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(71) Applicant: **MARSILLI & CO. S.P.A.**
26012 Castelleone (CR) (IT)

(72) Inventor: **Parati, Gian Battista**
26012 CASTELLEONE CR (IT)

(74) Representative: **Modiano, Micaela Nadia**
Modiano & Partners (IT)
Via Meravigli, 16
20123 Milano (IT)

(54) Machine for winding toroidal components of electrical machines

(57) A machine (1) for winding toroidal components of electrical machines, which comprises first means (5) for supporting the toroidal component (6) to be wound and first means (7) for actuating the toroidal component (6) with a rotary motion about its own axis (6a) in relation to the first supporting means (5). The machine also comprises: a winding element (14), which is shaped like a ring that can be closed in a position which is concatenated with the toroidal component (6), second means (17) for supporting the winding element (14) so that its axis (14a) is arranged substantially at right angles to the axis (6a) of the toroidal component (6), and second means (22) for the actuation of the winding element (14) with a rotary motion about its own axis (14a) with respect to the second supporting means (17). The winding element (14) is provided with a magazine (26) for gathering the winding wire (27) arranged on the winding element (14). The winding element (14) is rotatable about its own axis (14a) in relation to the second supporting means (17) by the action of the second actuation means (22) in one direction of rotation to accumulate the wire (27) that arrives from a spool (34) in the magazine (26) and to wind the wire (27) around the toroidal component (6) in a winding direction and in the opposite direction to wind the wire (27) around the toroidal component (6) in an opposite winding direction, by using at least part of the wire (27) accumulated in the magazine (26).

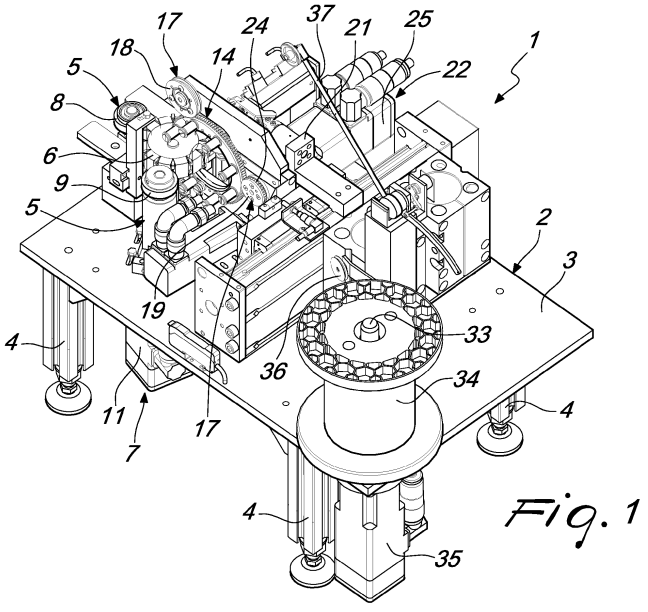

Fig. 1

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Description

[0001] The present invention relates to a machine for winding toroidal components of electrical machines.

[0002] Toroidal components, commonly known as "toroids", for electrical machines, such as for example generators, motors and transformers, with windings constituted by turns of wire made of electrically conducting material, generally copper, arranged around the toroid, are known.

[0003] Currently, the operation of arranging the turns of wire around the toroid, commonly known as "winding", is performed by using a winding element which is ring-shaped and is concatenated with the toroid. More particularly, such winding element is generally composed of two half-rings which are pivoted to each other at one of their ends and are provided, at their opposite end, with engagement elements that can engage each other to close the winding element or can be disengaged to open the winding element when it is necessary to disengage it from the toroid or concatenate it with the toroid.

[0004] The operation of winding the toroids by means of these winding elements is performed by concatenating the winding element with the toroid and by arranging manually the amount of wire required around the winding element. One end of the wire loaded onto the winding element is coupled to a region of the toroid and the winding element is then actuated with a rotary motion about its own axis, which is arranged at right angles to the axis of the toroid, so as to progressively unwind the wire from the winding element and wind it around the toroid, which is progressively rotated about its own axis. A method of this kind allows the winding of toroids in only one winding direction.

[0005] The winding of toroids is generally performed by sectors, i.e., in each instance the winding of a sector of the toroid is completed before winding of a contiguous sector is performed.

[0006] The aim of the present invention is to provide a machine for winding toroidal components of electrical machines that allows the winding of each sector of the toroidal component or toroid along two winding directions or more generally can perform sequentially two winding steps with mutually opposite winding directions.

[0007] Within this aim, an object of the invention is to provide a machine that makes it possible to complete the winding of a toroid without requiring interventions for disassembly and reassembly of the winding element.

[0008] Another object of the invention is to provide a machine that can complete the winding of a toroid without requiring intermediate cuts of the wire used for winding.

[0009] Another object of the invention is to provide a machine that has high precision and excellent reliability in operation.

[0010] Another object of the invention is to provide a machine that can also operate with a winding wire that has a small diameter.

[0011] Another object of the invention is to provide a machine that can achieve high productivities and can be manufactured at competitive costs.

[0012] This aim, as well as these and other objects that will become better apparent hereinafter, are achieved by a machine for winding toroidal components of electrical machines, characterized in that it comprises:

- first means for supporting the toroidal component to be wound;
- first means for actuating the toroidal component with a rotary motion about its own axis in relation to said first supporting means;
- a winding element, which is shaped like a ring that can be closed in a position which is concatenated with the toroidal component;
- second means for supporting said winding element so that its axis is arranged substantially at right angles to the axis of the toroidal component;
- second means for the actuation of said winding element with a rotary motion about its own axis with respect to said second supporting means;
- a magazine for gathering the winding wire arranged on said winding element;

said winding element being rotatable about its own axis in relation to said second supporting means by the action of said second actuation means in one direction of rotation to accumulate the wire that arrives from a spool in said magazine and to wind the wire around the toroidal component in a winding direction and in the opposite direction to wind the wire around the toroidal component along an opposite winding direction, by using at least part of the wire accumulated in said magazine.

[0013] Further characteristics and advantages of the invention will become better apparent from the description of a preferred but not exclusive embodiment of the machine according to the invention, illustrated by way of non-limiting example in the accompanying drawings, wherein:

Figure 1 is a schematic perspective view of the machine according to the invention;
Figure 2 is a schematic perspective view of the machine according to the invention, taken from a different angle than in Figure 1;
Figure 3 is a schematic top plan view of the machine according to the invention;
Figure 4 is a schematic front elevation view of the machine;
Figure 5 is a partially sectional enlarged-scale view of a detail of Figure 4, with some elements omitted for the sake of simplicity and greater clarity;
Figure 6 is a sectional view of Figure 5, taken along the line VI-VI;
Figure 7 is a sectional view of Figure 5, taken along the line VII-VII;
Figure 8 is a view of the beginning of the winding of

the wire around a sector of the toroidal component in one winding direction, with the machine shown schematically in a perspective view;

Figure 9 is a view of the same step of Figure 8, with the machine shown schematically in a partially sectional front view;

Figure 10 is a view of the final step of the winding of the wire around a sector of the toroidal component in the same winding direction as shown in Figures 8 and 9, with the machine shown schematically in a perspective view;

Figure 11 is a view of the same step of Figure 10, with the machine shown schematically in a partially sectional front view;

Figure 12 is a view of the beginning of the winding of the wire around a sector of the toroidal component in a winding direction that is opposite to the one shown in Figures 8 to 11, with the machine shown schematically in a perspective view;

Figure 13 is a view of the same step as in Figure 12, with the machine shown schematically in a partially sectional front view;

Figure 14 is a view of the final step of the winding of the wire around a sector of the toroidal component along a winding direction that is opposite to the one shown in Figures 8 to 11, with the machine shown schematically in a perspective view;

Figure 15 is a view of the same step as in Figure 14, with the machine shown schematically in a partially sectional front view;

Figure 16 is an enlarged-scale perspective view of a detail of the toroidal component concerning one end of a wire winding sector, illustrating the reversal of the wire winding direction.

[0014] With reference to the figures, the machine according to the invention, generally designated by the reference numeral 1, comprises a supporting structure 2, which is constituted by a substantially horizontal bench 3, provided with feet 4 by means of which it rests on the ground. The bench 3 supports first means 5 for supporting the toroidal component 6 to be wound and first means 7 for actuating the toroidal component 6 with a rotary motion about its own axis 6a with respect to the first supporting means 5.

[0015] More particularly, the first supporting means 5 comprise at least three rollers 8, 9, 10 which are supported, so that they can rotate about the corresponding axes 8a, 9a, 10a, by the supporting structure 2 or by the bench 3. The axes 8a, 9a, 10a are oriented parallel to the axis 6a of the toroidal component 6 to be supported and the rollers 8, 9, 10 can engage by contact the outer lateral surface of the toroidal component 6.

[0016] At least one of such rollers, which in the illustrated case is the roller 9, is connected to an electric motor or gear motor 11, which is arranged below the bench 3 and can be actuated so as to cause the controlled rotation of the toroidal component 6 about its own axis 6a. Said electric motor or gearmotor 11 constitutes the above-mentioned first actuation means 7.

[0017] Moreover, the position of at least one of the rollers 8, 9, 10 with respect to the other rollers can be adjusted along a direction which is perpendicular to the axes 8a, 9a, 10a of said rollers so as to make it possible to adjust the distance of this roller from the other two as a function of the diameter of the toroidal component 6 to be supported. In the illustrated embodiment, the roller 9 is connected to the output shaft of the motor 11 and said output shaft passes through a slot 12 that is defined in the bench 3. The motor 11 is supported below the bench 3 by means of screws 42 that pass through slots that are elongated in a manner similar to the slot 12, so as to make it possible to move the roller 9, with the entire motor 11, along the slot 12 to vary the distance between the roller 9 and the rollers 8 and 10 in order to adapt it to the diameter of the toroidal component 6 to be supported.

[0018] It should be noted that the toroidal component 6, as usually occurs, is divided into a plurality of sectors which are delimited by protrusions 13, also known as posts, which protrude from the end faces and from the outer lateral surface of the body of the toroidal component 6. The posts 13 define, on the outer lateral surface of the toroidal component 6, portions of mutually opposite axial shoulders and the rollers 8, 9, 10 make contact with the outer lateral surface of the toroidal component 6 between these mutually opposite axial shoulders. In this manner, the toroidal component 6 is supported and locked axially by the rollers 8, 9, 10 so that its axis 6a is oriented preferably vertically and the actuation of the roller 9 with a rotary motion about its own axis 9a determines the rotation of the toroidal component 6 about its own axis 6a, whereas the rollers 8 and 10 rotate freely about the respective axes 8a and 10a, following the rotation of the toroidal component 6 and supporting it precisely during its rotation.

