle 4. The rotating sleeve 14 is rotationally supported in the ball bearing 49 with respect to a retaining sleeve

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22 which surrounds the rotating sleeve. The rotating sleeve 14 is inserted into a ring flange 18 at its end facing the transmission device 13.

A first spiral spring 17 is wound up on the outer sides of the ring flange 18 and the rotating sleeve 14. The said spring is used to provide the rotationally rigid connection of the ring flange 18 and the rotating sleeve 14 in a rotational direction opposite to the feed rotational direction of the rotating sleeve 14, i.e. the direction of rotation through which both the rotating spindle 4 and also the actuation element 5 are displaced in the regulating direction 6.

The ring flange 18 protrudes essentially coaxially to the drive shaft 2, respectively rotating spindle 4 from a transverse wall 19. The said wall is arranged in the region of the device housing 7 where it is releasably connected to the subhousing 51.

A retaining sleeve 20 is rotationally rigidly connected to the transverse wall 19 radially outwards relative to the ring flange 18, see especially Figure 3. The rotationally rigid connection is realised by screwing one end 21 of the retaining sleeve 20 to the transverse wall 19. The retaining sleeve 20 extends up to its end 22 which faces away the transverse wall 19. The said retaining sleeve is rotationally supported relative to a guide sleeve 24 on this said end via a ball bearing 53. A second spiral spring 23 is wound up on the outsides of both the retaining sleeve and also the guide sleeve 24.

The guide sleeve 24 extends to a housing cover 36 through which the actuating element 5 is passed. The guide sleeve 24 exhibits longitudinal guides 27 running in the regulating direction 6 and in which guide elements 26 engage. The said guide elements protrude outwards radially from the spindle head 25.

In the region of the longitudinal guides 27 the guide sleeve 24 is inserted into a ring flange 34 which protrudes from an inner side 35 of the housing cover 36. A clamping sleeve 29 is rotationally supported by suitable bearings on an external

side 33 of the ring flange 34 and on an external side 32 of the retaining sleeve 20. The clamping sleeve 29 is releasably connected at its end 39 facing the drive device 3 by screwing to a toothed ring 42. The toothed ring 42 exhibits inner teeth as tooth system 38 which engages the gearwheels 37, 41. The gearwheel 37 can be rotated by a first electric motor 28 and the other gearwheel 41 by a second electric motor. The electric motors 28, 40 are realised as stepper motors.

A dog 30 protrudes radially inwards approximately centrally to the clamping sleeve 29 and said dog can be coupled to one end 31 of the second spiral spring 23, so that, depending on the rotation of the rotating sleeve 29, the second spiral spring 23 can be wound up more or less on the retaining sleeve 20 and the guide sleeve 24.

A torsion spring 43 is arranged between the clamping sleeve 29 and ring flange 34. The said spring can be clamped between the ring flange 34 and the rotating sleeve 29 when the clamping sleeve 21 is rotated for winding up the second spiral spring 23.

In the following the function of the actuating device according to the invention is briefly explained based on the enclosed figures.

Since the servomotors 8, 9 are mounted on the drive shaft 2, they can be used singly as well as in combination. Single application occurs especially when one of the servomotors 8, 9 is to replace the other one. Common actuation of both servomotors 8, 9 is especially then provided when a higher torque is to be transferred onto the drive shaft 2, which may amount to twice the torque which can be transferred by one servomotor.

Both servomotors 8, 9 are connected via separate feed cables, see the connections 44, 45, and the partially illustrated connection line 50, to their respective motor control devices 11, 12. One of the servomotors 8, 9, or both

motors can be actuated and controlled via these control devices and separate electrical supplies to the motor control device and also to the servomotors.

The motor control devices 11, 12 are especially formed in that one of the servomotors is wired as the master and the other as the slave and synchronisation of both motors to the common drive of the drive shaft 2 occurs by software.

