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(54) **Cable braking and backward tension device**

(57) A cable braking and backward tension device (14) for providing a braking and backward pulling force to a cable (4) comprising a stand (2), a spool (3) rotatably attached to the stand (2), the spool (3) being adapted for the cable (4) to be wound on it, a braking disk (5) with a plurality of permanent magnets (7) attached to it, the braking disk (5) being rotatably attached to the stand (2), an actuator (6) coupled to the braking disk (5) and configured to rotate the braking disk (5), wherein the braking disk (5) is located coaxially with a spool (3) and wherein the spool (3) is made of ferromagnetic or paramagnetic material.

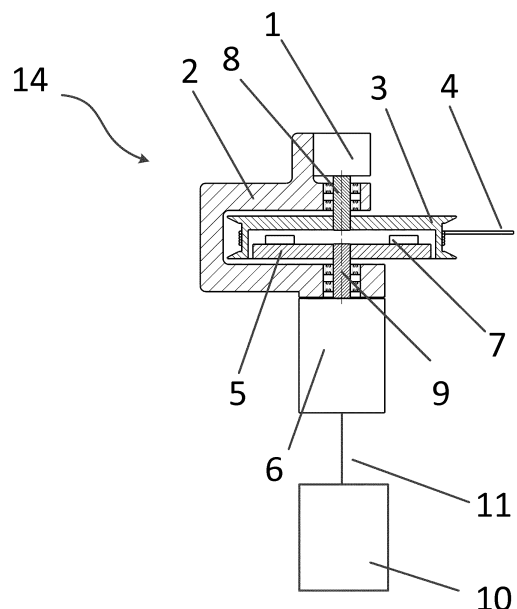


Figure 3

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Description**Technical Field**

5 **[0001]** The present invention relates to a cable braking and backward tension device and in particular to a device for providing a braking and backwards pulling force to an advancing cable for linear position sensors for self-propelled robots.

Background Art

10 **[0002]** A cable on a spool commonly has been used for a precision measurement of a self-propelled robot position. Usually the spool is attached to a stand and the free end of the cable to the robot. When the robot moves away from the stand the cable unwinds from the spool and by measuring the length of the unwound cable the distance from the stand to the robot can be measured. The cable length may be measured by measuring the rotation angle of the spool. 1.

15 **[0003]** Such a device may further comprise an angle sensor to determine the robot's position on a plane, or two angular sensors if the robot position needs to be determined in space.

[0004] It is important when measuring the robot position to keep the cable under permanent but a relatively small tension, because strong cable tension may influence the robot movement whereas too small tension may increase the measurement error. It is also important that the tension is strong enough to prevent the cable from touching the ground. Finally, the tension should be adjusted during the robot movement to prevent cable from sagging and jerking.

20 **[0005]** In case of linear disposition measurements under relatively small cable tension forces, which are specific for measurements like small size mobile robot position, the measurement precision becomes very much dependent on the length of the cable advanced from the spool due to sag caused by its own mass. To compensate for this error, the cable tension should be controlled with a high precision and according to complex rules.

25 **[0006]** As measuring the position of different types of robots may require different cable tensions, it is desirable that the cable tension setting could be changed electronically without disassembling the measurement device.

[0007] Traditionally in such measuring devices a coil spring is used for the cable tension and backtracking.

30 **[0008]** For example, the U.S. patent No. 5,236,144 discloses a cable extension linear position transducer, where a spool is attached to a spring providing a tension force to the cable. This solution enables to prevent formation of the cable curvature. This device has the following disadvantages. First is an uncontrollable non-linear character of the provided tensions force, which is the function only of length of the cable advanced from the spool. Thereby the device cannot respond to fast sudden changes in measuring distance that may cause unwanted curvature of the cable and errors in measurements. Second is inability to change the spring without disassembling the device. While the device itself might be used under different measuring setups, the tensions force cannot be adjusted without mechanical change of the spring.