[0019] The machine according to the invention comprises a winding element 14, which is ring-shaped and can be closed in a position which is concatenated with the toroidal component 6.

[0020] More particularly, the winding element 14 is composed of two segments 15, 16, which are hinged or otherwise connected to each other at one of their ends and can be fixed detachably to each other, so as to constitute as a whole an annular element which, if necessary, can be opened and then reclosed to concatenate the toroidal component 6 to be wound or can be opened for extracting the toroidal component 6 at the end of its winding.

[0021] The winding element 14 is arranged on second supporting means 17 so that its axis 14a is oriented substantially at right angles to the axis 6a of the toroidal component 6, i.e., preferably horizontally.

[0022] The second supporting means 17 comprise at least three wheels 18, 19, 20, which are supported, so that they can rotate about the corresponding axes 18a, 19a, 20a, parallel to the axis 14a of the winding element

14, by a frame 21, which is associated with the supporting structure 2. The three wheels 18, 19, 20 engage the outer lateral surface of the winding element 14.

[0023] Each one of the wheels 18, 19, 20 is provided, on its lateral surface, with a groove in which a perimetric portion of the winding element 14 enters, so that the winding element 14 is supported by the wheels 18, 19, 20 so that it can rotate about its own axis 14a and locked axially.

[0024] Conveniently, there are second means 22 for actuating the winding element 14 with a rotary motion about its own axis 14a with respect to the second supporting means 17.

[0025] More particularly, the winding element 14 is provided with a ring gear 23 on its outer lateral surface.

[0026] One of the three wheels 18, 19, 20 that support the winding element 14, which is constituted by the wheel 19 in the illustrated case, is provided, on the bottom of its groove, with a set of teeth which constitutes a gear 24 that engages the ring gear 23. The wheel 19 is connected to an electric motor or gearmotor 25, which constitutes the second actuation means 22 and can be actuated to cause, by means of the meshing between the gear 24 and the ring gear 23, the rotation of the winding element 14 with a rotary motion about its own axis 14a.

[0027] The winding element 14 is provided with a magazine 26 for gathering the wire 27 to be used to wind the toroidal component 6.

[0028] Preferably, the magazine 26 is provided on one of the two end faces of the winding element 14 and is composed of rollers 28 which are connected to said end face of the winding element 14 and are oriented so that their axes are parallel to the axis 14a of the winding element 14. The rollers 28 are arranged with their axes along an imaginary cylindrical surface which is coaxial to the winding element 14, so as to define an imaginary cylindrical surface on which the wire 27 to be used to perform the winding of the toroidal component 6 can be wound.

[0029] Preferably, the rollers 28 are supported by the winding element 16 so that they can rotate about their axes, so as to facilitate the sliding of the wire 27 toward the toroidal component 6 during the execution of its winding.

[0030] Conveniently, the magazine 26 has in output a guiding roller 29 which has, on its side wall, a groove 30 for guiding the wire 27, which conveniently is arranged substantially at a diametrical plane of the toroidal component 6 that is arranged on the rollers 8, 9, 10.

[0031] The winding element 14 can move on command along a direction which is parallel to its axis 14a with respect to the toroidal component 6 arranged on the first supporting means 5.

[0032] More particularly, the frame 21, which supports the winding element 14, is constituted by a slider which is supported, so that it can slide, along guides 31 which are fixed to the bench 3 and are oriented parallel to the axis 14a of the winding element 14. The slider 21 is further connected to the piston of a fluid-operated cylinder or to a linear actuator with electrical actuation 32, which is supported by the bench 3 and can be actuated to move the slider 21 along the guides 31.

[0033] The bench 3 further supports, so that it can rotate about its own axis, which is preferably oriented vertically, a spool supporting shaft 33, which is designed to support a reel or spool 34 of wire 27 to be used to perform the winding of the toroidal component 6.

[0034] Conveniently, the machine comprises means 27 for gathering the wire that is in excess upon reversal of the rotation of the winding element 14 about its own axis 14a, as will become better apparent hereinafter. These wire gathering means 27 are constituted by an electric motor or gearmotor 35, which is connected to the spool supporting shaft 33 and can be actuated to cause the rotation of the spool supporting shaft 33 and therefore of the spool 34 about its own axis in one direction, so as to dispense the wire 27, or in the opposite direction, to recover the wire 27.

[0035] Suitable guiding elements 36 and a tensioning element 37 with an oscillating arm of a known type are arranged between the spool 34 and the winding element 14.

[0036] Advantageously, tension relieving means 38 are arranged between the spool supporting shaft 33 and the winding element 14 so as to reduce the tension of the wire 27 during a step of the operation of the machine according to the invention, as will become better apparent hereinafter.

[0037] The tension relieving means 38, shown only in Figures 8 to 16, comprise a drum 39 which is supported, so that it can rotate about its own axis, by the bench 3 and is connected to an electric motor or gearmotor 40, which can be actuated to cause its rotation about its own axis. In practice, the wire 27, which arrives from the spool 34, is wound partially around the drum 39 and said drum is actuated with a rotary motion about its own axis so as to assist the entrainment of the wire 27 in the direction of the winding element 14.

[0038] Operation of the machine according to the invention is as follows.

[0039] The winding element 14, utilizing its possibility to be opened and then closed again, is concatenated with the toroidal component 6. The toroidal component 6 is then arranged between the rollers 8, 9, 10.

[0040] At the beginning of the winding, the wire 27 that arrives from the spool 34 is engaged with the tensioning element 37, wound around the drum 39 of the tension relieving means 38 and passed onto the guiding roller 29. The free end of the wire 27 is then coupled, manually or by means of automated clamps of the type usually used in machines for winding electrical coils, to a region of the toroidal component 6, for example to one of the posts 13 that delimit a preset sector from which one wishes to begin in order to perform the winding of the toroidal component 6, as shown in Figures 8 and 9.

[0041] At this point, the winding element 14 is actuated with a rotary motion about its own axis 14a in one direction

of rotation, for example clockwise. Due to this rotation, the wire 27 that arrives from the spool 34 is wound around the preset sector of the toroidal component 6. Simultaneously, due to the rotation of the winding element 14 about its own axis 14a, the wire 27 progressively accumulates in the magazine 26 provided on the winding element 14. More particularly, the wire 27 that arrives from the spool, before reaching the toroidal component 6, winds around the rollers 28 which are fixed to an end face of the winding element 14, as shown in Figures 10 and 11.

[0042] In this step, the drum 39 of the tension relieving means 38 is actuated so as to assist the drawing of the wire 27 from the spool 34 to the winding element 14. This function of assistance to the drawing of the wire 27 is particularly useful for avoiding the breakage of the wire 27 if the wire 27 used has a small diameter and therefore a low tensile strength.

[0043] Once the winding of a sector of the toroidal component in one direction has been completed, the wire 27, by exploiting the possibility to turn the toroidal component 6 about its own axis 6a and the winding element 14 about its own axis 14a in both directions of rotation, is wound partially around the post 13 that lies closest to the end of the wound sector, as shown in Figure 16, and the direction of rotation of the winding element 14 is then reversed for winding said sector with the opposite winding direction with respect to the winding performed previously.

[0044] In this step, while the wire 27 is wound onto the sector of the toroidal component 6, the rotation of the winding element 14 in the direction opposite to the preceding one, for example counterclockwise, produces the unwinding of the wire 27 previously accumulated in the magazine 26 for gathering the wire 27, which is at least partially used to perform this step of winding. The excess wire 27 is recovered by actuating the spool 34 with the direction of rotation opposite to the preceding one, as shown in Figures 12 to 15. In this step, the tension relieving means 38 can be deactivated or the drum 39 can be allowed to rotate freely about its own axis.

[0045] Once this winding of the sector of the toroidal component 6 also has been completed, the winding of a contiguous sector begins in a manner similar to what has already been described and one proceeds until the winding of the toroidal component 6 has been completed.

[0046] In practice it has been found that the machine according to the invention fully achieves the intended aim and objects, since it makes it possible to wind toroidal components of electrical machines with the possibility to perform the winding of each sector of the toroidal component along two winding directions, performing in succession two winding steps with mutually opposite winding directions.

[0047] Another advantage of the machine according to the invention is to be able to complete the winding of the toroid without requiring intermediate cutting of the wire used for winding and thus ensuring the electrical continuity of the winding.

[0048] A further advantage of the machine according to the invention is that it is possible to reverse the winding direction without requiring a stop of the machine and without requiring manual interventions on the winding element.

[0049] Still another advantage of the machine according to the invention is that it can wind toroidal components by arranging the portions of the turns on the outer lateral surface of the toroidal component according to mutually parallel lines, improving the performance of the electrical machine for which the toroidal component is to be used.

[0050] The machine thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the appended claims; all the details may further be replaced with other technically equivalent elements.

[0051] In practice, the materials used, as well as the dimensions, may be any according to requirements and to the state of the art.

[0052] The disclosures in Italian Patent Application No. MI2010A001995 from which this application claims priority are incorporated herein by reference.

[0053] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. A machine for winding toroidal components of electrical machines, **characterized in that** it comprises:

   - first means (5) for supporting the toroidal component (6) to be wound;
   - first means (7) for actuating the toroidal component (6) with a rotary motion about its own axis (6a) in relation to said first supporting means (5);
   - a winding element (14), which is shaped like a ring that can be closed in a position which is concatenated with the toroidal component (6);
   - second means (17) for supporting said winding element (14) so that its axis (14a) is arranged substantially at right angles to the axis (6a) of the toroidal component (6);
   - second means (22) for the actuation of said winding element (14) with a rotary motion about its own axis (14a) with respect to said second supporting means (17);
   - a magazine (26) for gathering the winding wire (27) arranged on said winding element (14);

   said winding element (14) being rotatable about its own axis (14a) in relation to said second sup-

porting means (17) by the action of said second actuation means (22) in one direction of rotation to accumulate the wire (27) that arrives from a spool (34) in said magazine (26) and to wind the wire (27) around the toroidal component (6) in a winding direction and in the opposite direction to wind the wire (27) around the toroidal component (6) along an opposite winding direction, by using at least part of the wire (27) accumulated in said magazine (26).

2. The machine according to claim 1, **characterized in that** said magazine (26) is arranged on one of the two end faces of said winding element (14).

3. The machine according to claims 1 and 2, **characterized in that** said magazine (26) is composed of rollers (28) which are connected to one of the end faces of said winding element (14) and are oriented so that their axes are parallel to the axis (14a) of said winding element (14), said rollers (28) being arranged so that their axes lie along an imaginary cylindrical surface that is coaxial to said winding element (14).

4. The machine according to one or more of the preceding claims, **characterized in that** said rollers (28) are supported by said winding element (14) to be rotatable about their own axes.