The electric motors 28, 40, formed as stepper motors, are also arranged double in order to substitute one of the stepper motors with failure, damage or a similar condition. Also in this case, the control of the stepper motors can occur independently of one another over dedicated feed cables and dedicated motor control devices.

Otherwise the actuating device according to the invention functions as follows:

The ball nut 15 is rotated through the rotating sleeve 14 by rotating the drive shaft 2. Since the said ball nut is fixed in the axial direction relative to the device housing 7, the rotating spindle 4 is displaced in the regulating direction 6 when the ball nut 15 is rotated. The actuating element 5 is also displaced at the same time as the rotating spindle 4, because the said actuating element is connected to the rotating spindle 4 via the spindle head 25. The displacement of the actuating element 5 can be measured via the position sensor 47.

The force applied to the actuating element from the direction of the control device, which is not illustrated, in the opposite direction to the regulating direction 6 is transferred via the first spiral spring 17 from the rotating sleeve 14 to the ring flange 18 and therefore to the housing 7.

For resetting the actuating element 5 in the opposite direction to the regulating direction 6, the second spiral spring 23 is released via the dog 31, the said spiral spring holding the guide sleeve 24 with the retaining sleeve 20 rotationally

rigid in the direction opposite to the feed rotational direction. With the second spiral spring 23 released, the guide sleeve 24 can rotate in the direction opposite the feed rotational direction, whereby the rotation onto the guide sleeve 24 is transferred via the guide elements 26 of the spindle head 25 corresponding to the reverse rotation of the rotating spindle.

If due to the failure of both stepper motors 28, 40 a release of the second spiral spring 23 is not possible, the release of the spiral spring 23 occurs through the torsion spring 43, which was tensed on winding up the second spiral spring 23 for the rotationally rigid connection of the guide sleeve 24 and retaining sleeve 20 between the clamping sleeve 29 and the ring flange 34.

CLAIMS

1. Actuating device (1) for regulating a control mechanism which is subjected to a force against the direction of regulation (6), said actuating device comprising a drive device (3) which has a drive shaft (2) and is connected in a moveable manner to a rotating spindle (4), by which means an actuating element (5) can be axially displaced in the direction of regulation (6), in a housing (7) receiving the device,
   characterised in that
   the drive device (3) comprises at least two electric motors (8, 9) which can both be actuated and controlled independently of one another for the rotation of the drive shaft (2).

2. Actuating device according to Claim 1,
   characterised in that
   the electric motors (8, 9) are arranged one behind the other in the longitudinal direction (10) of the drive shaft (2).

3. Actuating device according to Claim 1 or 2,
   characterised in that
   a dedicated motor control device (11, 12) is assigned to each electric motor (8, 9).

4. Actuating device according to one of the previous claims,
   characterised in that
   the electric motors (8, 9) are servomotors.

5. Actuating device according to one of the previous claims,
   characterised in that
   a rotating sleeve (14) can be driven using the drive shaft (2) via a transmission device (13), the said rotating sleeve being rotationally rigidly

connected to a ball nut (15) of a feed device (16), whereby the rotating spindle (4), realised as a recirculating ball spindle, is rotationally supported in the ball nut (15) for movement in the regulation direction (6).

6. Actuating device according to one of the previous claims,
characterised in that
the rotating sleeve (14) can be fixed via a first spiral spring (17) opposed to a feed rotational direction on a ring flange (18) rotationally rigidly arranged in the device housing (7).

7. Actuating device according to one of the previous claims,
characterised in that
the ring flange (18) protrudes from a transverse wall (19) in the device housing (7) essentially coaxial to the drive shaft or rotating sleeve (14).

8. Actuating device according to one of the previous claims,
characterised in that
a retaining sleeve (20) is rotationally rigidly connected at one of its ends (21) to the transverse wall (19), whereby the retaining sleeve is rotationally rigidly connected at its other end (22) via a second spiral spring (23) to a guide sleeve (24) in the direction opposing the feed rotational direction and in the said guide sleeve (24) the actuating element (5), which is connected to the recirculating ball spindle (4), is supported for longitudinal displacement.