35 **[0009]** A cable braking device is disclosed in the patent EP 0440246 B1, which provides two stage breaks: a mechanical and eddy current brakes. Both are motion dependant, which means that the applied breaking force and the resulting cable tension force is a function of the cable advancing speed. This braking device is universally applicable for any cable, which is pulled out from the spool. The main disadvantage of this device is its cable tension force, which depends on the spool rotation speed. It means that, while the cable is advanced slowly, the cable tension force is low.

40 **[0010]** The U.S. patent No. 6,543,152 describes a measuring cable travel sensor that includes a housing accommodating a measuring cable drum and a rotary spring urging the cable drum in the direction of winding a measuring cable thereon. Several braking magnets are arranged on the housing to provide for magnetic control of the rotary movement. An eddy current produced in the drum prevents an excessive acceleration of the cable drum. However, during the measuring process when the cable has to be pulled back to spool, the provided tension is not enough and thus causes cable to curve, which consequently causes the decrease of measurement precision. Therefore, apart from having additional protection from excessive acceleration of the cable drum this sensor does not provide any substantial improvement over a traditional spring powered sensors.

45 **[0011]** It is an object of the present invention to provide a cable braking and backward tension device that can provide permanent but a relatively small tension on the measuring cable. It is the other object of the invention to provide the cable tension strong enough to prevent the cable from touching the ground. It is another object of the invention to provide a device in which the cable tension could be adjusted during the robot movement to prevent cable from sagging and jerking.

[0012] It is still another object of the present invention to provide a device capable to provide a changeable cable tension force without disassembling the device.

55 **[0013]** It is yet another object of the present invention to provide a device capable by using a controller to implement specific tension force control rules to adjust the cable tension force depending on length of the cable advanced from the spool even when the cable stands still.

[0014] It is still further object of the invention to provide a device capable to function as a spool brake, which operates such that, when the cable is rapidly advanced away from the spool the cable tension force increases without involving

a controller.

Summary of invention

[0015] The above objects and advantages of the present invention are achieved through the device according to claim 1.

[0016] In the present invention there is only one braking and backward pulling arrangement consisting of a cable spool, a brake disk with permanent magnets attached to it and an actuator, which can rotate the brake disk in relation to the spool with variable rotation speed. The spool is made of ferromagnetic or paramagnetic material. Such a solution allows controlling of the cable tensions force through control of the brake disk rotation speed relative to the spool rotation speed. When the brake disk with the attached permanent magnets rotates relative to the spool, eddy currents are generated in the spool, thereby producing a movement dependant moment. While the brake disk rotates in the opposite direction to the cable advancing direction, the generated eddy current produces a drag force in the opposite direction to the spool rotation direction. The produced drag force causes a constant tension of the cable. In case of a sudden increase of the spool rotation speed, the drag force increases accordingly, thereby providing brake functionality.

[0017] The most useful advantage of the proposed device is a possibility to provide constantly adjusting the drag forces and, as a consequence, the cable tension.

[0018] Another useful advantage of the proposed device is a possibility to set the level of drag forces and, as a consequence, the cable tension, tailoring it to particular usage modes.

Definitions

[0019] In the present application, the term "**cable**" is intended to encompass all linear structures, such as wires, yarns, bands, strands, ropes and the like.

Brief description of drawings

[0020]

Figure 1 is a graph showing a dependence of the position measurement error against the measuring distance due to the measurement cable sagging.

Figure 2 is a perspective view of a device according to the invention.

Figure 3 is a partial section of the device shown in Fig. 2.

Figure 4 is a schematic diagram of a device according to the invention.

Description of embodiments

[0021] Figure 2 is a schematic view of a device embodying the current invention and Figure 3 is the same device as in Figure 2 shown in a partial section revealing the inner construction of the device.