5. The machine according to one or more of the preceding claims, **characterized in that** said first supporting means (5) comprise rollers (8, 9, 10) which are rotatably supported about their corresponding axes (8a, 9a, 10a) by a supporting structure (2); said rollers (8, 9, 10) being arranged so that their axes (8a, 9a, 10a) are parallel to the axis (6a) of the toroidal component (6) to be supported and being adapted to engage by contact the outer lateral surface of the toroidal component (6).

6. The machine according to one or more of the preceding claims, **characterized in that** said second supporting means (17) comprise wheels (18, 19, 20) which are supported to be rotatable about their respective axes (18a, 19a, 20a), which are oriented parallel to the axis (14a) of said winding element (14), by a frame (21) which is associated with said supporting structure (2); said wheels (18, 19, 20) having, on their lateral surface, a groove that can be engaged by a perimetric region of said winding element (14).

7. The machine according to one or more of the preceding claims, **characterized in that** said perimetric region of the winding element (14) is constituted by a ring gear (23) which is coaxial with said winding element (14), at least one wheel (19) of said wheels (18, 19, 20) being provided in the form of a gear (24) whose teeth are defined on the bottom of the corresponding groove and mesh with said ring gear (23).

8. The machine according to one or more of the preceding claims, **characterized in that** said first actuation means (7) comprise at least one motor (11) which is connected to at least one roller (9) of said rollers (8, 9, 10) of the first supporting means (5).

9. The machine according to one or more of the preceding claims, **characterized in that** said second actuation means (22) comprise at least one motor (25) which is connected to said gear (24).

10. The machine according to one or more of the preceding claims, **characterized in that** it comprises means for taking up the wire when the direction of rotation of said winding element reverses.

11. The machine according to one or more of the preceding claims, **characterized in that** it comprises tension relieving means (38) adapted to reduce the tension of the wire (27) at least during its accumulation in said magazine (26).

12. The machine according to one or more of the preceding claims, **characterized in that** said tension relieving means (38) comprise a motorized drum (39) on which the wire (27) winds partially between said spool (34) and said winding element (14), said drum (39) being actuatable with a rotary motion about its own axis to assist the drawing of the wire (27) from said spool (34) to said winding element (14).

13. The machine according to one or more of the preceding claims, **characterized in that** said winding element (14) is arranged so that its axis (14a) is substantially horizontal and the toroidal component (6), on said first supporting means (5), is arranged so that its axis (6a) is substantially vertical.

14. The machine according to one or more of the preceding claims, **characterized in that** said winding element (14) is movable on command along a direction that is parallel to its axis (14a) with respect to the toroidal component (6) arranged on said first supporting means (5).

15. The machine according to one or more of the preceding claims, **characterized in that** said magazine (26) has in output a guiding roller (29) which has, on its side wall, a groove (30) for guiding the wire (27), which is arranged substantially at a diametrical plane of the toroidal component (6) arranged on said first supporting means (5).

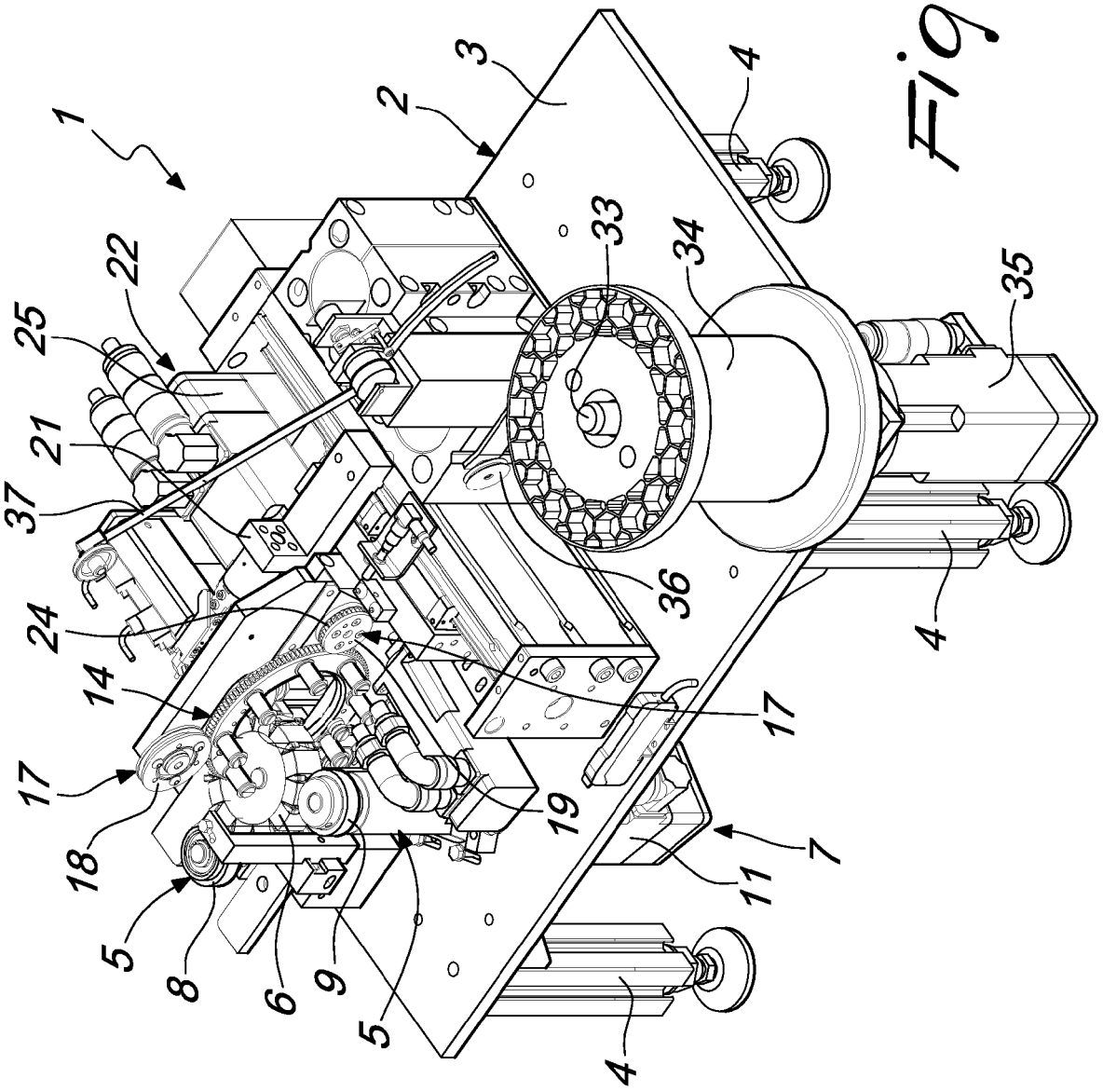

Fig. 1

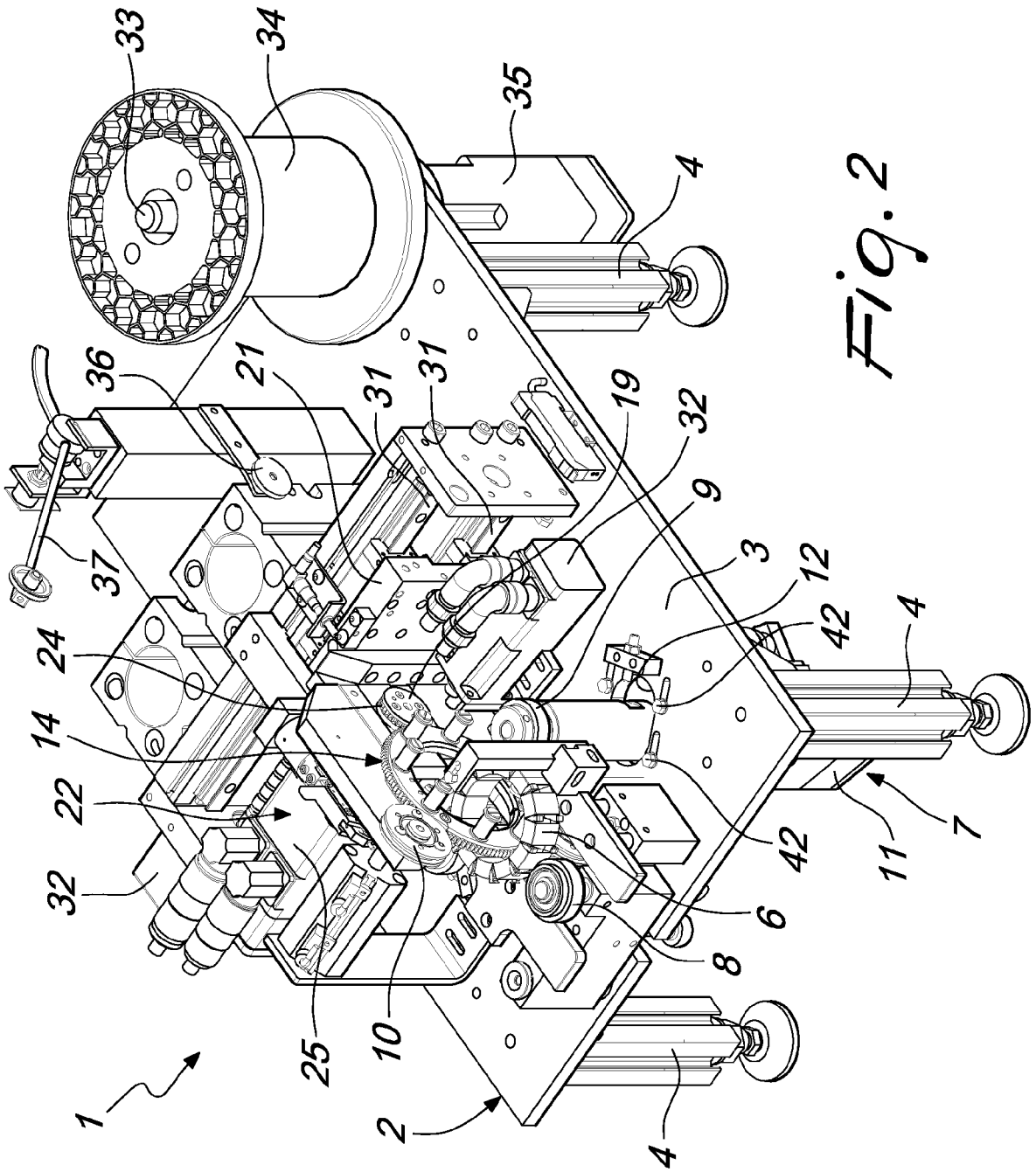
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Fig. 2