9. Actuating device according to one of the previous claims,
characterised in that
the actuating element (6) is connected to the recirculating ball spindle (4) via a spindle head (25).

10. Actuating device according to one of the previous claims,
characterised in that

the spindle head (25) comprises at least one guide element (26), protruding radially outwards, which engages a longitudinal guide (27) running along the regulating direction (6) in the guide sleeve (24).

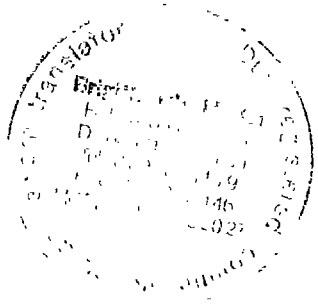
11. Actuating device according to one of the previous claims,
characterised in that
the second spiral spring (23) is drive-connected to at least one electric motor (28) for winding on the retaining sleeve (20) and the guide sleeve (24).

12. Actuating device according to one of the previous claims,
characterised in that
the electric motor (28) is drive-connected to a clamping sleeve (29) from which a dog (20) protrudes radially inwards, the said dog being able to be connected for movement with essentially one end (31) of the second spiral spring (23).

13. Actuating device according to one of the previous claims,
characterised in that
the clamping sleeve (29) is rotationally supported on an outer side (32) of the retaining sleeve (20) and an outer side (23) of a ring flange (34) engaging in the device housing (7), whereby the ring flange (34) protrudes from an inner side (35) of a housing cover (36).

14. Actuating device according to one of the previous claims,
characterised in that
the electric motor (28) exhibits a gearwheel (37) which engages teeth (38) on one end (39) of the clamping sleeve (29).

15. Actuating device according to one of the previous claims,
characterised in that



another electric motor (40) is arranged especially diametrically opposite the first electric motor (28) and a gearwheel (41) meshing with the teeth (38) can be driven by it.

16. Actuating device according to one of the previous claims,
characterised in that
the teeth (38) are formed by a toothed ring (41) with inner teeth, the said toothed ring being releasably mounted on the end (39) of the clamping sleeve (29).

17. Actuating device according to one of the previous claims,
characterised in that
the first and second electric motors (28, 40) can be actuated and controlled independently of one another.

18. Actuating device according to one of the previous claims,
characterised in that
a torsion spring (43) is arranged between the clamping sleeve (29) and the ring flange (34) and the said spring can be tensed when the clamping sleeve (29) is rotated for winding the second spiral spring (23).

19. Actuating device according to one of the previous claims,
characterised in that
the first and second electric motors (28, 40) are stepper motors.

20. Actuating device according to one of the previous claims,
characterised in that
at least two separate electrical connections (44, 45) are arranged on the housing cover (46) which is adjacent to the electric motors (8, 9).

21. Actuating device according to one of the previous claims,
characterised in that

both electric motors (8, 9) can be operated simultaneously.

22. Actuating device according to one of the previous claims,
characterised in that
the electric motors (8, 9) are synchronised especially by software via their motor control devices (11, 12).

23. Actuating device according to one of the previous claims,
characterised in that
one electric motor (8, 9) is used as the master and the other electric motor (9, 8) is used as the slave.

24. Actuating device according to one of the previous claims,
characterised in that
the electric motors (8, 9) are direct current motors.

25. Actuating device according to one of the previous claims,
characterised in that
a position sensor (47) is assigned to the drive shaft (2).

As a state-certified, duly registered and commissioned translator for the English language, publicly appointed and generally sworn by the President of Munich I Regional Court (Landgericht München I), I hereby certify that the foregoing English translation of the document submitted to me in the German language as an original copy is correct and complete.
Munich I Regional Court Reg. No. UE 131/91
Munich, 06 April 2003

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Sworn translator's signature and seal