[0022] In the embodiment presented in Figure 2 and Figure 3 the spool position sensor 1 is attached to the device stand 2. The spool 3 is mounted on a shaft 8, which is supported for free rotation in relation to the stand 2. On the same shaft 8, the spool position sensor 1 is attached, which can be used to determine the length of the cable 4 advanced from the spool 3. The brake disk 5 is supported by another shaft 9. The actuator 6 is also supported by the shaft 9, which allows the actuator to rotate the brake disk 5 at a speed set by a speed controller 10. The shafts 8 and 9 do not depend on each other, allowing the brake disk 5 and spool 3 to rotate with any speed difference relative to each other. A set of permanent magnets 7 is attached to the brake disk 5, which in case of relative speed difference between the brake disk 5 and the spool 3 that is made of ferromagnetic or paramagnetic material generates eddy currents in the spool 3. The generated in the spool 3 eddy currents provide a force that affects the spool 3 rotation in the same direction as the brake disk 5 rotates. As a consequence, if the actuator 6 rotates in the opposite direction of the cable advancing direction, then it produces a substantially unchanging tension of the cable 4. Thereby the cable 4, which is coiled on the spool 3, can be advanced out of the spool or wound into the spool using only the produced tension force. As the rotation speed of the brake disk 5 increases relatively to the spool 3, the tension force of the cable 4 is increased accordingly. This effect provides means to react on a sudden increase of the cable 4 advancing speed in a way that brake disk 5 rotation speed relative to the spool 3 rotation speed increases accordingly and thereby increases generated tension force of the cable 4 acting as a brake preventing the cable 4 from fouling. The generated cable 4 tension force may be adjusted to particular measuring environments by adjusting actuator 6 rotation speed. It is done by the tension force controller 10 providing control signals to the actuator 6 through control lines 11.

[0023] The electrical schematic diagram of the same embodiment is presented in Figure 4. As shown in the scheme, the actuator 6, which is in this embodiment a direct current motor with permanent magnets in its stator, through the

torque transfer device 12, is coupled to the spool 3. The torque transfer device 12 is an eddy current clutch formed by the brake disk 5 and the spool 3. The length of the cable 4 advanced from the spool 3 is determined by the sensor 5, which submits the length data to the tension force controller 10 through the signal line 13. The tension force controller 10, using the data about the length of advanced cable 4, adjusts the rotation speed of the actuator 6 through the control connections 11. Thereby the cable 4, which is coiled on the spool 3, can be advanced out of the spool or pulled into the spool only using the produced tension force. As the rotation speed of the actuator 6 increases the tension force produced by the eddy current clutch 12 on the cable 4 is increased accordingly.

[0024] The importance of the measurement cable tension control may be demonstrated by the following example.

[0025] Some linear position measurements, for example measuring position of a small size mobile robot, should be made under relatively small cable tension forces, in that circumstances the measurement precision becomes very much dependent on the length of the cable advanced from the spool due to sag caused by its own mass. The dependence rule in general case is depicted in Figure 1 showing the measurement error ω as a function of the measuring distance l . The rule is driven from the catenary equation:

$$L = l + \frac{l^2 \cdot g^2}{24 \cdot \sigma^2} + \frac{l^5 \cdot g^4}{384 \cdot \sigma^4} \quad (1)$$

where L is a total length of the cable advanced from the spool, l is a measuring distance without sag, g is a specific load of the cable caused by its own weight only, a tension force applied to the cable is

$$\sigma = \frac{F}{S} \quad (2)$$

where F is an applied tension force in N, but S is the section area of the cable.

[0026] In order to decrease the error component in measurement the tension force might be adjusted according to the tension force control rule, which minimises F :

$$F = \sqrt{\frac{l^2 \cdot g^2 \cdot S^2}{24 \cdot \varepsilon}} \quad (3)$$

where F is an applied tension force in N, but S is the section area of the cable, l is a measuring distance without sag, g is a specific load of the cable caused by its own weight only, ε is a maximum allowed measurement error in m. The tension force control rule can be derived from only the second component of the catenary equation:

$$\frac{l^2 \cdot g^2}{24 \cdot \sigma^2} \quad (4)$$

because it provides sufficient precision in most cases. To implement the tension force control rule any appropriate controller component may be used.

[0027] This technical solution allows to achieve the following positive effects:

- 1) The tension force controller 10 applying the tension forces control rule provides means for compensation of the cable sag during the measurements;
- 2) In case of a sudden increase of the cable 4 advancing speed, the eddy current clutch 12 due to its working principles provides an additional tension force to the cable 4 acting as a braking device;
- 3) Due to lack of any kind of direct gearing between the spool 3 and the actuator 6 the smooth tension force change is ensured.