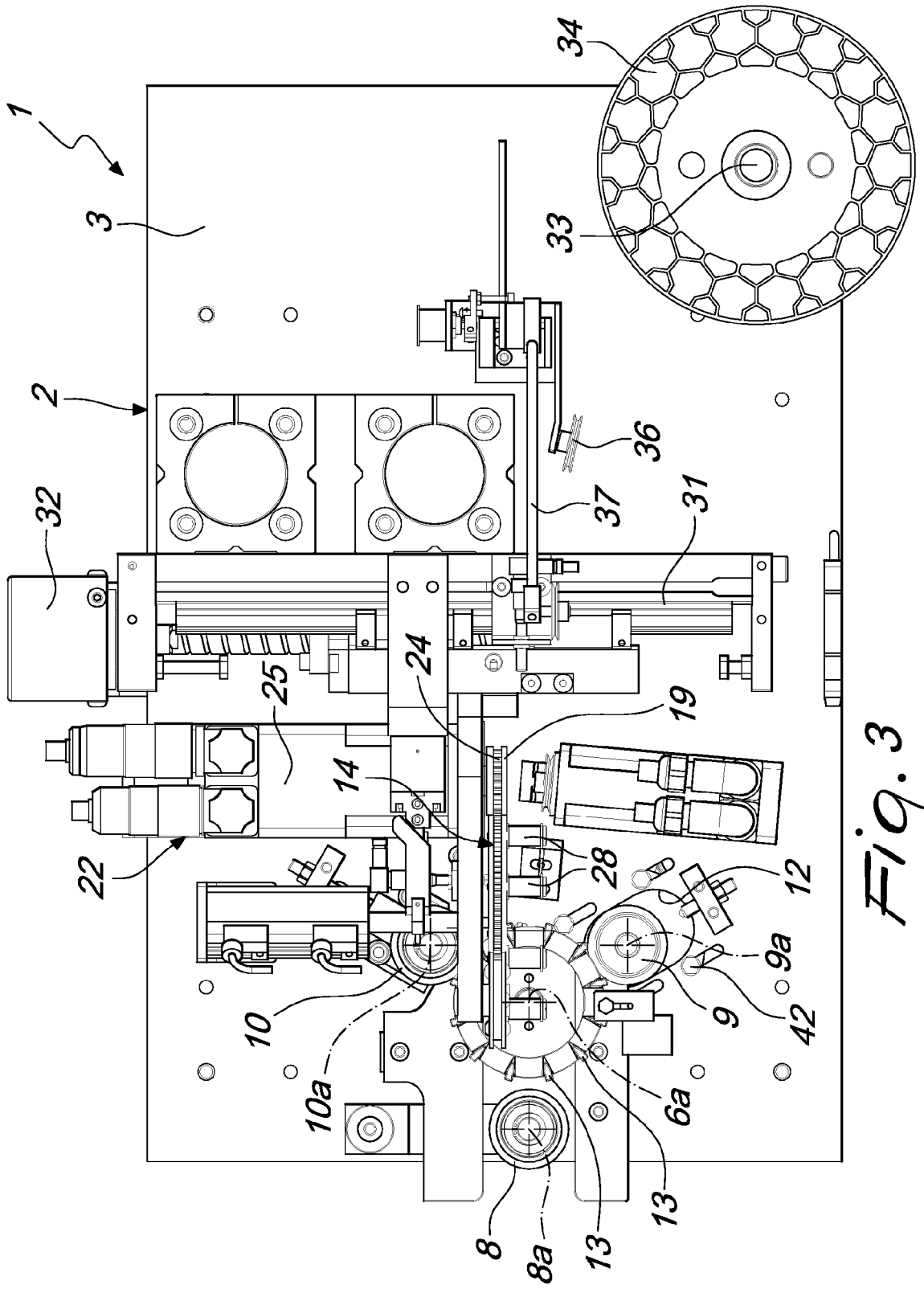

Fig. 3

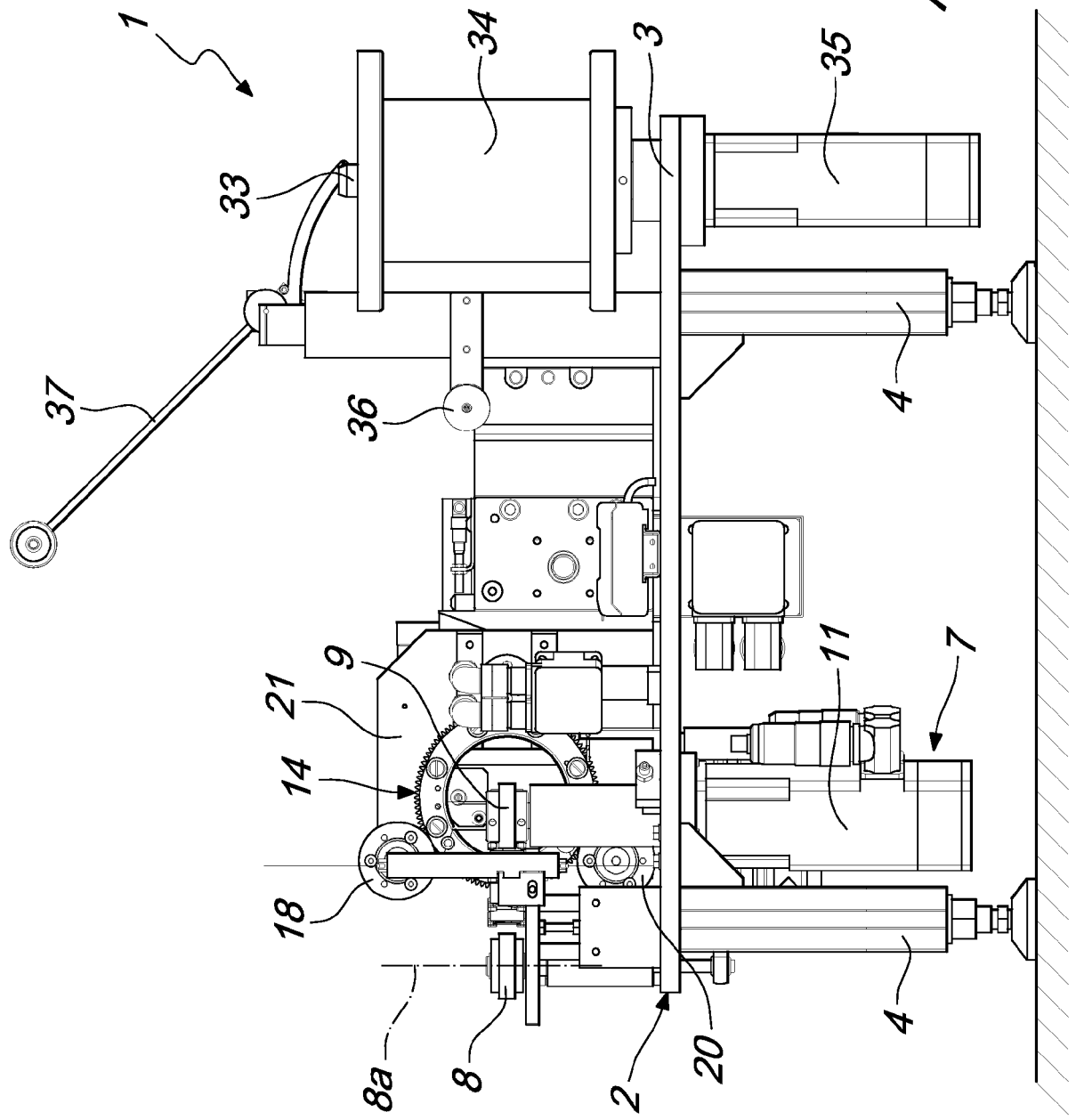

Fig. 4

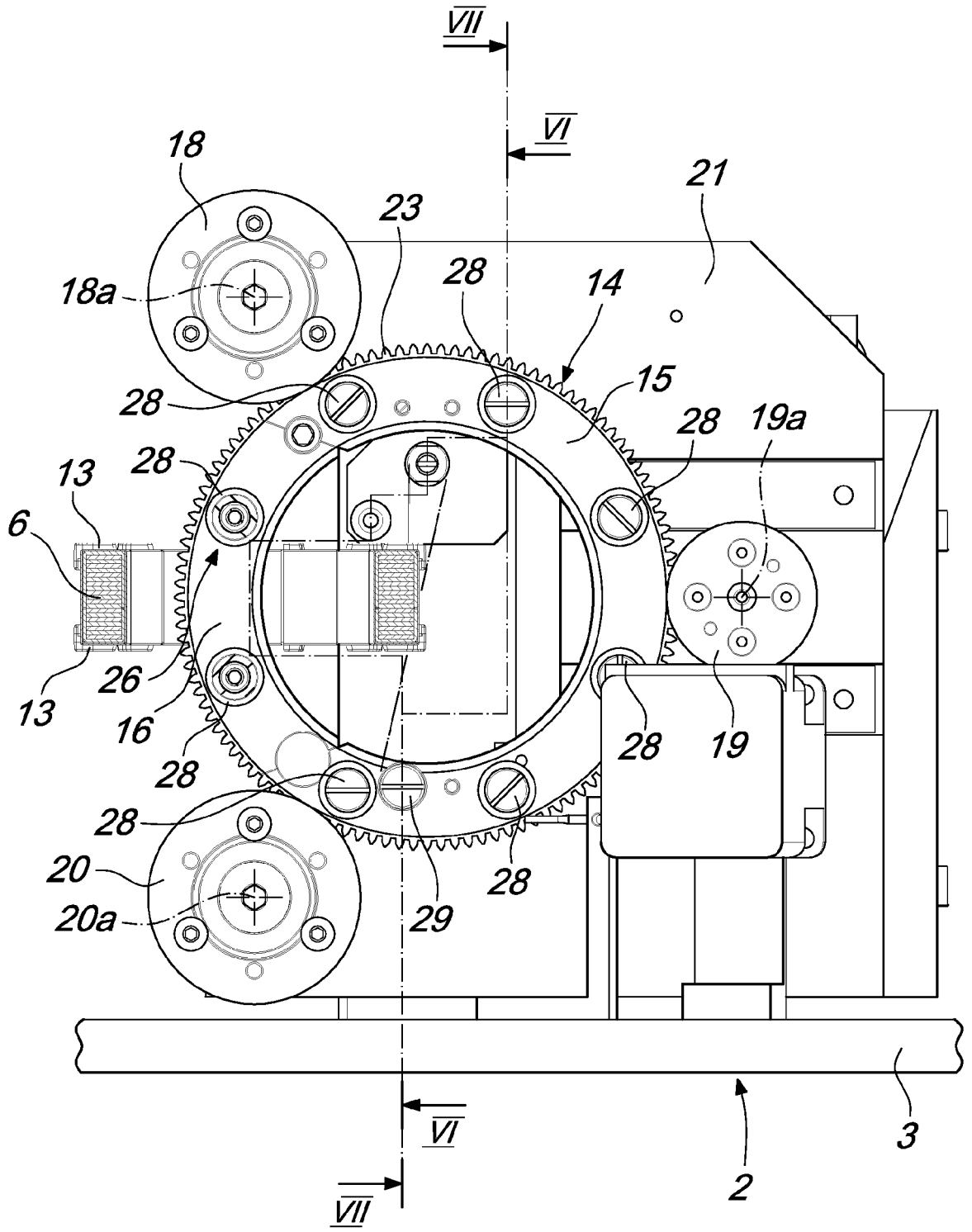
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Fig. 5

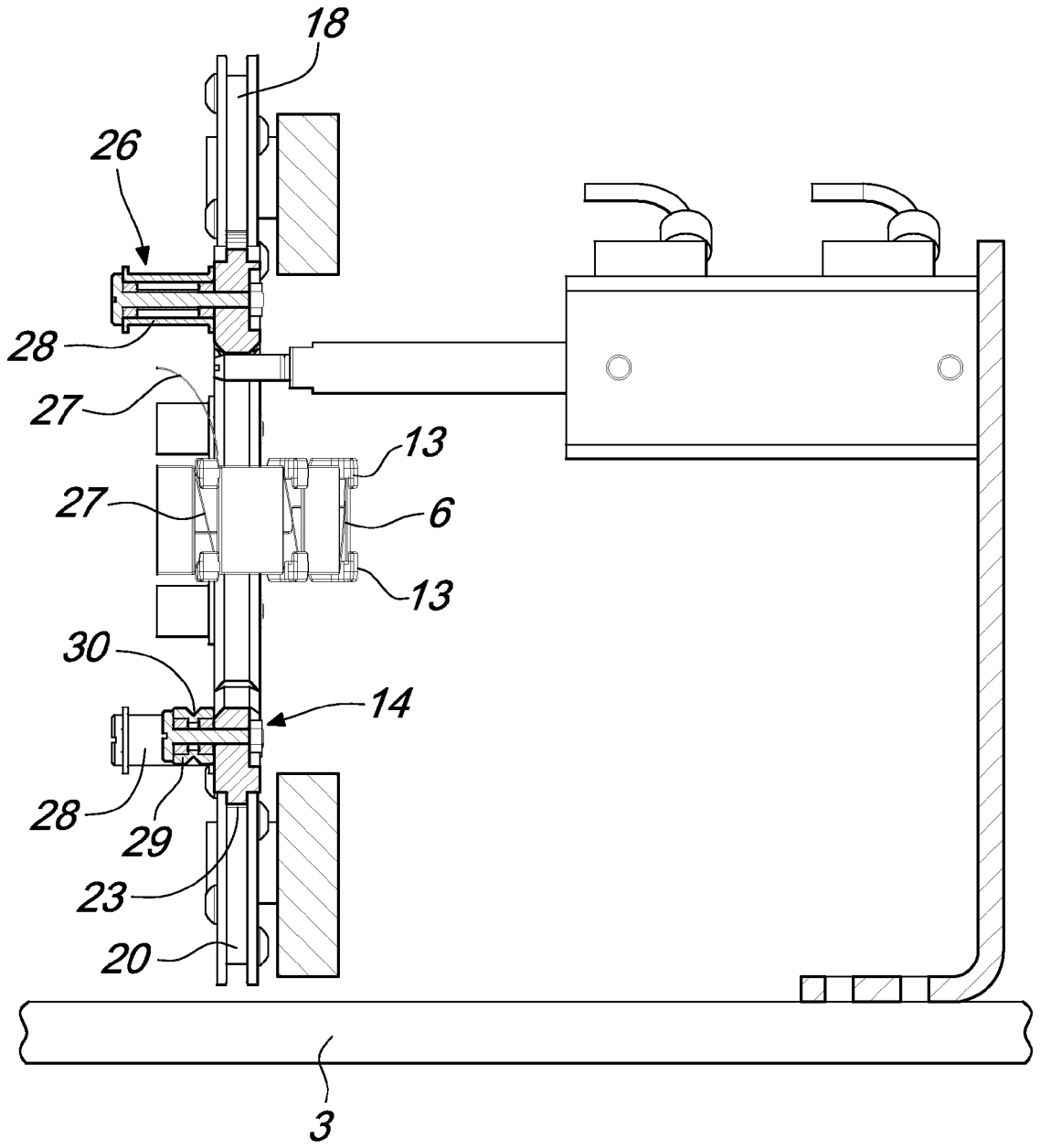

Fig. 6

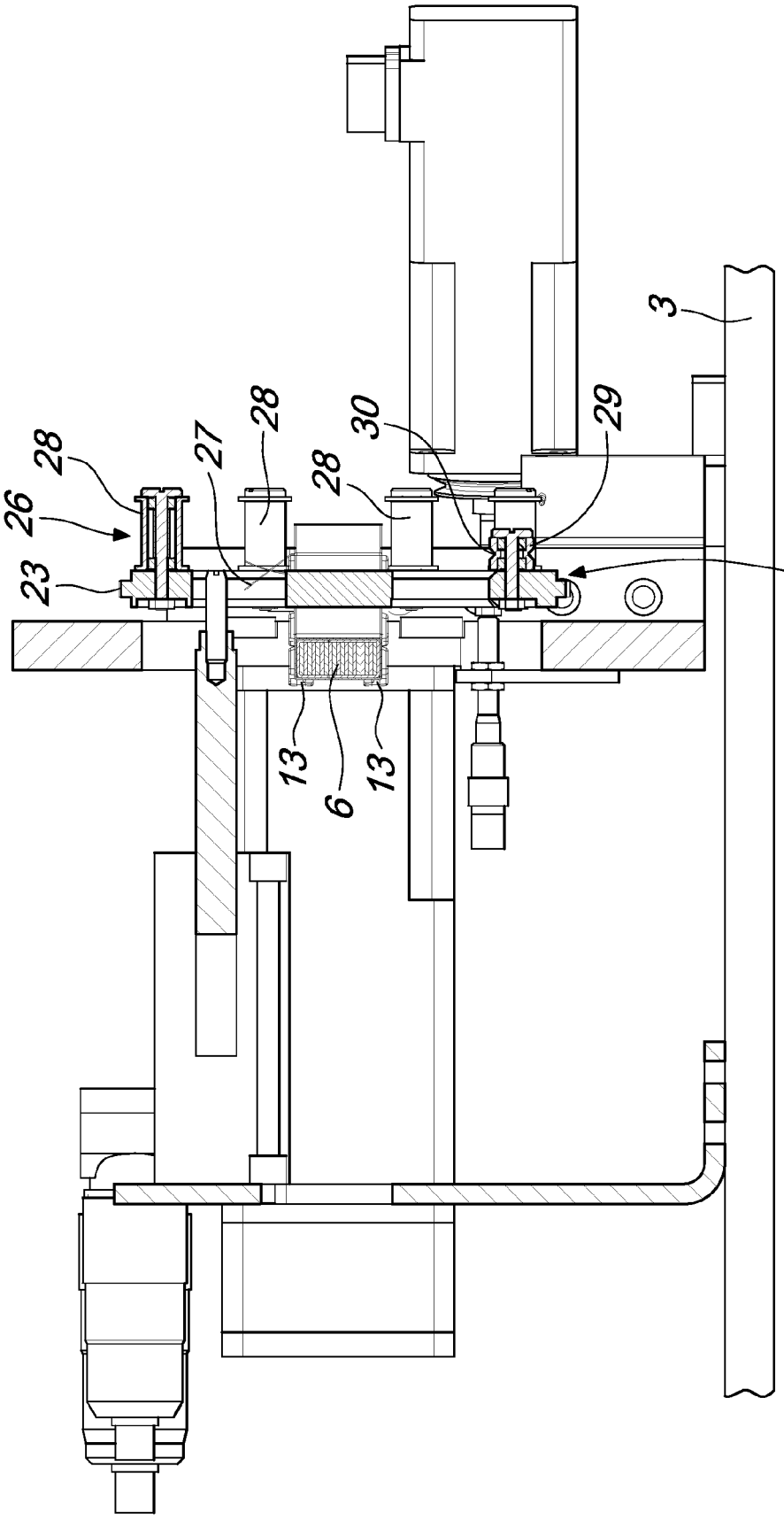

Fig. 7

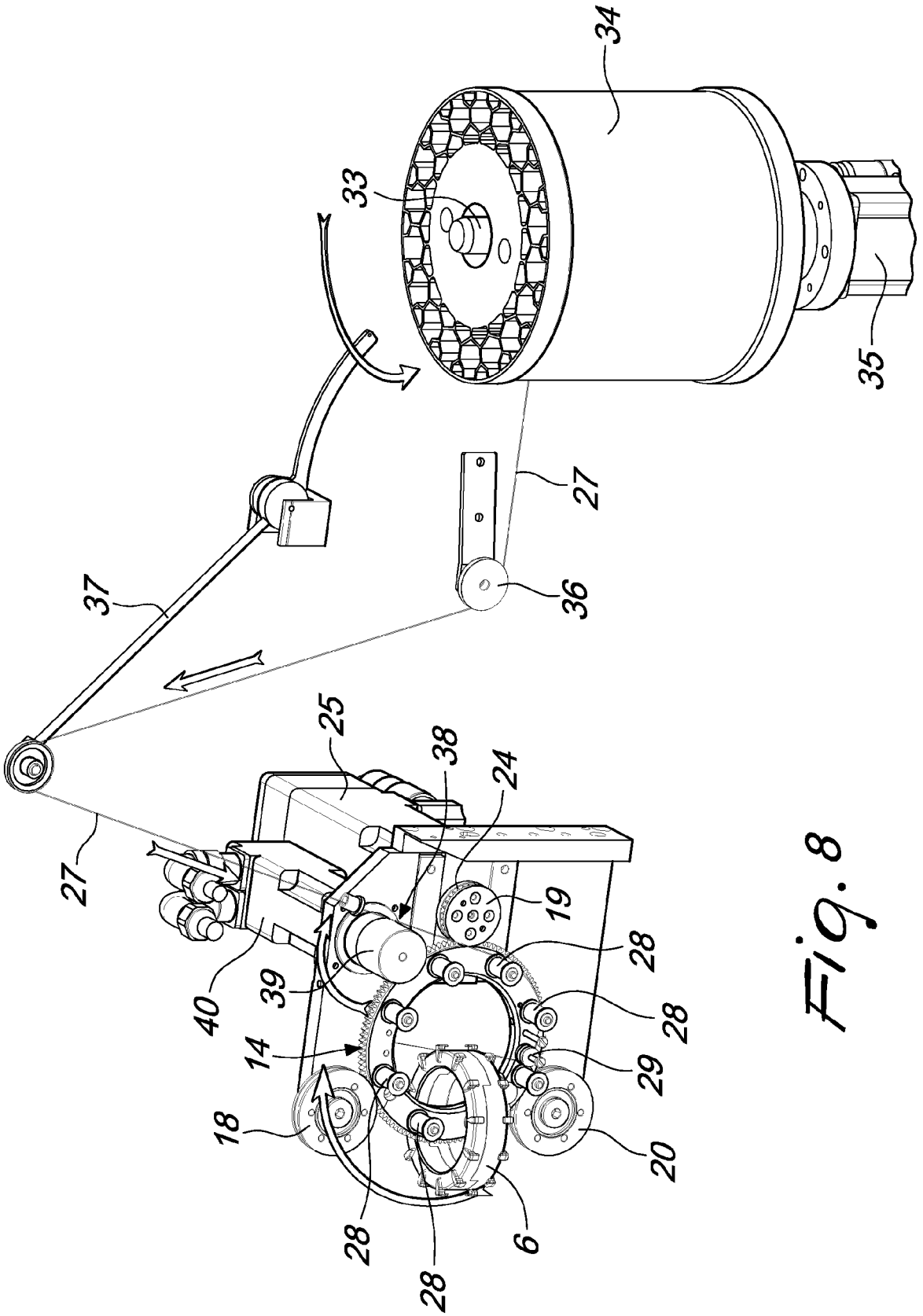

Fig. 8

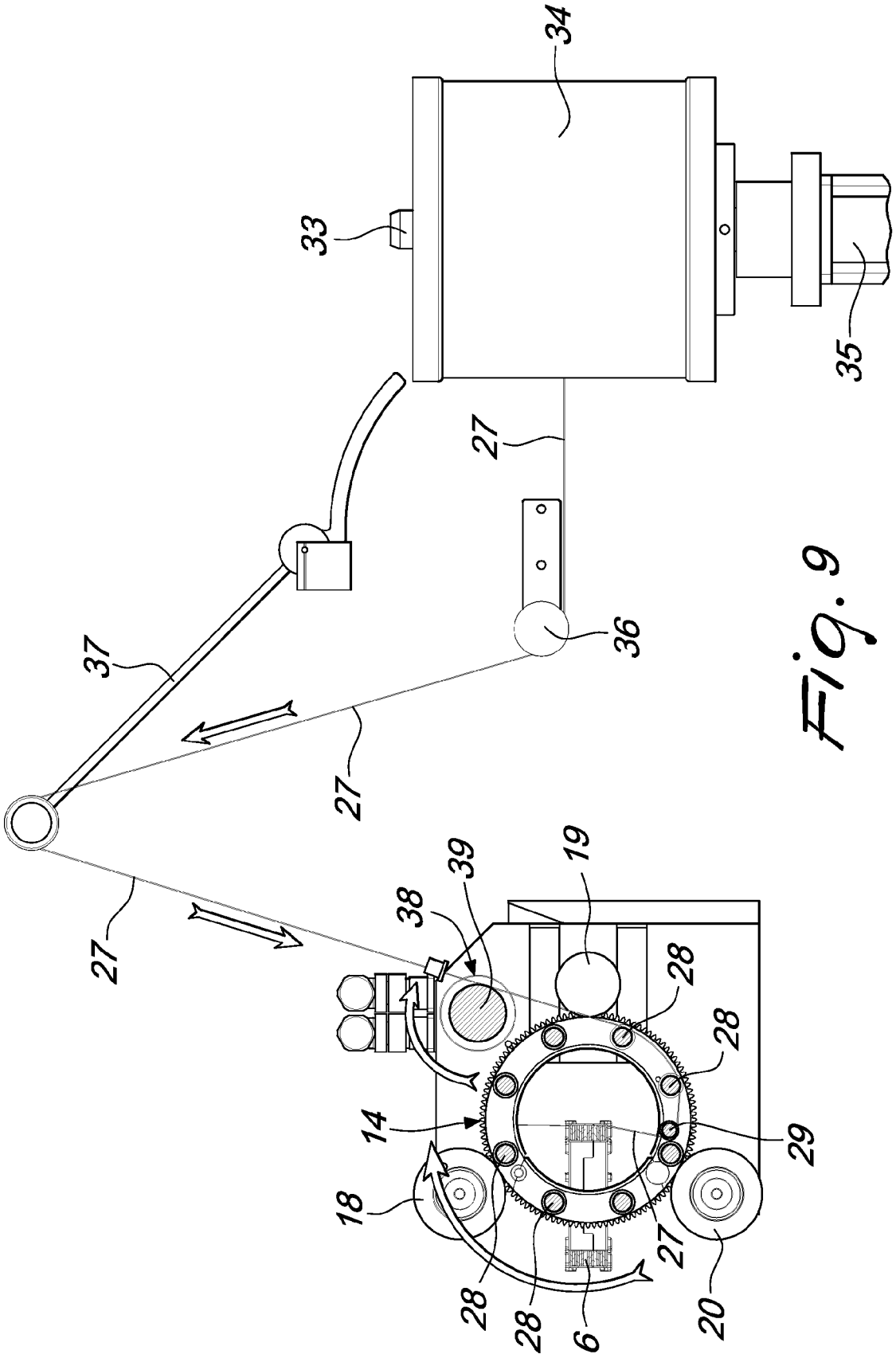

Fig. 9