[0028] The device embodying the current invention may be advantageously applied, for example, in the following

application domains:

- 1) High precision position measurements of moving objects with relatively small mass like mobile robotic devices, where the cable tension force, its smoothness and dynamic change influences the actual measured values;
- 2) Signal cable tension devices, where relatively small tension forces may be applied due to cable design specifics in order to avoid its physical damage.

Reference signs list

[0029]

1. spool position sensor
2. device stand
3. spool
4. cable
5. brake disk
6. actuator
7. permanent magnets
8. shaft (spool)
9. shaft (brake disk)
10. controller
11. control line
12. torque transfer device (eddy current clutch)
13. sensor signal line
14. cable braking and backward tension device

Citation list

[0030]

US5236144
EP0440246
US6543152

Claims

1. A cable braking and backward tension device (14) for providing a braking and backward pulling force to a cable (4) comprising:
 - a stand (2),
 - a spool (3) rotatably attached to the stand (2), the spool (3) being adapted for the cable (4) to be wound on it,
 - a braking disk (5) with a plurality of permanent magnets (7) attached to it, the braking disk (5) being rotatably attached to the stand (2),
 - an actuator (6) coupled to the braking disk (5) and configured to rotate the braking disk (5), wherein the braking disk (5) is located coaxially with a spool (3) and wherein the spool (3) is made of ferromagnetic or paramagnetic material.
2. The tension device (14) according to claim 1, further comprising a controller (10) connected to the actuator (6) for changing a rotation speed of the actuator (6).
3. The tension device (14) according to claim 2, further comprising a spool position sensor (1) installed on the stand (2) and connected to the controller (10), wherein the controller (10) is configured to change the rotation speed of the actuator (6) in accordance with a signal from the spool position sensor (1).
4. The tension device (14) according to claim 3, wherein the controller is configured to calculate a length of a wound out portion of the cable (4) and adjust the rotation speed of the actuator (6) in accordance with said length.

5. The tension device (14) according to claim 2 or 3 wherein the spool position sensor (1) is an angular spool position sensor.
6. A self-propelled robot position measuring apparatus comprising a cable braking and backward tension device according to claim 1.

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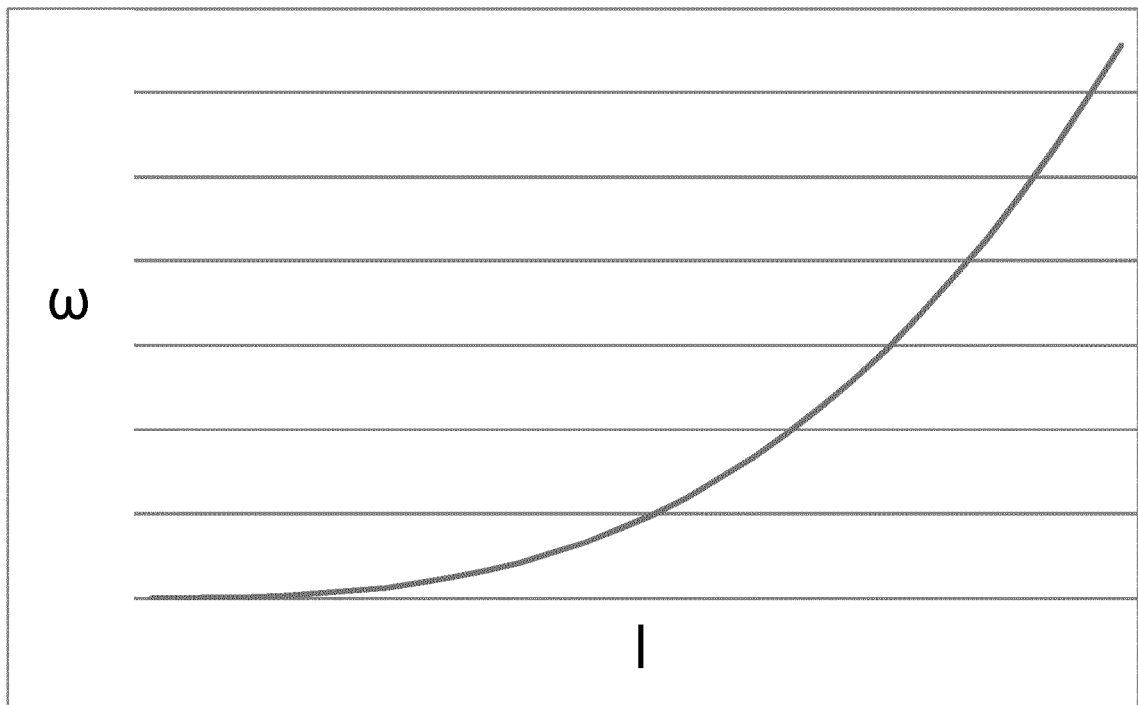