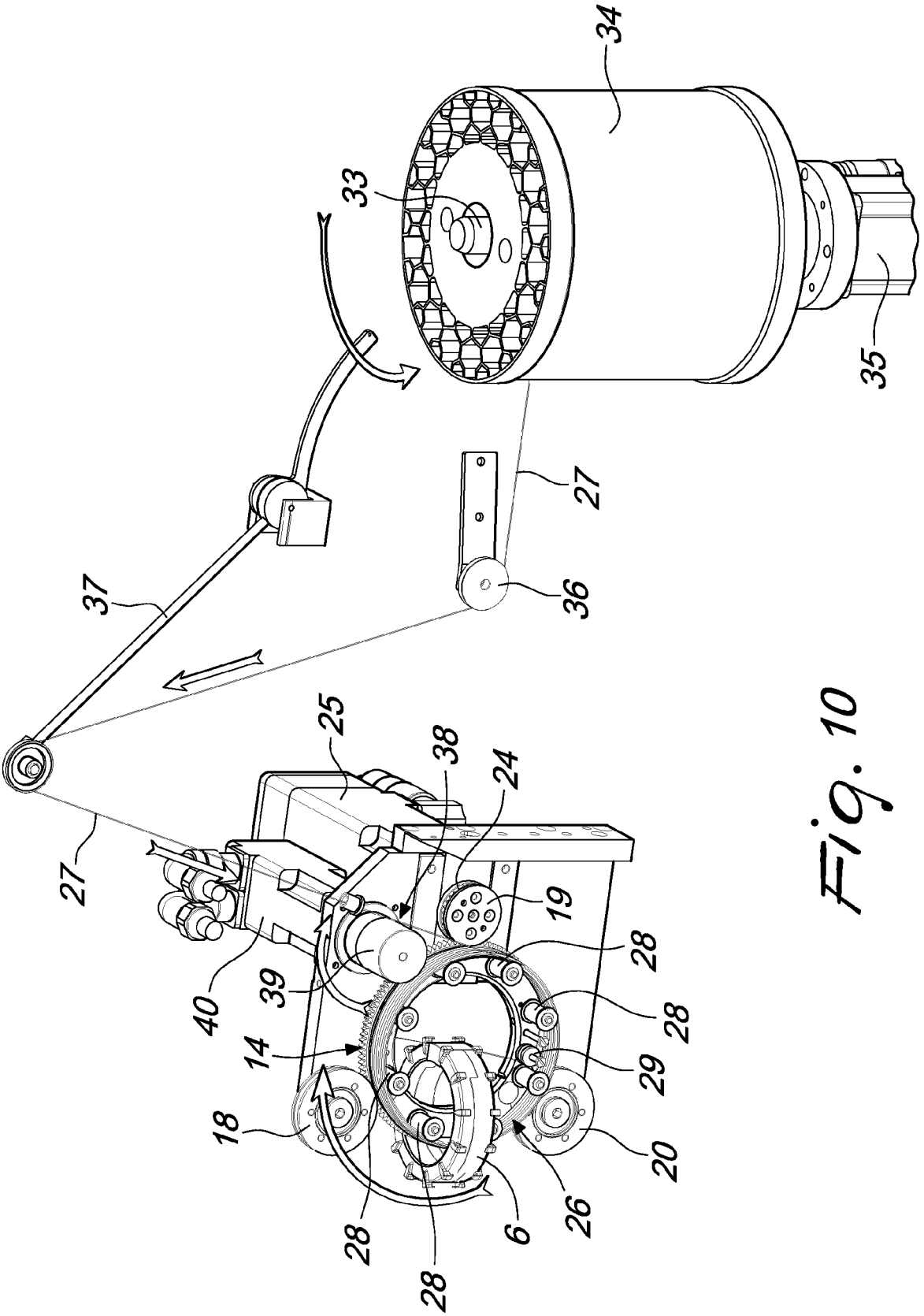

Fig. 10

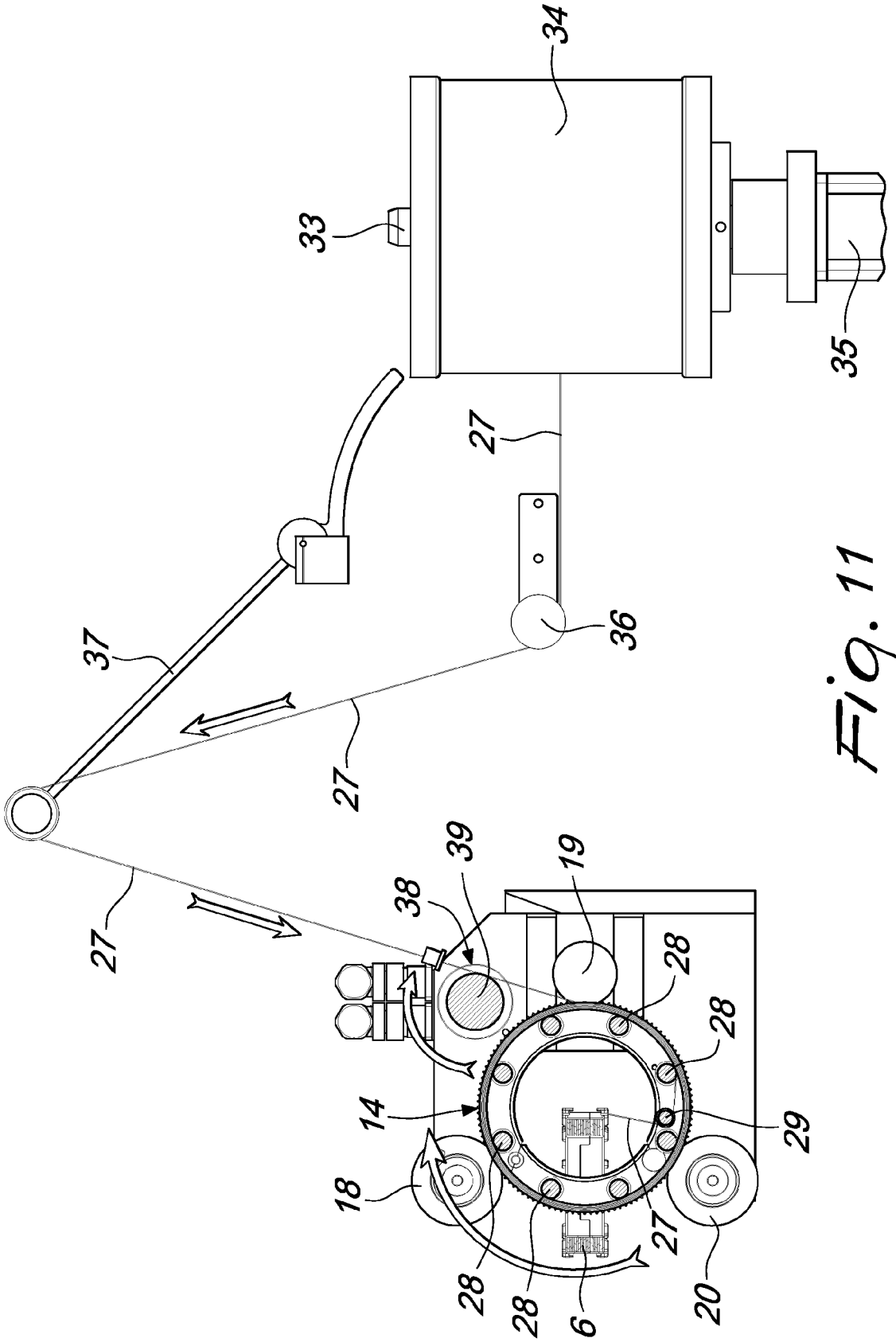

Fig. 11

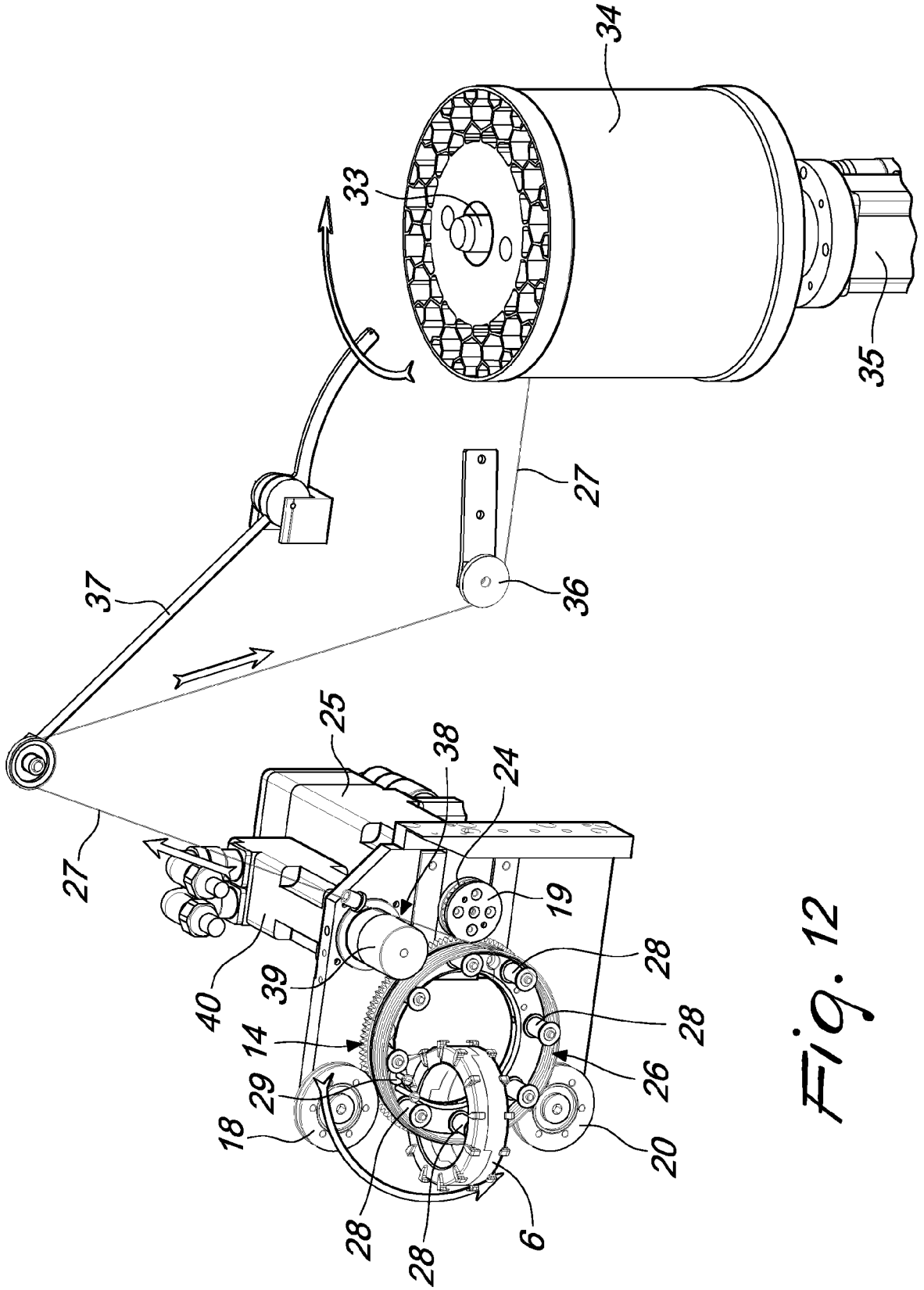

Fig. 12

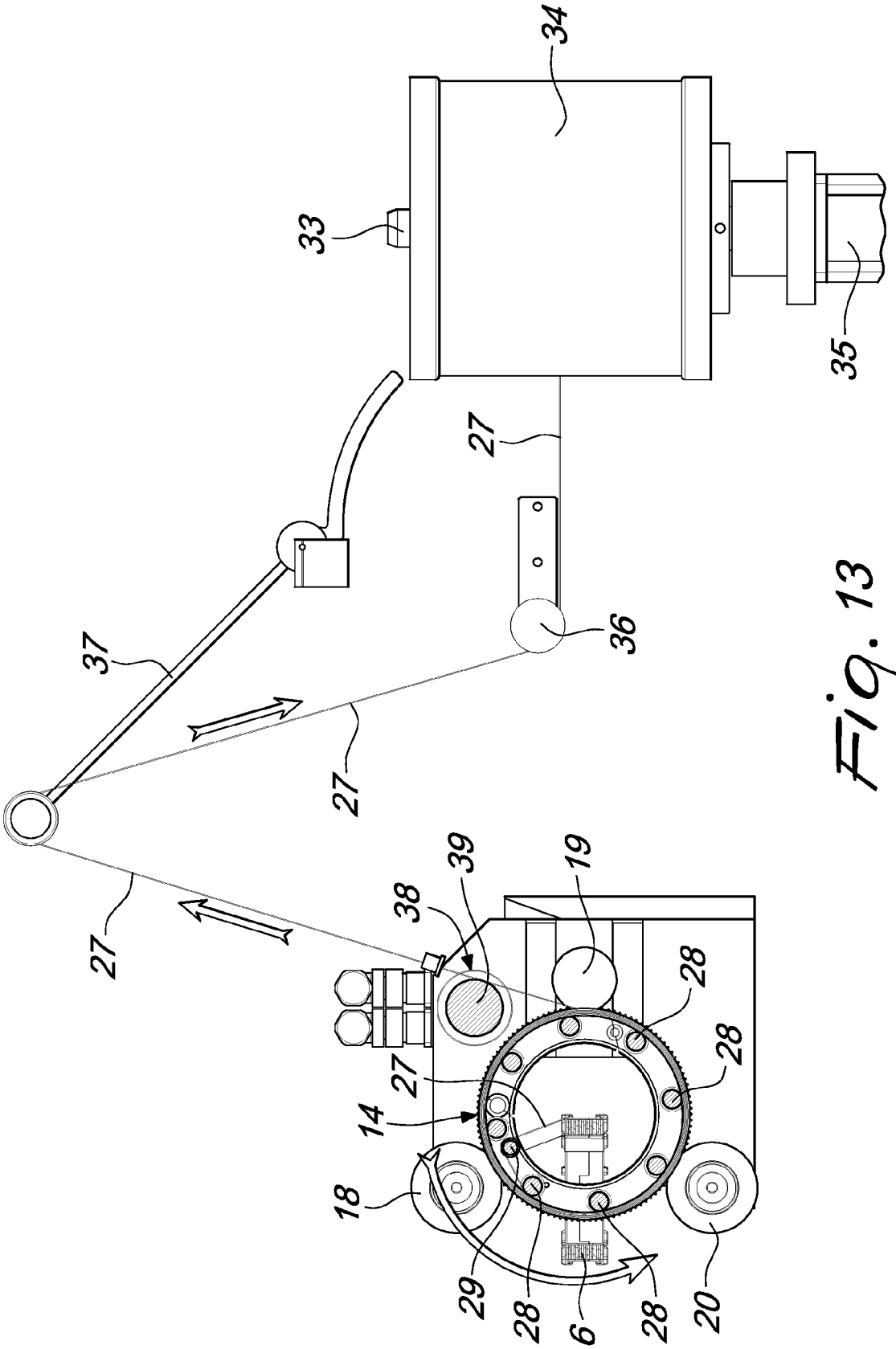

Fig. 13

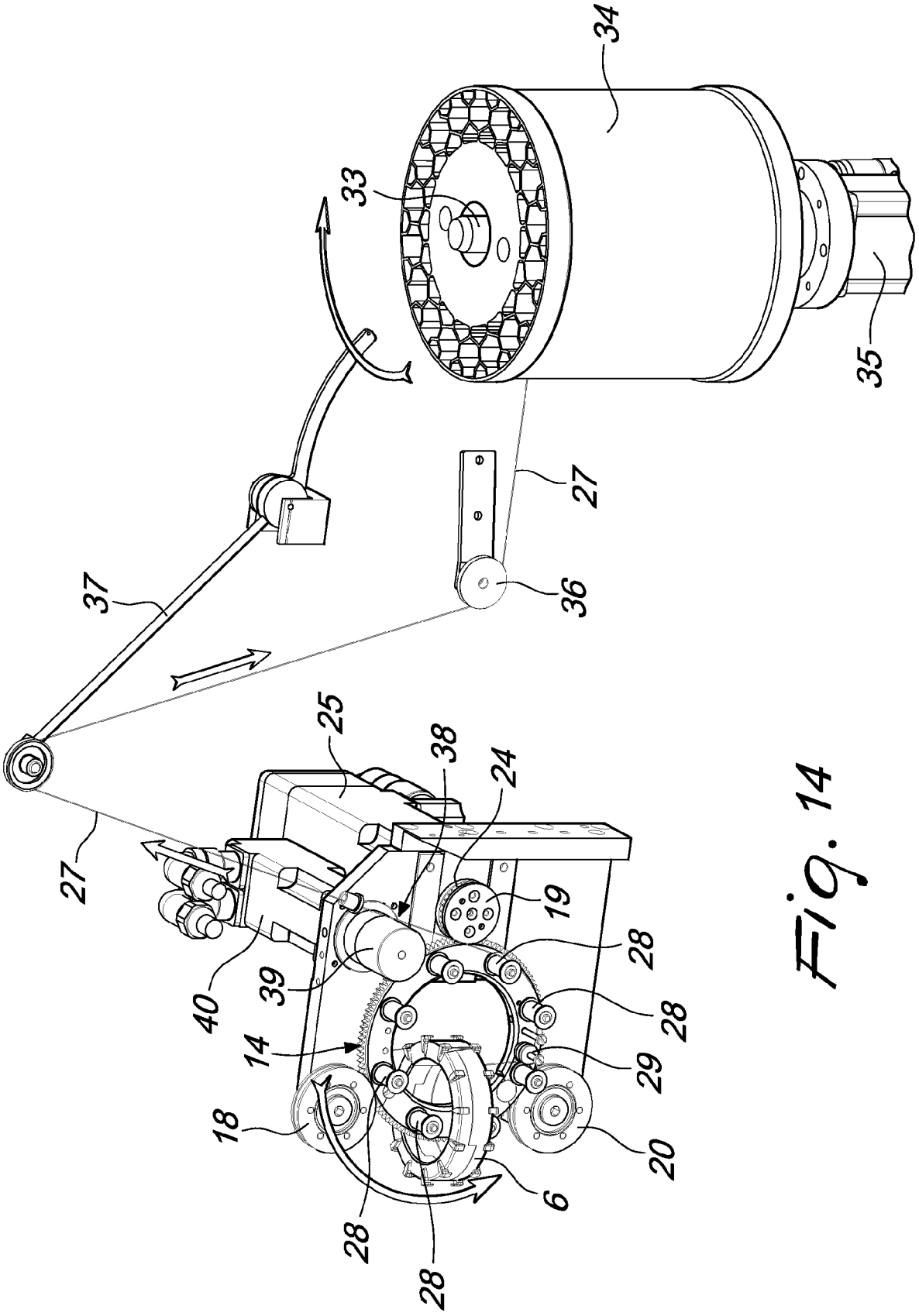

Fig. 14

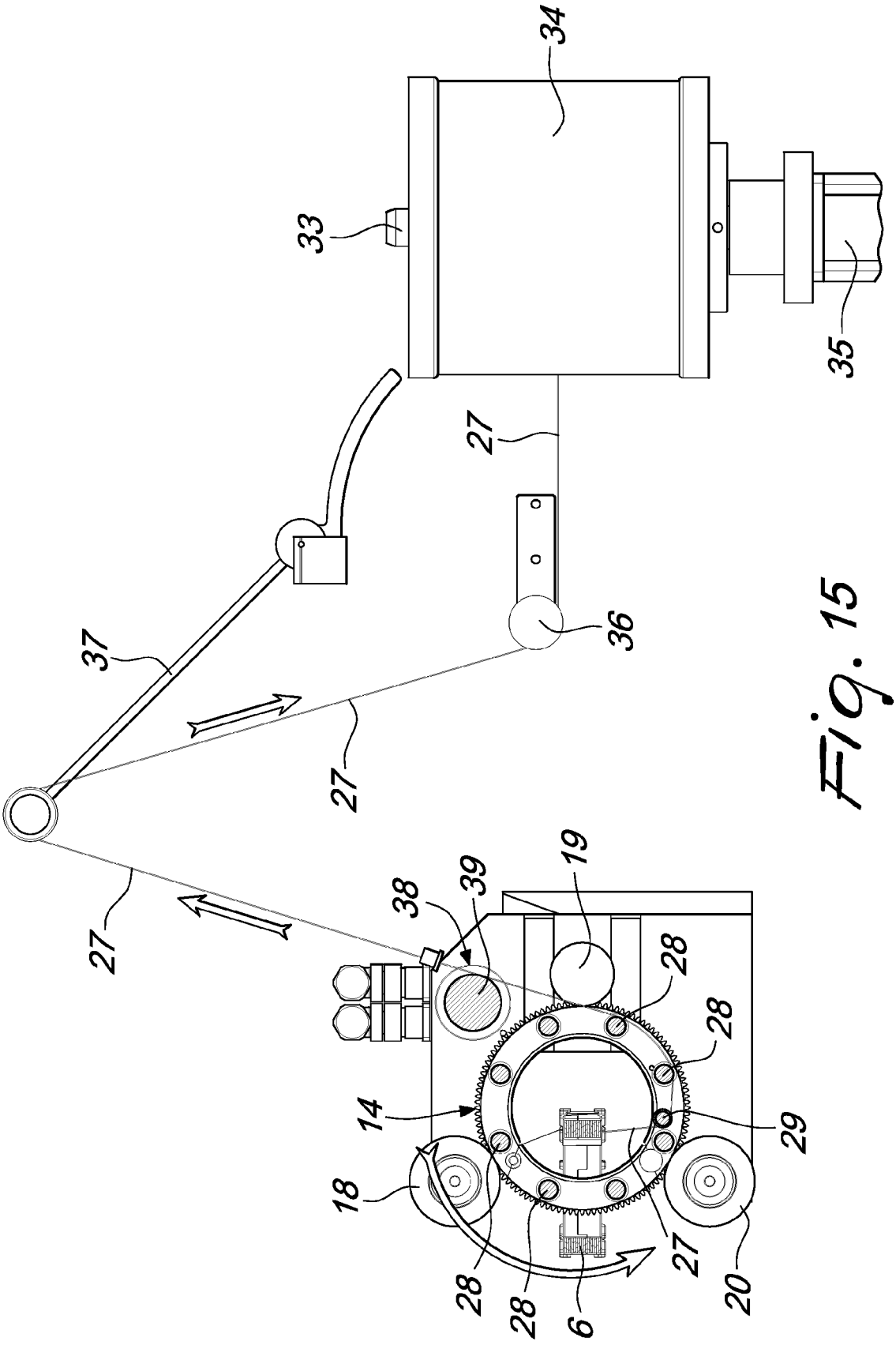

Fig. 15

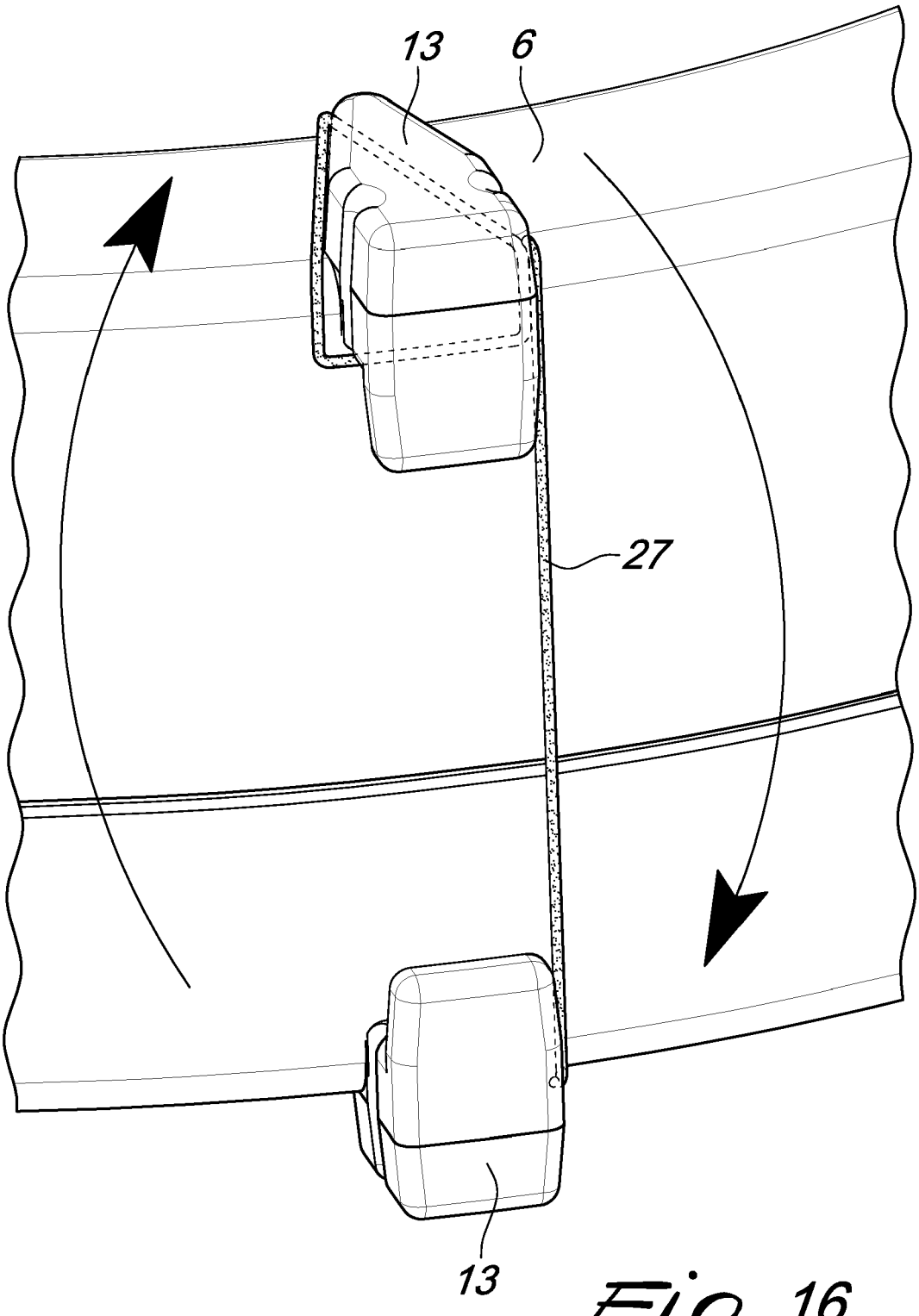

Fig. 16

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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 5782

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H01F
H02K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	15 November 2011	Van den Berg, G

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