Figure 1

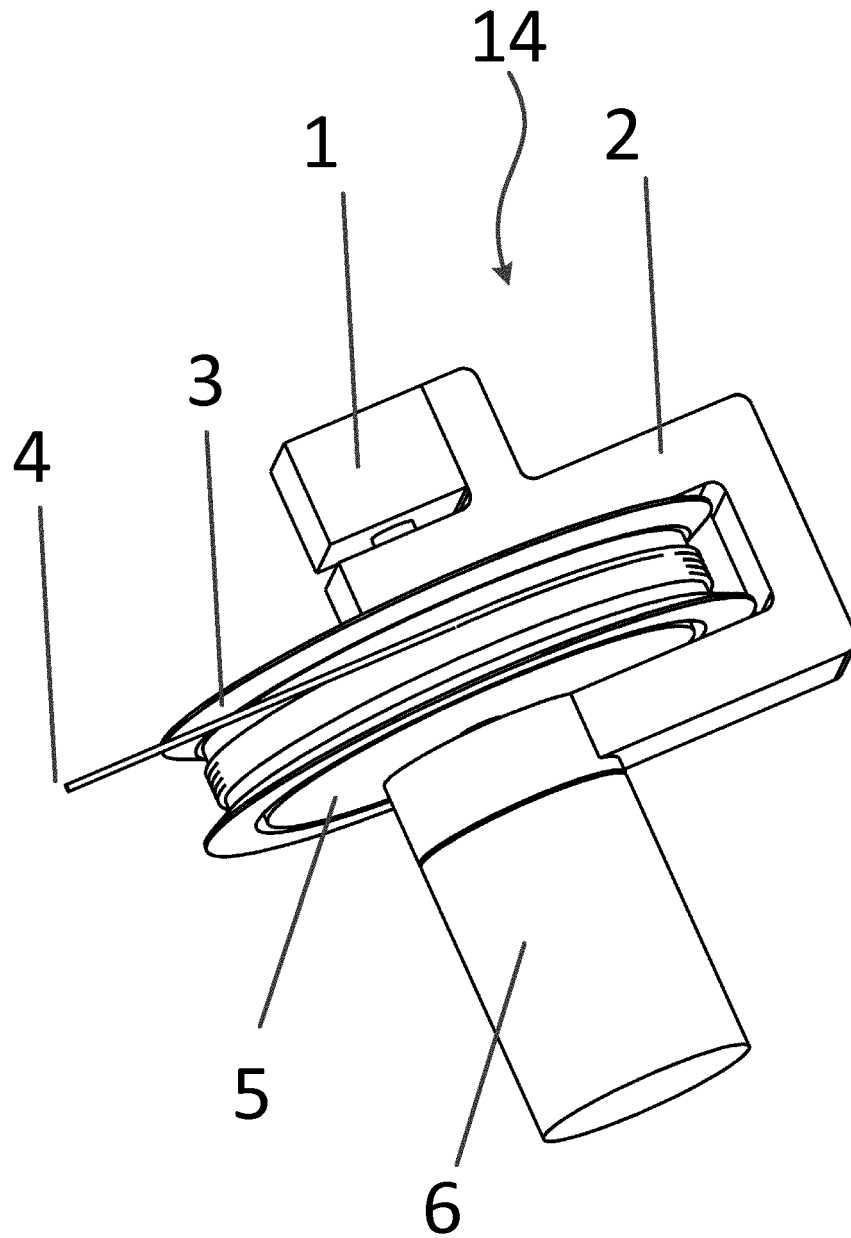


Figure 2

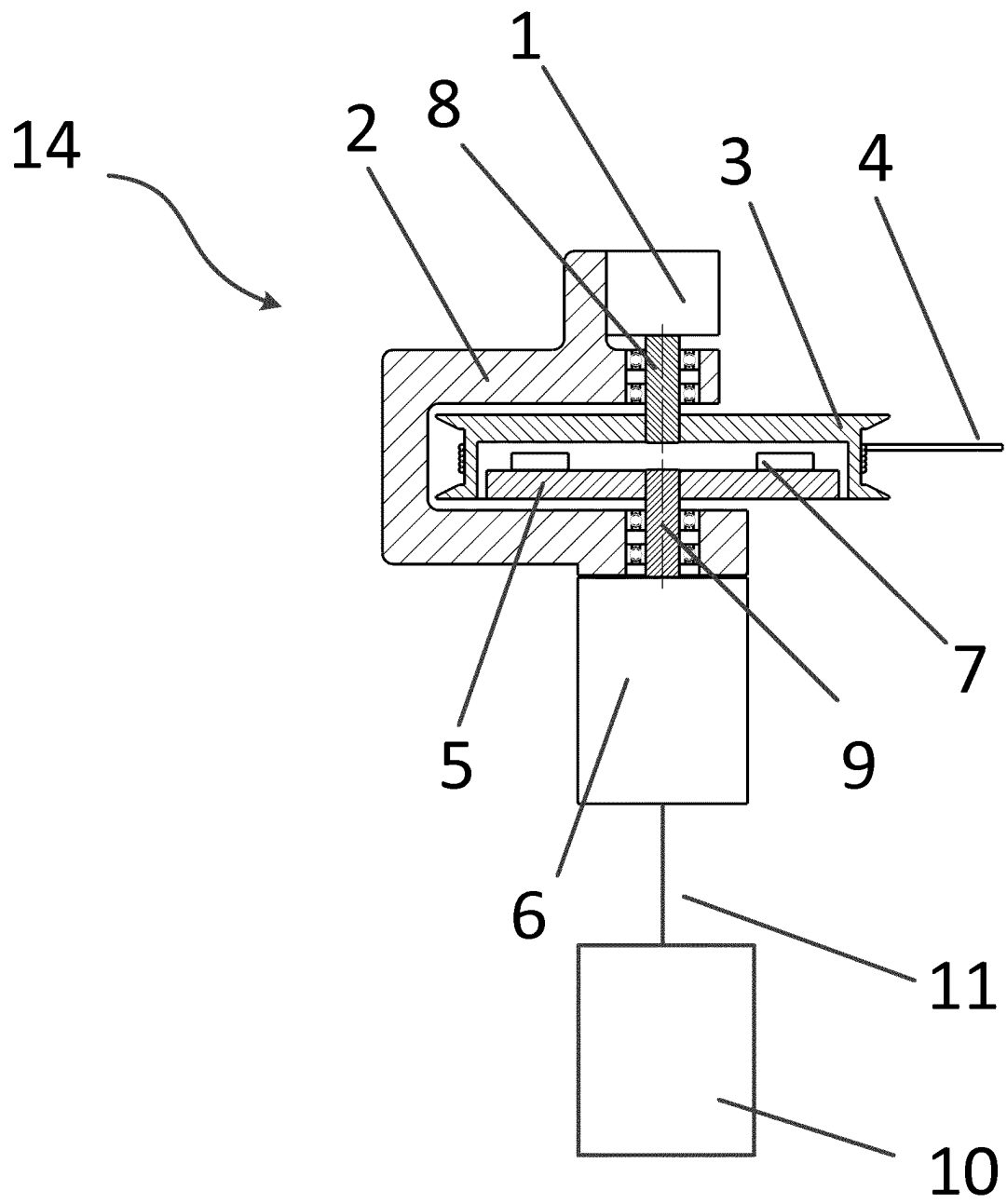


Figure 3

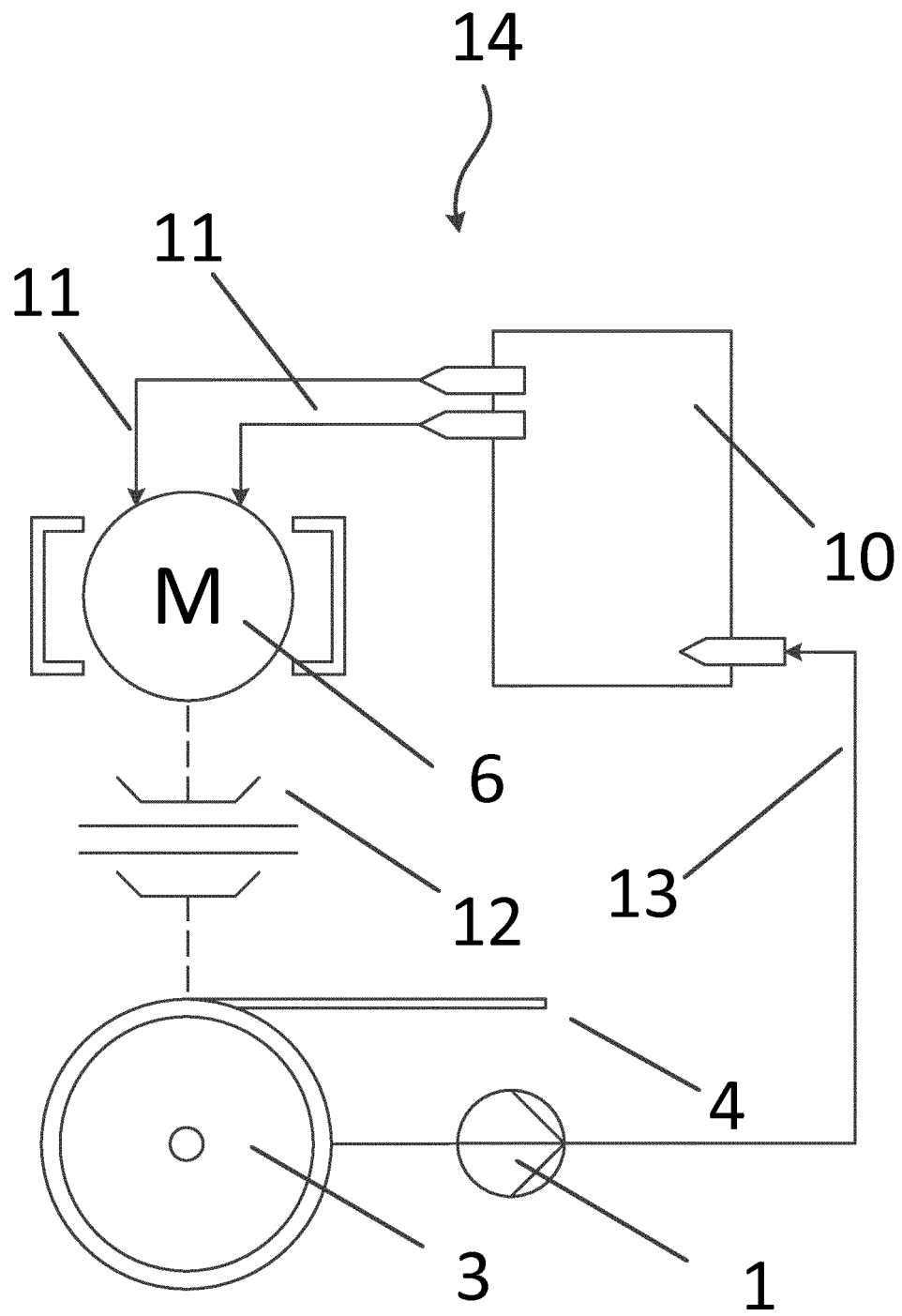


Figure 4



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 Application Number
EP 13 17 1399

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 17 October 2013	Examiner Pussemier, Bart
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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